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HEAVY METALS ASSESSMENT AND ASSOCIATED POTENTIAL HEALTH RISK OF BUILDING SEDIMENT DEPOSITION IN OKPARE CREEK, NIGERIA

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ABSTRACT

Heavy metals concentrations in sediments may pose significant threats to human health and well-being of the general ecosystem. Therefore, it's crucial to conduct a thoughtful assessment of sediment characteristics with regards to heavy metal concentration as a raw material for building in the studied area. Twenty sediment samples were collected (five each from localities) and analysed using atomic absorption spectrophotometer (AAS). The highest concentrations of Zn, Cu, Cd, Cr, Pb, V, Fe and Ni were 6.33, 2.65, 0.45, 1,201, 0.38, 0.00, 1026.39 and 0.65 mg/kg respectively in each of the four localities. The results exceeded both recommended limit and other scientist report of similar environment. Also, the health risk impacts computed were all higher than limits. These high values may be attributed to the nature of the area geological formation, application of fertilizer to the farmlands and petroleum exploration and production activities. Cd stood out as the main culprit for potential ecological risks. The average contamination level, as indicated by I-geo values ranging from 0.28 to 0.79 mg/kg, raised concerns, especially at locality 1. Across the board, I-geo values remained generally low (< 2). Cd and Pb, with an I-geo value of about 1, significantly impacted sediment pollution. Average EF values were from 0.02 to 5.76 which revealed that human activities heavily influenced the sediment, marking them as significantly enriched with observed heavy metals. In particular, Cd played a major role in the sediment's enrichment, indicating a high level of environmental impact.

Keywords: Heavy metals pollution; hydrocarbon waste; potential ecological risk; Sediment; Okpare

INTRODUCTION

Okpare Creek in Ughelli South is mainly known for fishing and sand mining. These activitiesespecially sand mining is of great concern as it is used as raw material for building of houses by the residents. The creek is characterized by hydrocarbon pollutants such as gas flaring, discharged of contaminated produced water, agricultural waste water, contaminated sand and sludge into the Creek water body. These hydrocarbon pollutants may associate with heavymetals such aslead, zinc, chromium, cadmium, vanadium, copper, iron, and nickel which may be detrimental to living things (Ayenimo*et al.*, 2004). The physical, chemical and biological effects of heavy metals range from beneficial stimulation of living things to harmful retardation and sometimes could lead to death (Oyewo, 1998). The harmful nature of heavy metals is primarily linked to the ability of metal ions to create stable complexes with proton active sites (Bastami*et al.*, 2014).Once heavy metals enter living things' systems, they cannot be broken down easily through biological

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degradation, but instead accumulate in the body systems (Faramobi*et al.*, 2007). High concentrations of these metals could harm the normal functions of living things and could cause death if not avoided. Scientists overtime, have studied heavy metals concentrations in sediments and their harmful health impact on man and his environment (Ekiye and Zejiao, 2010; Cao *et al.*, 2015; Idris*et al.*, 2007; Ruilian*et al.*, 2008; Bastami*et al.*,2014; Hosono*et al.*, 2011; Paramasivam*et al.*, 2015; Fu and Wang, 2011).

In Nigeria, there is no reported data (To the best of our knowledge) on heavy metals concentration of sediment in Okpare Creek, despites the constant sand mining activities in the area. Also, reports from the local health centers showed that cases of cancer and other disease in patients are increasing daily. Hence the research work is aim at assessing the concentration of heavy metals in the studied area sediments as raw material for building of houses and their health risk in the locality and environments. The results of this study will provide base line data (firsthand information) that can be used to appraise heavy metals health implications on the residents. This will help the Government to make policies that would help in regulating the sediment mining activities and keep the standard of living of the people as safe as possible.

