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REVIEW ARTICLE **OJAS0501002-602**

ASSESSMENT OF PHYSICOCHEMICAL PARAMETERS AND METAL CONTAMINATION IN SEDIMENTS OF THE PERI-URBAN AMAGBA-OKOROMA RIVER, BENIN CITY, NIGERIA.

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ABSTRACT

The key role of sediments in aquatic systems is widely known, sediments are frequently neglected as a factor in the evaluation of water quality assessment. This study assessed the sediment quality of the Peri-urban Amagba-Okoroma River, Benin City, Nigeria, emphasizing physicochemical parameters and heavy metal contamination. Three sites (Upstream site 1, Midstream site 2 and Downstream site 3) were studied and river sediments were collected from each of these sites using Van veen grab. The sediments were collected three times each in the month of March and July, 2023. The results revealed temperature (25.67°C-26°C), slightly alkaline pH (7.55-7.68), and low electrical conductivity (49.33µS/cm-54.67µS/cm). Heavy metals evaluated were all within threshold/probable effect level guideline: Cd (0.09-0.10 mg/kg), Cr (5.61-6.10mg/kg), Cu (18.62-19.90mg/kg), Pb (0.33t-0.37mg/kg), and Zn (32.47-35.01mg/kg). However, Cu slightly exceeded thresholds-effect level limits at midstream site 2 and downstream site 3, indicating localized pollution sources. Principal component analysis and cluster analysis identified significant correlations between Cd-Cr and Cu-Zn, suggesting shared pollution sources likely from industrial or agricultural runoff. Cluster analysis reveal that sites 2 and 3 are more similar compare to site 1 (upstream). The heavy metal pollution indices collectively indicated no sediment contamination across the sites. Geo-accumulation index values for Cd, Cr, Cu, Pb, and Zn suggested unpolluted conditions across all sampling sites. Contamination factor values corroborated these findings, indicating low contamination levels for all metals. Contamination degree values further confirmed the sediment's low degree of contamination, aligning with Pollution load index values, indicating non-pollution. This study underscores the significance of regular monitoring and targeted mitigation efforts to sustain the ecological health of the river ecosystem amidst potential anthropogenic pressures.

Keywords: *Amagba-Okoroma River, Heavy metal pollution, Peri-urban, Sediment quality, Sediment guidelines.*

INTRODUCTION

Sediments are crucial components of aquatic ecosystems, made from the decay of plants and animals' parts or soil erosion deterioration (USEPA, 2002). Contaminants in aquatic environments are significantly influenced by sediments, which serve as sinks for various anthropogenic and natural pollutants (Vinodhini and Narayanan, 2008). Changes in water quality due to human activities or natural events can impact sediment quality (Ogamba and Ebere, 2017). This makes sediment contamination a significant environmental issue, as suspended sediments can affect water users and increase water treatment costs (Zhang *et al*., 2018). Increased metal levels in sediments often result from anthropogenic sources like farming, development, and atmospheric deposition (Binning and Baird, 2001). Sediments provide habitats for various aquatic organisms, and their composition affects species diversity and abundance. Mixed substrates offer diverse surfaces for colonization and complex microhabitats, leading to higher diversity and abundance of aquatic organisms (Yan *et al*., 2010). Sediment quality values help screen for potential contaminant-induced biotic consequences and put side by side sediment contaminant concentrations with sediment quality guidelines (Spencer and Macleod, 2002).

Heavy metal toxicity and concentration in sediments pose significant threats to aquatic environments and ecological health (Muneer *et al*. 2014). River sediments act as repositories for metals, which can be discharged into the water column under certain circumstances, impacting water characteristics and aquatic biota (Islam *et al*., 2015). Metals can accumulate in river sediments via multiple routes including atmospheric deposition, industrial discharge and agricultural runoff (Zhang *et al*., 2018). These metals remain in the environment and can have toxic effects on aquatic fauna, disrupting biological functions and ecosystems (Massaquoi *et al*. 2015; Singh *et al*., 2017; Enuneku *et al.*, 2018).

In inland waters, metals can shape the diversity, density, and biomass of benthic fauna, which are critical components of the river systems (Islam *et al*., 2015). The bioavailability of these metals in sediments can lead to bioaccumulation in freshwater organisms, which may enter the food chain and pose health risks to higher trophic levels, including humans (Zhu *et al*. 2013). The monitoring of metal pollution in peri-urban river sediments is essential for understanding sources of pollution, such as industrial discharges, agricultural runoff, and residential waste. Regular monitoring helps identify and control these pollution sources.

The Amagba-Okoroma River is a Peri-urban River at the outskirt or peri-urban area of Benin City, Nigeria. It is a key water source for local communities and play a critical role in the supply of ecosystem services. This river is prone to pollution from various anthropogenic activities, making it essential to assess its sediment quality. Contaminated sediments can affect freshwater man and organisms through the food chain. This study investigated the river sediment characteristics of the Amagba-Okoroma River in Edo State, Nigeria, focusing on the levels and distribution of metals and their potential implications. The objectives are to ascertain the levels of physicochemical parameters in the sediment, assess spatial variations, and evaluate metal pollution using metal pollution indices. These metrics provide an additional understanding to the overall ecological health of the Amagba-Okoroma River.