MATERIALS AND METHOD

Sampling Location

The research was conducted along the Okpare Creek in the Ughelli South Local Government Area of Delta State, Nigeria. This area is positioned between latitudes 05", 27 N and 05", 33 N and longitudes 005", 53 E and 006", 04 E (Figure1). The freshwater creek originates from Umuaja byUmutuand flowing through Abraka, Agbon, Ughelli, Okpare Creekand eventually reaching the Atlantic Ocean at Forcados.This region experiences two main seasons, the dry and the wet due to its equatorial location (Airen and Emenim, 2021).

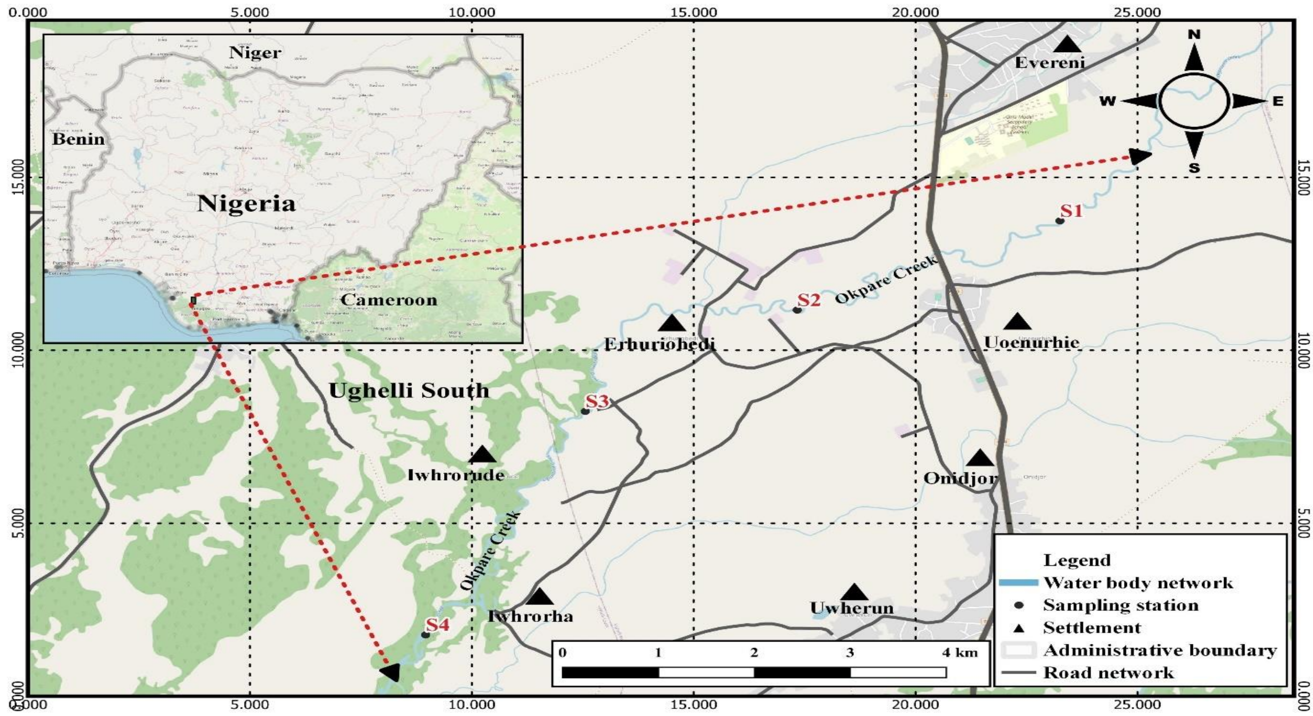

Figure 1: Map of the Study Area

The Urhobo-Olomu people are the main inhabitants of this region, and they engage in various activities such as farming, fishing, trading, and molding. The land is primarily made up of rugged, coarse sandy soil, with decomposed organic material from plants biomass along the riverbank. The creek has a depth of 8 meters, and the water flows at a speed of 0.8 meters per second. The landscape is adorned with lush tropical rainforest trees, including Rubber trees, oil palm trees, Indian Bamboo, and cola trees (Airen and Emenim, 2021).
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Sampling and Analysis

A total of twenty sediment samples were collected (five sample each from one station). Scientific systematic approach was applied during sampling.The samples were put on uncontaminated stainless steel trays and air dried for three days. The dried samples where grindedusing ceramic mortal and pestle and sieved with 2mm mesh to eliminate coarse materials from it. Subsequently, precisely measured weights of the samples (10g) went through digestion using a 1:1 ratio by volume of hydrogen peroxide and concentrated nitric acid. The samples filtrate were analysed using atomic absorption spectrophotometer (AAS)made in UK. To calibrate the analytical process, a standard solution of metals was meticulously prepared, incorporating 25% of the acid used in the solution. Both the sediment extracts and the standard solution were aspirated into a SOLAAR 969 UNICAM Series air-acetylene flame AAS for precise determination of heavy metal concentrations (Olomukoro and Azubuike, 2009; Ogbeibu et *al*., 2014).

Dataanalysis

Potential Ecological Risk Index (PERI)

The PERI method is a tool for assessing risk posed on human by heavy metals (Hakanson, 1980)). PERI comprises of three fundamental components namely;potential ecological risk factor (ER), toxic-response factor (TR) and the degree of contamination (CD). The equations below can be used to determine the potential ecological risk and its comprehensive potential ecological risk index (RI) for an individual.

$$\mathrm{C_f^i} = \frac{\mathrm{C_D^i}}{\mathrm{C_R^i}} \text{...}(1)$$

whereC^i_D= measured heavy metal concentration in each sample, C^i_R= background heavy metal reference value of analyedsediment and C^i_f= single element factor pollution.

$$\mathrm{E_R^i} = \mathrm{T_R^i} \times \mathrm{C_f^i} \text{...}(2)$$

where
E^i_R= potential ecological risk of a single element while T^i_R= biological toxic factor which can be determined using the following element values: Zn = 127, Cu = 32, Cr = 71, Cd =0.2, Pb = 16, Ni = 49

$$RI = \sum_{i=1}^{m} E_R^i \text{...}(3)$$

RI = is a comprehensive potential ecological risk index(Martin and Meybeck 1979).

The equation delineated by Muller (1969) was used in computing the Geo-accumulation index, as illustrated by Boszke*et al.*, (2004).

The Geo-Accumulation Index

$$\mathrm{I - geo} = \log 2 \left(\frac{\mathrm{Ci}}{1.5} \mathrm{Cri} \right) \text{..................................}(4)$$

Where*Ci*is the measured concentration of the examined metal *i*in the sediment, and *Cri* is the geochemical background concentration or reference value of the metal *i* (Muller 1987; Chakravarty and Patgiri, 2009).

Enrichment Factor (EF)

The EF is a method use to evaluate the level heavy metal pollution quantitatively in sediment.

$$EF = (X/Fe)_{sediment}/(X/Fe)_{bakcground} \text{..........(5)}$$

Where $(X/Fe)_{sediment}$= ratio of heavy metal (X) to Fe and $(X/Fe)_{bakcground}$= ratio of natural background value of Fe which is232.7 mg/kg for iron (Fe). The geological origin is suggested when Enrichment factor (EF) values are slightly closed to unity, values less than 1.0 indicate potential depletion of metals and values exceeding 1.0, point towards an anthropogenic origin (Nweke and Ukpai, 2016). Also, EF values exceeding 1.0 indicate anthropogenic origin (Zseferet *al.*,1996).

RESULT AND DISCUSSION

The results of heavy metal concentrations of Okpare Creek sediment are presented in Table 2. These values were compared with the Nigeria Federal Ministry of Environmental (FMEnv, 2005).