MATERIALS AND METHODS

Description of Study Sites

The study was executed at a meeting between two peri-urban rivers the Amagba River and Oko-Roma River, located within the latitudes N 6˚13'12.558", N 6˚13'13.122", and N 6˚13'21.936" and longitudes 5˚35'7.692" E, 5˚35'4.68" E, and 5˚35'6.312" E. This river is situated within the wet tropical rainforest belt of Edo State, southern Nigeria, characterized by alternating wet and dry seasons. It flows through the Amagba, Oko-Roma, and Obazagbon communities, within the Ikpoba-Okha Local Government Area (Figure 1). The Amagba-Okoroma River is an inland water body with significant economic importance.

The climate features distinct humid tropical dry and wet seasons. The rainy season typically occurs from April to October, with the highest relative humidity and lowest temperatures observed between July and August during peak rainfall. The dry season last from November to March, characterized by low relative humidity and high atmospheric temperatures. The mean yearly temperature ranges from 21°C to 35°C.The river is bordered by secondary rainforest vegetation, including species such as water lily (*Nymphaea lotus*), Awolowo weed (*Chromolaena odorata*), *Calopogonium mucunoides*, palm trees (*Elaeis guineensis*), signal grass (*Urochloa panicoides*), elephant grass (*Pennisetum purpureum*), and various shrubs.

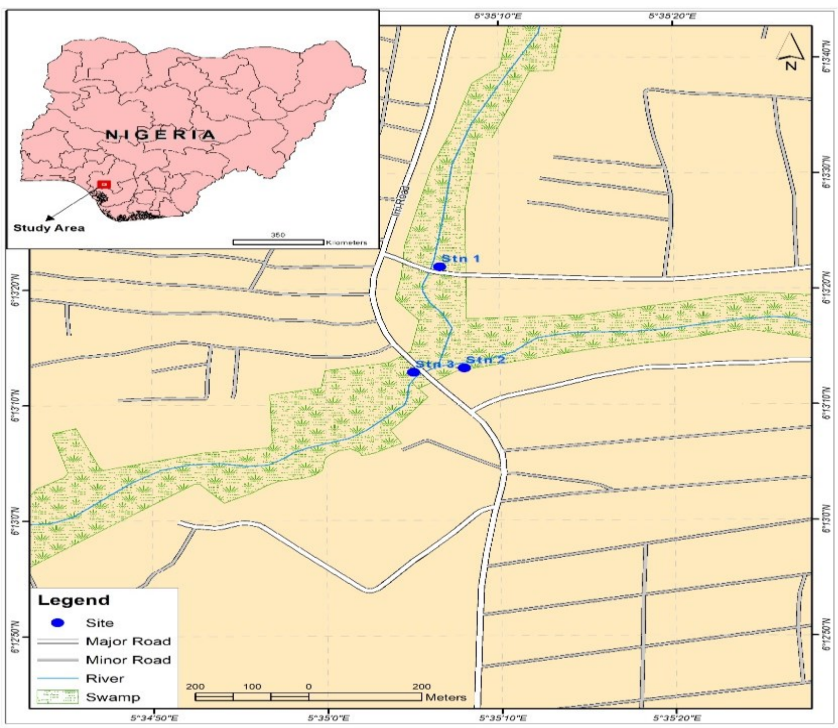


Figure 1: A map of the Amagba-Okoroma River showing the three sampling sites

Sampling Sites

The study was conducted in the month of March and June, 2023 across three sampling sites within the Amagba and Okoroma communities, Benin City, Nigeria. The sites were chosen based on accessibility and human pressure. River sediments were collected from the three sites namely: Site 1 (Amagba River) upstream was located at latitude N 6˚13'12.558" and longitude 5˚35'7.692" E, this site features a bridge under which the river flows. Various anthropogenic activities occur here, including bathing, washing, and water fetching. The site is also prone to littering, contributing to organic and inorganic waste deposition in the sediment. Site 2 (Okoroma River) midstream is situated at latitude N 6˚13'13.122" and longitude 5˚35'4.68" E, this site's sediment is composed of mud, silt, and decaying organic matter. The site is commonly used for swimming and bathing. Additionally, the surrounding vegetation, including aquatic plants, influences the sediment composition through the deposition of plant debris. Site 3 (Oko-Roma) downstream is positioned at latitude N 6˚13'21.936" and longitude 5˚35'6.312" E, this site is characterized by activities such as water fetching, traditional worship, and animal grazing. The presence of livestock contributes to the organic matter and nutrient levels in the sediment. This site is also influenced by seasonal flooding, which affects sediment deposition patterns. These sites were selected to represent different levels of human impact and environmental conditions within the Amagba-Okoroma River, providing a comprehensive understanding of the sediment quality across the study area.

Field sampling and frequency

Sampling was carried out at the three sites along the Amagba-Okoroma river three times in march (dry season) and June (wet season) 2023 each. The fieldwork spans between 9am and 12noon at every visit. A total of eighteen (18) sediment samples, (six per site) were taken near the riverbank using a Van veen grab sampler during the period of the study. Each river sediment sample was placed in a clean, sterilized, and labelled polythene bag and then transferred to the laboratory for analysis.