Heavy metals concentrations

Table 2: The results of heavy metal concentrations of Okpare Creek sediment

Parameters (mg/kg)	**Locality 1** X̅±SD (MIN-MAX)	**Locality 2** X̅±SD (MIN-MAX)	**Locality 3** X̅±SD (MIN-MAX)	**Locality 4** X̅±SD (MIN-MAX)	**FMEnv. Standard**
Lead	0.12±0.08 (0.01-0.29)	0.11±0.06 (0.02-0.30)	0.15±0.09 (0.02-0.38)	0.10±0.05 (0.02-0.23)	0.040
Zinc	2.49±1.75 (1.13-6.33)	1.41±1.26 (0.01-4.23)	3.35±2.24 (0.76-8.71)	1.76±1.36 (0.02-4.73)	0.030
Copper	0.96±0.66 (0.12-2.14)	0.33±0.46 (0.02-1.91)	1.16±0.74 (0.12-2.65)	0.38±0.50 (0.02-2.09)	0.030
Cadmium	0.12±0.08 (0.02-0.31)	0.05±0.04 (0.00-0.14)	0.13±0.11 (0.02-0.45)	0.03±0.05 (0.00-0.23)	0.030
Nickel	0.06±0.13 (0.01-0.65)	0.02±0.02 (0.00-0.06)	0.04±0.03 (0.00-0.11)	0.01±0.02 (0.00-0.08)	0.006
Chromium	4.05±1.82 (1.40-7.13)	1.55±0.81 (0.03-3.61)	54.31±24.25 (1.75-1201.00)	1.65±1.03 (0.67-5.16)	0.012
Vanadium	0.001±0.00 (0.00-0.00)	0.001±0.00 (0.00-0.00)	0.001±0.00 (0.00-0.00)	0.001±0.00 (0.00-0.00)	N/A
Iron	509.56±143.97 (283.23-761.36)	439.32±92.06 (303.78-634.69)	638.53±197.09 (326.75-1026.39)	560.37±154.79 (319.73-850.11)	N/A

N/A: Means not specified by FMEnv. (Federal Ministry of Environment Nigeria

Lead (Pb)

The highest concentration value Pbrecorded is 0.38 mg/kg at locality 3 and the lowest value is 0.01 mg/kg recorded at locality 1. The mean Pb results ranged from 0.10 mg/kg at locality 4 to 0.15 mg/kg at locality 3. The obtained sediment values were all lower than the (FMEnv, 2005) recommended limitand researchers reported values in similar (Benin River and Ekpan Creek) environment (Ogbeibu, 2011; Ogbeibu*et al.,* 2014; Olomukoro and Azubuike, 2009; Radojevic and Bashkin, 1999). The existence of Pb in the ecosystem could be ascribed to geological formation of the area and elevated anthropogenic activities.

Zinc (Zn)

The zinc content ranged from 1.13 to 6.33, 0.01 to 4.23, 0.76 to 8.71, and between 0.02 to 4.73 mg/kg atlocalities 1, 2, 3 and 4 respectively with mean values of 2.49, 1.41, 3.35 and 1.76 at the mentioned localities respectively. The highest valuewas 8.71 mg/kgatlocality 3 while the lowest value was recorded as 0.01 mg/kg atlocality 2.The obtained zinc values were all higher than the (FMEnv, 2005) recommended limit but were in agreement with the valuesreported by previous workers(Ihenyen, 2001; Ogbeibu, 2011; Ogbeibu et *al*., 2014;Anglin-Brown *et al.,* 1995). This high zinc values may be attributed to the regular flow of wastes waters andsewage to the location runoff which may contained high concentration of zinc, geological formation, application of fertilizer to local farmlands and other similar anthropogenic activities.

Copper (Cu)

The obtained values of copper rangedfrom 0.12 and 2.14, 0.02 to 1.91, 0.12 and 2.65, and 0.02 to 2.09 mg/kg at localities 1, 2, 3 and 4 respectively. The highest value was 2.65 mg/kg at locality 3, while the lowest value was 0.02 mg/kg at locality2 and 4 respectively. The mean of copper 1.16 mg/kg was highest at locality 3 and as lowest as 0.33 mg/kg at locality 2. The obtained zinc values are also higher than the (FMEnv, 2005) recommended limit, but are in agreement with the values by obtained and reported in Orogodo River and Benin River sediments respectively (Puyate*et al*., 2007; Ogbeibu, 2011; Ottaway, 1978). This high zinc values may be attributed to geological formation of the area and anthropogenic activities such as hydrocarbon waste discharged/filling of gas into the atmosphere and oil spillage.