Laboratory Analysis of Physicochemical Properties and Metal Concentration of Amagba-Okoroma River Sediment

Amagba-Okoroma River sediment was air-dried to remove moisture content before analysis. All reagents and chemicals employed were of analytical reagent grade quality. The sediment temperature was measured using a mercury-in-glass thermometer. The device was inserted into the sediment and left for five minutes before taking the reading. To measure the pH of each river sediment sample, 20 grams of the air-dried sediment was weighed into a beaker, and 25 millilitres of deionised water was added. The suspension was stirred occasionally and allowed to stand. The electrode of the handheld pH meter (H196107, HANNA Instrument) was then dipped into the suspension for a few minutes, and the pH was measured. The electrical conductivity was measured with a handheld conductivity metre (HI96301, HANNA Instrument) using the same sediment suspension prepared for pH measurement. The electrode was inserted into the partly settled suspension, and the electrical conductivity was recorded after few minutes. Nitrate and phosphate concentrations in the river sediment samples were determined using the colorimetric method. This involved preparing the samples and reagents according to standard procedures and measuring the absorbance at specific wavelengths to quantify the concentration of these nutrients.

The Nitric-Perchloric acid digestion procedure was employed to measure the metal levels. The instrumentation used was Atomic Absorption Spectrophotometer (Buck scientific 210 VGP) and the reagents included Nitric Perchloric acid mixture, ratio 2:1, and Nitric acid-water mixture, ratio 1:1. Ig of dried, ground, and sieved sample was weighed into the digestion tube. Ten millilitres (10ml) of the mixed acid were added and the digestion tube was taken to the heater to be heated continually until a clean solution was recorded. It was removed from the heater and kept aside for the temperature to reduce, and then an additional quantity of de-ionised water was added. The solution was filtered with a Whatman filter paper into a 25ml volumetric flask. Deionized water was added to make the volume up to the mark. A reagent blank was prepared and the flame Atomic Absorption Spectrophotometer (Model Buck Scientific 210 VGP) was used to determine the metals of interest.

Data analysis

Inter-site comparisons were carried out to check for significant differences in the sediment physicochemical parameters using One-way ANOVA. When the difference among the sites is significant, a Holm Sidak post-hoc test was used to determine the source of variation among the sites. One-way ANOVA was carried out using SigmaPlot version 14.1 from Systal Software. Inc. Pearson's correlation coefficients were used to determine the linear relationships between physicochemical parameters and heavy metals. Cluster analysis and Principal component analysis were employed to find the likely sources of metal and group the sites based on the sediment physicochemical characteristics in Amagba-Okoroma River using PAST 4.03. All statistical computations were carried out using Microsoft office excel 2019.

Heavy Metal Pollution Indices

Geo-accumulation Index (I_{geo})

It is a gauge that is harnessed to evaluate the occurrence and concentration of man-made contaminant deposition on surface soil (Barbieri, 2016). Müller (1969) proposed this index. I_{geo} is represented as

$$I_{geo} = \mathrm{Log}_2 \frac{Cn}{1.5Bn} \quad (1)$$

Where C = concentration of element 'n', B = geochemical background of the metal (n)

Factor 1.5 = possible variation of the background data due to lithogenic effect

Contamination Factor (CF)

CF is employed to investigate the metal pollution load of the sediment. An effective means utilises for metal contamination observation (Fang *et al*., 2019). It is estimated by applying the equation below (Kumar *et al*., 2012).

$$\mathrm{CF} = \frac{\text{observed metal concentration}}{\text{Background concentration of the same metal}} \quad (2)$$

Contamination Degree (CD)

CD is the sum total of all individual contamination factors. It is depicted as

$$\mathrm{CD} = \sum_{i=1}^{n} \mathrm{CF} \quad (3)$$

Pollution Load Index (PLI)

It is an index employed to estimate to what degree the contamination of sediment by metals surpasses the background level. PLI can be regarded as the nth root of the multiplications of the concentrations (Enuneku *et al*., 2018).

$$PLIx=\sqrt[n]{CF1 \ x \ CF2 \ x \ CF3 \ x \ \ldots \ x \ CFn} \quad (4)$$

Table 1: Classification of Sediment Pollution Status Based on I_{geo}, CD, and PLI Indices

I_{geo} **group**	**Sediment status**	**CD class**	**Sediment status**	**PLI class**	**Sediment status**
$I_{geo} \leq 0$ (grade 0)	Unpolluted	CD < 6	Low Contamination degree	PLI < 1	Excellent sediment health
$0 < I_{geo} \leq 1$ (grade 1)	Slightly polluted	6 < CD < 12	Moderate Contamination degree	PLI > 1	Progressive deterioration of sites
$I < I_{geo} \leq 2$ (grade 2)	Moderately polluted	12 < CD < 24	Considerable Contamination degree	PLI = 1	Baseline levels of pollutants present
$2 < I_{geo} \leq 3$ (grade 3)	Moderately severely polluted	CD > 24	High Contamination degree		
$3 < I_{geo} \leq 4$ (grade 4)	Severely polluted				

(Muller, 1969; Eseyin *et al*., 2019; Mohiuddin *et al*., 2010)

RESULTS AND DISCUSSION

Physicochemical and Heavy Metal Characteristics of Sediment in Amagba -Okoroma River

The Amagba-Okoroma River sediment physicochemical parameters and metal concentrations were measured and analyzed (Table 2). The mean temperature was 25.67°C, 26.00°C and 26°C at Sites 1, 2 and 3 respectively. Spatially, there was no significant difference among the sites (P=0.34). The mean pH ranged from 7.55 to 7.68, indicating slightly alkaline conditions that are conducive to aquatic life. Mean electrical conductivity (EC) values, ranging from 49.33µS/cm to 54.67µS/cm, were within acceptable limits, indicating minimal salinity levels. The physicochemical parameters of the sediment in the Amagba-Okoroma River, were found to be consistent with studies conducted in similar aquatic ecosystems (Adesuyi *et al*., 2016; Ekere *et al*., 2017). These parameters collectively indicate a slightly alkaline environment with minimal salinity levels, which are generally conducive to aquatic life across different river systems (Barakat *et al*., 2012; Yan *et al*., 2010).

The mean cadmium levels ranged from 0.09 to 0.10 mg/kg, which is within the permissible limits set by the USEPA Sediment Quality Guideline and threshold/probable effect level, indicating non-pollution status. The mean chromium levels varied between 5.61 to 6.10 mg/kg, also within acceptable limits. Copper concentrations ranging from 18.62 to 19.90 mg/kg slightly exceeded the threshold effect level (TEL) at sites 2 and 3, suggesting potential ecological risk. Lead and zinc levels were found to be within the acceptable limits across all sites, with mean Pb ranging from 0.329 to 0.367 mg/kg and Zn from 32.47 to 35.01mg/kg. Comparing the concentrations of metals with other studies reveals varying levels of contamination across different rivers worldwide. For instance, studies in the Niger Delta and Central Nigeria have reported elevated levels of Cr and Pb in river sediments impacted by industrial and anthropogenic activities (Ekere *et al*., 2017; Issa *et al*., 2011). Contrarily, the concentrations noticed in the Amagba-Okoroma River sediment were generally within acceptable limits, except for elevated Cu levels in localized areas, consistent with findings in other less industrialized regions (Enuneku and Ineh, 2020; Mohiuddin *et al*., 2010). This is probably because Amagba-Okoroma River is located in a peri-urban area of Benin City, where human pressure on the river is relatively less compare to rivers in the urban area.

Correlation Analysis

Table 3 highlights several significant correlations among sediment physicochemical parameters in the Amagba-Okoroma River. Sediment temperature has a strong negative correlation with pH ($r = -0.99$) and chromium ($r = -0.99$), but a strong positive correlation with copper ($r = 0.99$). pH is positively correlated with Cr ($r = 0.96$) and negatively with Cu ($r = -0.96$). Nitrate-nitrogen shows a very strong negative correlation with zinc ($r = -0.99$) and moderate correlations with other parameters, such as a positive correlation with EC ($r = 0.89$). Phosphate has a very strong positive correlation with lead ($r = 0.99$) (Figure 2). These findings indicate complex interrelations among temperature, pH, and metals like Cr and Cu, emphasizing their collective impact on sediment quality. Pearson correlation coefficients revealed a significant positive relationship between Cd and Cr, and between Cu and Zn, indicating similar pollution sources or geochemical behaviours.

Principal Component Analysis and Cluster Analysis of metals and other parameters in Amagba-Okoroma River

Principal Component 1 (PC1) accounts for 0.95 % of the variance. This component is strongly influenced by EC with a loading of 0.90, indicating that EC is the primary variable contributing to the variability captured by PC1. Nitrate-nitrogen and zinc also show moderate contributions to PC1, with loadings of 0.14 and -0.41, respectively. Principal Component 2 (PC2) explains 9.47 % of the variance. The most significant contributors to PC2 are copper (Cu) with a negative loading of -0.70 and zinc with a positive loading of 0.55. Chromium also contributes moderately to PC2 with a loading of 0.27. The first component, accounting for the majority of the variance, was heavily weighted by Cu and Zn, suggesting industrial or agricultural runoff as potential sources. The second component, characterized by Pb and Cr, might be linked to atmospheric deposition or vehicular emissions. The eigenvalues represent the amount of variance explained by each principal component. PC1, with an eigenvalue of 9.07, explains a very small portion of the variance in the dataset, while PC2, with an eigenvalue of 90.53, explains a slightly higher but still minor portion of the variance. These multivariate statistical analyses provide insights into the possible origin and interactions of metals in the Amagba-Okoroma river sediments. The PCA analysis conducted in this study identified a significant relationship between Cd-Cr and Cu-Zn, suggesting potential common pollution sources such as industrial runoff and agricultural activities (Yan *et al*., 2010; Mohiuddin *et al*., 2010). This finding aligns with similar studies that have utilized multivariate statistical techniques to discern sources of metal pollution in river sediments (Sharifuzzaman *et al*., 2016; Ogamba *et al*., 2017). Cluster analysis (CA) was employed to determine similarity among the three study sites. CA (Bray Curtis similarity) revealed that the sites were grouped into two clusters based on sediment physicochemical parameters (Figure 4). CA was utilized on various metals to determine their origins, employing

Ward's method and Euclidean distance to measure similarity (Figure 5). The metals such as Zn and Cu form the same cluster.