Cadmium (Cd)

The highest value of Cd in sediment was0.45 mg/kgobtained atlocality 3 while the lowest value 0.00 mg/kgwas observed at localities 2 and 4. The mean concentrations of the metal were 0.03 and 0.13 mg/kg at localities 4 and 3respectively. The statistical evaluation of the mean values for this element revealed a fluctuation-drift in its concentrations among the sampled localities. However, the obtained Cd values partially exceeded the (FMEnv, 2005) recommended limit. This relatively high Cd values could be attributed togeological formation of the area, commercial fertilizers appliedon agriculturefarmland (Young, 2005).Exposure to cadmium and its compounds through inhalation and ingestion of metals may put human and the living organisms in high health risk in the area (ATSDR, 1989).

Nickel (Ni)

The nickel values were0.01 and 0.65, 0.00 to 0.06, 0.00 to 0.11 and 0.00 to 0.08 mg/kg at localities 1, 2, 3 and 4 respectively.The highest value of the metal was 0.65 mg/kg at locality 1 while the other three localities had similar value of0.06, 0.11 and 0.08 mg/kg respectively. The average concentration of the metal varied from 0.01 mg/kg at locality 4 to 0.06 mg/kg at locality1. These values were below recommended limit and reported research work onBenin river sediments(Ogbeibu*et al.*,2014; Olomukoro and Azubuike, 2009).

3.1.6 Chromium (Cr)

The highest obtained value of Cr is 1,201 mg/kg atlocality3 while the lowest value is 0.03 mg/kg at locality 2. The average valuesranged fromlocalities 3 to 2 with values54.31mg/kg and 1.55mg/kg respectively. The mean Cr values recorded were all lower than recommended limit (FMEnv, 2005) and other previousreported work (Olomukoro and Azubuike, 2009) and far higher than values (0.25 - 1.68 mg/kg) reported for Benin river (Ogbeibu*et al*., 2014).

3.1.7 Vanadium (V)

There was no range of values obtained. All values were below the detectable limit (BDL).

3.1.8 Iron (Fe)

The highest obtained value of Iron was1026.39 mg/kg atlocality 3, while the lowest value was 283.23 mg/kg atlocality 1. The average values of iron ranged from 439.32 mg/kg at locality 2 to 638.53 mg/kg at locality 3.The mean concentrations of iron recorded exceeded the values reported by other researcher in similar environment (Puyate*et al*., 2007; Akan *et al*., 2010; Ogbeibu, 2011). These variations may be attributed to anthropogenic activities carried out in the neighbourhood (Kakulu, 1985; Kakulu*et al*., 1987; Adefemi*et al*., 2007 and Ogbeibu*et al*., 2014).

Table 3: Potential Ecological Risk Index (PERI) in Okpare Creek sediment

Localities	Pb	Zn	Cu	Cd	Ni	Cr	RI	Risk level	Interpretation
1	0.21	0.68	0.05	258.95	0.40	0.11	15.16	A	Slight
2	0.35	1.71	0.14	819.92	1.90	0.28	8.27	A	Slight
3	0.31	1.67	0.12	798.28	1.48	0.26	22.79	A	Slight
4	0.29	1.31	0.10	546.91	1.08	0.22	8.40	A	Slight
Average	**1.15**	**5.37**	**0.42**	**2424.06**	**4.86**	**0.87**		A	Slight