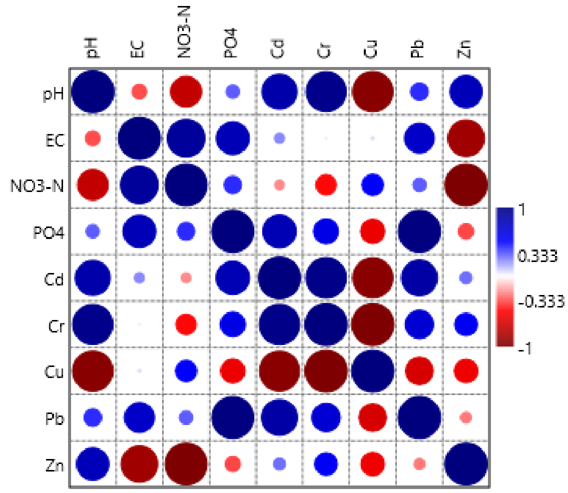


Figure 2: Correlation analysis of heavy metals and other parameters in sediment

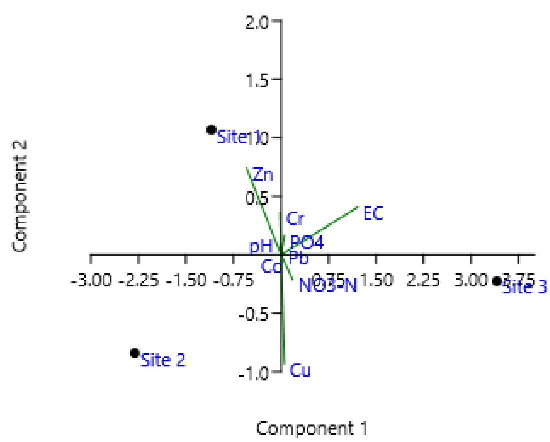


Figure 3: PCA biplot of physicochemical parameters

Table 2: Summary of measured sediment physio-chemical parameters (Mean ± SD and Range) in Amagba-Okoroma River, Benin City during the study period

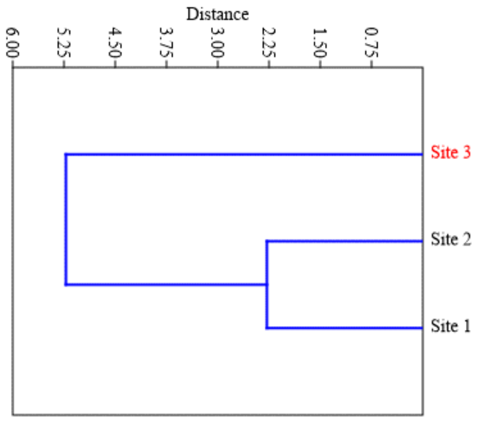
N/S	Parameters	Site 1	Site 2	Site 3	P value	World surface rock average [a]	USEPA SQG[b]			TEL[c]	PEL[c]
							Non-polluted	Moderately polluted	Heavily polluted		
1	Temp. (^{O}C)	25.67±0.41 (25-26)	26±0.55 (25 -26.5)	26±0.32 (25.5-26.5)	0.335	-	-	-	-	-	-
2	pH	7.68±0.17 (7.4-7.9)	7.57±0.28 (7.2-7.9)	7.55± 0.19 (7.3-7.8)	0.530	-	-	-	-	-	-
3	EC (µS/cm)	51±34.70 (6-94)	49.33±38.83 (6-100)	54.67± 45.88 (4-120)	0.973	-	-	-	-	-	-
4	NO_3-N (mg/kg)	0.155±0.09 (0.014-0.29)	0.29±0.21 (0.055-0.616)	0.98± 0.718 (0.101-1.824)	0.011	-	-	-	-	-	-
5	PO_4 (mg/kg)	0.603±0.57 (0.11-1.67)	0.328±0.296 (0.044-0.711)	0.623± 0.172 (0.432-0.812)	0.356	-	-	-	-	-	-
6	Cd (mg/kg)	0.113±0.045 (0.059-0.166)	0.09±0.005 (0.082-0.096)	0.101± 0.06 (0.063-0.17)	0.655	0.3	-	-	> 6	0.68	4.21
7	Cr (mg/kg)	6.102±2.18 (3.892-8.286)	5.606±2.36 (3.76-8.634)	5.69± 2.415 (3.762-8.77)	0.924	90	< 25	25-75	>75	52.3	160
8	Cu (mg/kg)	18.62±1.74 (15.97-20.23)	19.904±1.39 (18.73-21.56)	19.703± 1.77 (18.47-21.99)	0.37	45	< 25	25-50	50	18.7	108
9	Pb (mg/kg)	0.367±0.095 (0.213-0.496)	0.329±0.023 (0.295-0.355)	0.365± 0.018 (0.343-0.384)	0.459	20	< 40	40-60	> 60	30.2	112
10	Zn (mg/kg)	35.01±4.597 (29.55-39.75)	34.44±4.597 (27.85-46.322)	32.47± 10.31 (25.46-45.76)	0.861	95	< 90	90-200	> 200	124	271

- Indicates values unavailable

[a] Indicates Geochemical background taken is that given by Turekian and Wedepohl (1961)

[b] Indicates USEPA SQG given by Perin (1997)

[c] Threshold Effect Level/ Portable Effect Level (TEL and PEL) guidelines developed by MacDonald (1996)



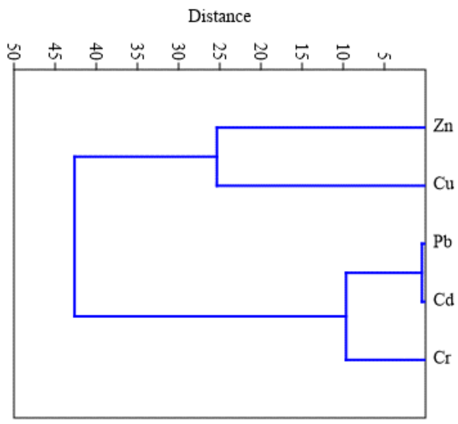


Figure 4: Cluster dendrogram showing the grouping sites based on sediment physicochemical parameters data in the Amagba-Okoroma River Edo State Nigeria

Figure 5: Cluster dendrogram of different sediment metal in Amagba-Okoroma River Edo State Nigeria

Contamination Degree (CD) and Pollution Load Index (PLI)

They were calculated and are summarized and presented in Table 3 and Figures 4 and 5. Table 4 presents the calculated pollution load index, contamination degrees, and contamination factors for sediment samples collected from the three sites in Amagba-Okoroma River. The CF for metals ranged between 0.004 and 0.553 across the sites, with Cu showing the highest values. This finding agrees with the findings of Singh *et al*. (2017), where CF values suggested low to moderate contamination levels in river sediments. The CD values were highest at site 1, with an average CD of 0.969, indicating a considerable contamination level. This finding is in contrast to the higher CD values observed in the Benin River by Enuneku *et al*. (2018), suggesting that the Amagba-Okoroma River has relatively lower contamination levels. The PLI ranged from 0.833 to 0.841 across sites, suggesting an excellent sediment health. This is similar to the PLI values reported in other studies (Olomukoro and Enabulele, 2024; Islam *et al*., 2015). These indices collectively indicate varying levels of metal contamination in the sediment of the Amagba-Okoroma River, reflecting potential environmental concerns that merit further investigation and management strategies. The heavy metal pollution indices indicated minimal sediment contamination and low ecological risk in the Amagba-Okoroma River, consistent with findings in sediment quality assessments from other less polluted river systems (Ekperusi *et al*., 2022; Ogbeibu *et al*., 2014). This proposes that despite localized pollution from Cu, the overall ecological health of the river sediments remains relatively stable compared to more contaminated rivers like those in heavily industrialized regions (Sharifuzzaman *et al*., 2016; Yan *et al*., 2010). These indices collectively show that the sediment quality of the Amagba-Okoroma River is generally good and poses minimal ecological risk. The relatively low contamination levels can be a result of the limited industrial activities in the peri-urban area. However, the elevated levels of Cu at certain sites indicate localized sources of contamination, which could be linked to specific man-made activities such as agricultural runoff or minor industrial discharges.

When comparing these results with the literature, it is evident that the sediment quality of the Amagba-Okoroma River is relatively better than some other water bodies. For instance, the study by Olomukoro and Enabulele (2024) on the Ozomu Lake in Southern Nigeria reported higher contamination levels for several metals, indicating greater ecological risk. Similarly, Singh *et al*. (2017) found higher levels of metal contamination in the River

Ghaghara, which posed significant ecological health concerns. Contrarily, the findings from the Amagba-Okoroma River sediments are in agreement with the findings from the study by Islam *et al*. (2015), which reported low to moderate levels of metal contamination in river sediments in Bangladesh. The relatively low contamination levels in the Amagba-Okoroma River could be attributed to lesser industrial activities since the rivers are located in a peri-urban area compared to more industrialized regions. Overall, the evaluation of metal contamination in the Amagba-Okoroma River sediment indicates that, except for elevated levels of Cu at certain sites, the sediment quality is within acceptable limits and poses minimal ecological risk. The use of various metal pollution indices such as I_{geo}, CF, CD, and PLI provides an extensive insight into the sediment quality and its potential impact on the ecological health of the Amagba-Okoroma River.

Table 3: Calculated contamination factor, contamination degree and Pollution Load Indexof sediment samples from Amagba-Okoroma River, Benin City.

Metals	**Site 1**	**Site 2**	**Site 3**
Cd	0.141	0.113	0.126
Cr	0.061	0.056	0.057
Cu	0.517	0.553	0.547
Pb	0.004	0.004	0.004
Zn	0.250	0.246	0.232
CD	0.974	0.971	0.967
PLI	0.841	0.839	0.833