Table 4: Index of Geo-accumulation (I-Geo) in Okpare Creek sediment

Localities	Cu	Zn	Cd	Pb	Elements	Mean I-Geo	Rank	Class	Results
1	1.02	0.89	2.87	3.13	Cu	0.29	<0	0	Unpolluted
2	0.08	0.22	0.01	0.01	Zn	0.28	≥ 0 > 1	0	Unpolluted
3	0.05	0.00	0.03	0.00	Cd	1	< 2	2	Moderately polluted
4	0.01	0.00	0.01	0.00	Pb	1	<2	2	Moderately polluted
Mean	**0.29**	**0.28**	**0.73**	**0.79**					

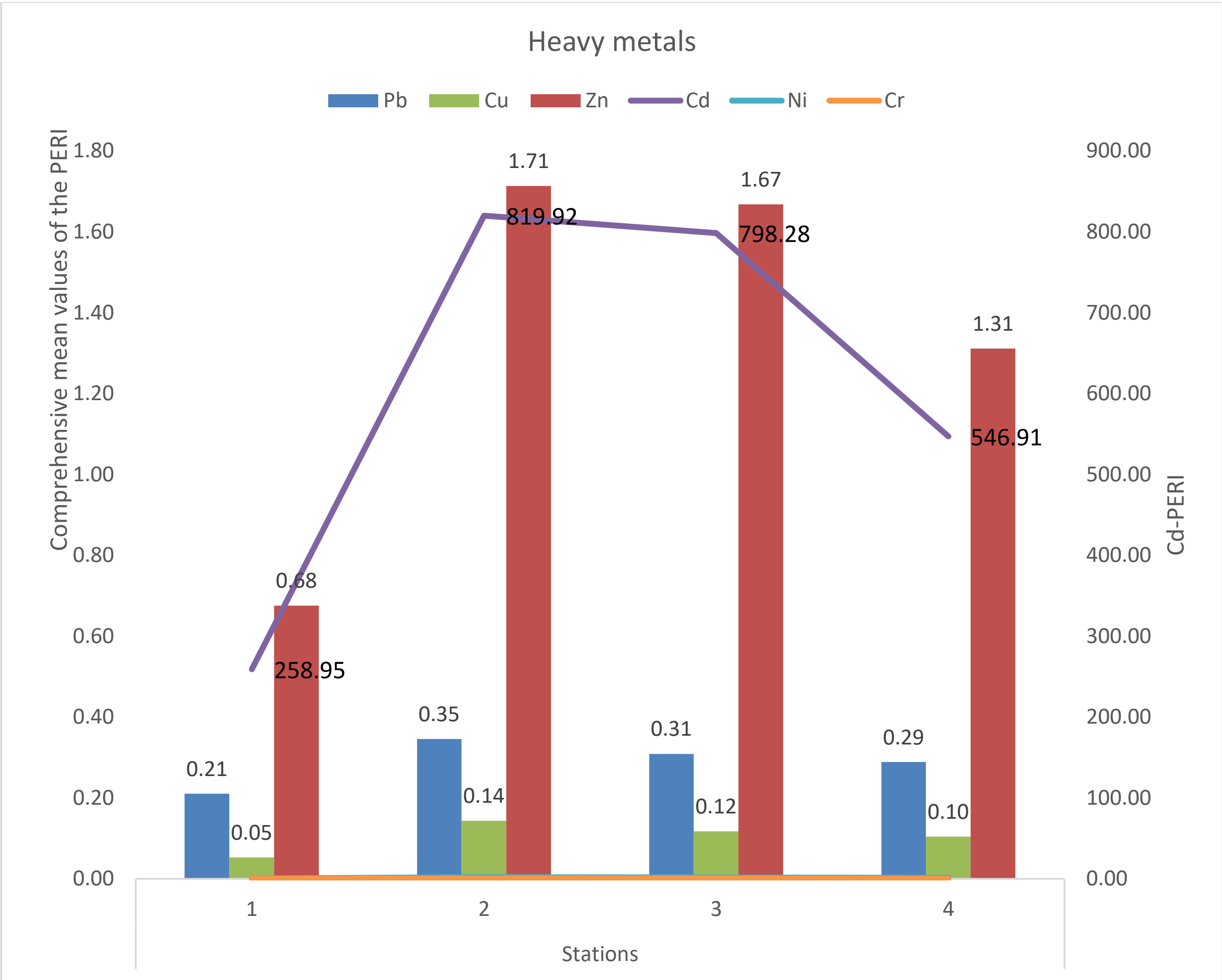

Figure 2: Heavy metals distribution and comprehensive PERI across the localities.