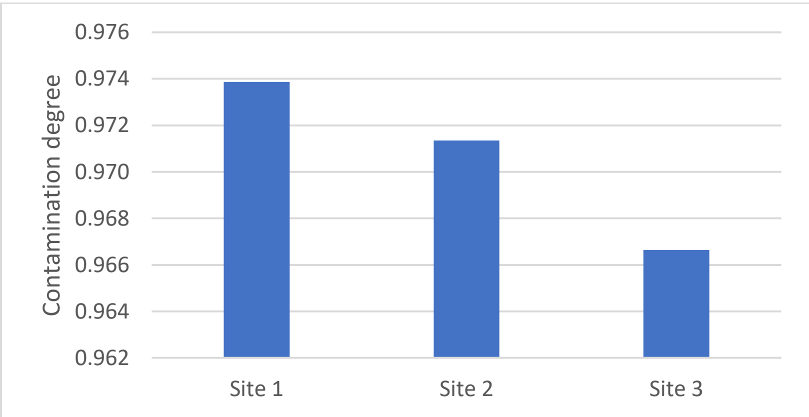


Figure 6: Contamination degree for the three sites at Amagba-Okoroma River

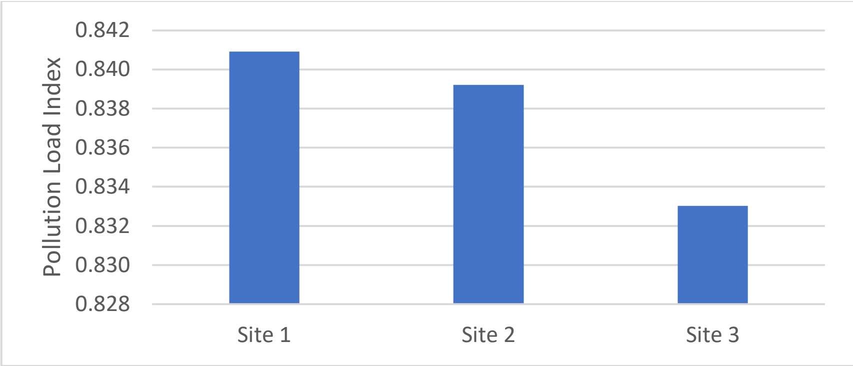


Figure 7: Pollution load index for the three sites at Amagba-Okoroma River

Geo-accumulation Index (*I_{geo}*)

The I_{geo} results reveal that all the sites are unpolluted with regards to all the metals analysed as shown in Table 4. The ecological health of the Amagba-Okoroma River sediments was evaluated using metal pollution indices. The I_{geo} values for all the metals indicated that all three sites were unpolluted. This finding aligns with the studies conducted by Islam *et al*. (2015) and Zhang *et al*. (2018), where the I_{geo} values also suggested low levels of metal pollution in river sediments.

Table 4: Geo-accumulation Index of Metals at Amagba-Okoroma River and Associated Pollution Status

Metals	Site 1	Site 2	Site 3	Pollution status
Cd	-1.994	-2.322	-2.156	unpolluted
Cr	-4.468	-4.590	-4.568	unpolluted
Cu	-1.858	-1.762	-1.776	unpolluted
Pb	-6.353	-6.511	-6.361	unpolluted
Zn	-2.025	-2.049	-2.134	unpolluted

CONCLUSION

While the sediment quality of the Amagba-Okoroma River is still relatively good, continuous monitoring is recommended to ensure that it remains within safe limits especially as Benin City continues to experience increased urbanization and development. Efforts should be made to control and reduce potential sources of metal contamination, particularly agricultural runoff and industrial discharges, to protect the peri-urban river and maintain the ecological status of the river.

CONFLICT-OF-INTEREST DISCLOSURE

No conflict of interest declared.

REFERENCES

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**(1): 16-27.

Barakat, A., El Baghdadi, M., Rais, J., and Nadem, S. (2012). Assessment of heavy metal in surface sediments of Day River at Beni-Mellal region, Morocco. *Research Journal of Environmental and Earth Sciences*, **4**(8):797-806.

Barbieri, M. (2016). The importance of enrichment factor (EF) and geoaccumulation index (*Igeo*) to evaluate the soil contamination. *Journal of Geology and Geophysics*, **5**(1): 1-4.

Binning, K., and Baird, D. (2001). Survey of heavy metals in the sediments of the Swartkops River Estuary, Port Elizabeth South Africa. *Water SA*, **27**(4): 461-466.

Ekere, N., Yakubu, N., and Ihedioha, J. (2017). Ecological risk assessment of heavy metals and polycyclic aromatic hydrocarbons in sediments of rivers Niger and Benue confluence, Lokoja, Central Nigeria. *Environmental Science and Pollution Research*, 24: 18966-18978.

Ekperusi, O. H., Ekperusi, A. O., and Olomukoro, J. O. (2022). Assessment of anthropogenic influences on the benthic invertebrate community of Oghan River in Edo State, Nigeria. *Journal of Applied Sciences and Environmental Management*, **26**(8): 1423-1431.

Enuneku, A. A., and Ineh, F. (2020). Assessment of Spatial Variations of Heavy Metals in Superficial Sediments of Ikpoba River and Comparison with Sediment Quality Guidelines. *FUTY Journal of the Environment*, **14**(1): 78-86.

Enuneku, A., Omoruyi, O., Tongo, I., Ogbomida, E., Ogbeide, O., and Ezemonye, L. (2018). Evaluating the potential health risks of heavy metal pollution in sediment and selected benthic fauna of Benin River, Southern Nigeria. *Applied water science*, **8**: 1-13.

Eseyin, O. O., and Osu, I. C. (2019). Effect of Municipal Solid Waste (MSW) Leachate on Groundwater Quality in Port Harcourt, Nigeria. *Journal of Geography, Environment and Earth Science International, (March)*, 1-12.

Fang, X., Peng, B., Wang, X., Song, Z., Zhou, D., Wang, Q. and Tan, C. (2019). Distribution, contamination and source identification of heavy metals in bed sediments from the lower reaches of the Xiangjiang River in Hunan province, China. *Science of the Total Environment*, **689**: 557-570.

Islam, M. S., Ahmed, M. K., Raknuzzaman, M., Habibullah-Al-Mamun, M., and Islam, M. K. (2015). Heavy metal pollution in surface water and sediment: a preliminary assessment of an urban river in a developing country. *Ecological indicators*, **48**: 282-291.

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

Kumar, A., Ramanathan, A. L., Prabha, S., Ranjan, R. K., Ranjan, S., & Singh, G. (2012). Metal speciation studies in the aquifer sediments of Semria Ojhapatti, Bhojpur District, Bihar. *Environmental Monitoring and Assessment*, **184**: 3027-3042.

MacDonald, D. D., Carr, R. S., Calder, F. D., Long, E. R. and Ingersoll, C. G. (1996). Development and evaluation of sediment quality guidelines for Florida coastal waters. *Ecotoxicology*. **5**(1): 253-278.

Massaquoi L. D., Ma H., Liu X. H., Han P. Y., Zuo S. M., Hua Z. X., Liu D. W. (2015) Heavy metal accumulation in soils, plants, and hair samples: an assessment of heavy metal exposure risks from the consumption of vegetables grown on soils previously irrigated with wastewater. Environ Sci Pollut R. https://doi.org/10.1007/ s11356-015-5131-1

Mohiuddin, K. M., Zakir, H. M., Otomo, K., Sharmin, S., and Shikazono, N. (2010). Geochemical distribution of trace metal pollutants in water and sediments of downstream of an urban river. *International Journal of Environmental Science & Technology*, **7**: 17-28.

Muller, G. M. (1969). Index of geoaccumulation in sediments of the Rhine River. *Geojournal*, **2**: 108-118.

Muneer, J., AlObaid, A., Ullah, R., Rehman, K. U., & Erinle, K. O. (2022). Appraisal of toxic metals in water, bottom sediments and fish of fresh water lake. *Journal of King Saud University-Science*, **34**(1): 101685.

Ogamba, E. N., Ebere, N., and Izah, S. C. (2017). Heavy metal concentration in water, sediment and tissues of Eichhornia crassipes from Kolo Creek, Niger Delta. *Greener J. Environ. Manage. Public Safety*, **6**(1): 001-005.

Ogundele, L. T., Ayeku, P. O., Adebayo, A. S., Olufemi, A. P., and Adejoro, I. A. (2020). Pollution indices and potential ecological risks of heavy metals in the soil: a case study of municipal wastes site in Ondo State, Southwestern, Nigeria. *Polytechnica*, **3**: 78-86.

Olomukoro, J. O., & Enabulele, C. O. (2024). Assessment of heavy metal contamination and sediment characteristics in Ozomu lake, southern Nigeria: Implications for environmental health. *Kuwait Journal of Science*, **51(2)**, 100192.

Perin, G., Bonardi, M., Fabris, R., Simoncini, B., Manente, S., Tosi, L. and Scotto, S. (1997). Heavy metal pollution in central Venice lagoon bottom sediments: evaluation of the metal bioavailability by geochemical speciation procedure. *Environmental technology*. **18**(1): 593-604.

Perin, G., Bonardi, M., Fabris, R., Simoncini, B., Manente, S., Tosi, L. and Scotto, S. (1997). Heavy metal pollution in central Venice lagoon bottom sediments: evaluation of the metal bioavailability by geochemical speciation procedure. *Environmental technology*. **18**(1): 593-604.

Sharifuzzaman, S.M., Haifizur, Rahman., Ashekuzzaman, S.M. and Mohammad, M. Islam. Heavy metals accumulation in coastal sediments. (2016). *Environmental remediation technologies for metal contaminated soils*: 21-42.

Singh, H., Pandey, R., Singh, S. K., and Shukla, D. N. (2017). Assessment of heavy metal contamination in the sediment of the River Ghaghara, a major tributary of the River Ganga in Northern India. *Applied Water Science*, **7**: 4133-4149.

Tomlinson, D. L., Wilson, J. G., Harris, C. R. and Jeffrey, D. W. (1980). Problems in the assessment of heavy-metal levels in estuaries and the formation of a pollution index. *Helgoländer meeresuntersuchungen.* **33**(1): 566-575.

Turekian, K. K. and Wedepohl, K. H. (1961). Distribution of the elements in some major units of the earth's crust. *Geological society of America Bulletin*. **72**(1): 175-192.

USEPA. (2002). Supplemental guidance for developing soil screening levels for superfund sites. *United States Environmental Protection Agency*, **12**: 1-187.

Vinodhini, R., and Narayanan, M. (2008). Bioaccumulation of heavy metals in organs of fresh water fish Cyprinus carpio (Common carp). *International Journal of Environmental Science and Technology*, **5**:179-182.

Yan, C., Li, Q., Zhang, X., and Li, G. (2010). Mobility and ecological risk assessment of heavy metals in surface sediments of Xiamen Bay and its adjacent areas, China. *Environmental Earth Sciences*, **60**: 1469-1479.

Yan, C., Li, Q., Zhang, X., and Li, G. (2010). Mobility and ecological risk assessment of heavy metals in surface sediments of Xiamen Bay and its adjacent areas, China. *Environmental Earth Sciences*, **60**: 1469-1479.

Zhang, Z., Lu, Y., Li, H., Tu, Y., Liu, B., and Yang, Z. (2018). Assessment of heavy metal contamination, distribution and source identification in the sediments from the Zijiang River, China. *Science of the Total Environment*, **645**: 235-243.