Table 5: Enrichment Factors (EF) in Okpare Creek sediment

Locality	Fe	Pb	Zn	Cu	Cd	Ni	Cr	Elements	EF	Rank	Interpretation
1	232.7	0.00	0.01	0.01	0.18	0.00	0.01	Pb	0.39	<1	Crustal origin
2	232.7	0.00	0.00	0.01	0.14	0.00	0.02	Zn	0.04	<1	Crustal origin
3	232.7	0.03	0.09	0.12	2.17	0.00	0.18	Cu	0.06	<1	Crustal origin
4	232.7	1.51	0.07	0.12	20.55	0.08	0.03	Cd	5.76	>1	Significant enrichment
Mean	**232.7**	**0.39**	**0.04**	**0.06**	**5.76**	**0.02**	**0.06**	Ni	0.02	>1	Crustal origin
								Cr	0.06	<1	Crustal origin

Ecological health risks (EHR)

The health risk implication to human and the environment due to heavy metals concentrations were computed and the obtained results of PERI, *I*-geo and Enrichment Factor are presented in table 3, 4 and 5 respectively. The PERI average results had its lowest and highest value as 0.42 and 2424.06 respectively. These values revealed a very strong potential health risk for dwellers using the sediment as raw material for building. The comprehensive PERI had the highest values of 15.16 and 22.79 in localities 1 and 3, so the ecological risk levels were slight.The *I*-geo mean results had its lowest and highest value as 0.28 and 0.79 respectively. This suggests a possible contamination (Moderately contaminated), especially in locality 1. The values were observed to be low in all cases (i.e. less than 2).However, Cd and Pbcontributed mostly to the pollution status of the sediment having an I-*geo*value of approximately 1 (moderately polluted).This observation aligns with results obtained by research work on the PERI assessment of heavy metals in sediments of water reservoirs (Ghaleno*et al*., 2015).The Enrichment Factor values meticulously exhibited a range of 0.02 to 5.76. The mean EF values unequivocally point towards the sediment samples originating from anthropogenic sources, indicating a substantial enrichment origin. Notably, the enrichment factor outcomes underscored the pronounced contribution of Cd to sediment enrichment, particularly in locality 3 and 4, where it attained elevated levels.An EF value falling between 0.5-1.5 suggests a crusted material or natural processes origin while an EF exceeding 1.5 leans towards an anthropogenic source (Zhang and Liu, 2002).However, the EF results revealed that Fe concentration as the background value indicated that Pb, Zn, Cu, Ni, and Cr enrichment factors were of crustal origin, signifying no discernible enrichment. This observation implies a potential mobilization of these metals (Zsefer *et al.,* 1996). In stark contrast, Cd exhibited a markedly significant enrichment, aligning with the characterization of being highly enriched, as per Sutherland's criteria.

CONCLUSION

The study has examined the heavy metals concentrations of building sediments at Okpare Creek. It has revealed that the potential ecological risk and other risk indices across the stations exceeded both recommended limits and other scientist reports on similar environment.As a result, such sediments would not be recommended as raw material for building and other civil construction work.Therefore, discharged hydrocarbon waste should be treated properly before release into the environment. Also, government should ensure total compliance by operators of government policies hydrocarbon waste and gas flaring in the area. In addition, there should be regular monitoring of heavy metal concentrations in sediments by both the hydrocarbon operators and appropriate government agencies.

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