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Evaluation of petroleum activities and pollution indices on heavy metals levels in the sediment of Epie Creek, Yenagoa, Bayelsa State

Douye Parkinson MARKMANUEL *

Department of Chemical Sciences, Faculty of Science, Niger Delta University, Wilberforce Island, P.M.B 071, Yenagoa, Bayelsa State Nigeria.

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Abstract

The levels of heavy metals (Pb, Cd, As, Cu, Fe, Zn, Cr, Ni, Co, and Mn) in the surface sediments from Epie Creek were studied to determine the impact of petroleum and anthropogenic activities on the pollution load of the Epie Creek, Yenagoa, Bayelsa State. The levels of the heavy metals were measured using Flame Atomic Absorption Spectrophotometer (FAAS). The mean levels (mg/kg) of the heavy metals in the four locations were found to be in hierarchical order of Cr > Cu > Fe > Pb > Zn > Ni > Mn > Co > As > Cd. The control sample (location 4) has the lowest value of metal concentrations while, location 3 recorded the highest, indicating the influence of the petroleum and other anthropogenic activities on the surface sediment of the Creek. The source connectivity of these metals was supported by Spearman's Correlation Analysis where most of the metals exhibited strong positive relationship, pointing to the same anthropogenic sources. Pollution indices study revealed that all of the metals have low contamination status except Cd that was highly contaminated. The geoaccumulation index values revealed that all the metals are practically unpolluted except Fe which ranked from moderately to extremely polluted in location 2, 3 and 1 respectively. The potential ecological hazard factors were in the order of Cd > Cu > Fe >Pb > As > Co >Cr > Ni > Zn > Mn > Fe. Among the four studied locations, location 3 has the highest metal levels and poses the greatest hazard risk. Therefore, the government of Bayelsa state and Nigerian Midstream/Downstream Petroleum Regulatory Authority (NMDPRA) should monitor and regulate the siting of petrol stations at Creeks and river bank; and also enact laws to stop indiscriminate dumping of wastes in the Epie Creek.

Key word: Epie Creek*;* Sediment Petroleum Activities*;* Heavy Metals*;* Pollution Indices

1. Introduction

The Epie Creek was very prominent, and of great importance to Epie indigenes and Yenagoa Local Government at large. The Creek was an important fresh water body that houses all kinds of fresh water fishes and other aquatic organisms. The Epie Creek was a major source of drinking water and other household activities. The Creek was also a major source of fishing and recreational activities especially during the Epie New Yam Festival. The Creek runs across the sixteen (16) communities in the Epie Clan namely; Igbogene, Yenegwe, Akenfa, Agudama-Epie, Akenpia, Edepie, Okutukutu, Opolo, Biogbolo, Yenizue-gene, Kpansia, Yenizue-Epie, Okaka, Ekeki, Azikoro and Amarata, down to Yenagoa in Atissa, Bayelsa State. The Epie Creek is linked to other rivers such as Orashi river, Nun River, Ekole river and Talyor river and as such it was a major water transportation route within the state and outside the state of the Niger Delta region of Nigeria (Rivers, Delta, Akwa-ibom and cross river).

However, sequel to the creation of Bayelsa State in 1996 by the then Military Head of State, late General Sani Abacha, the Creek became a sink for pollutants. This is because, Yenagoa, the capital city of Bayelsa, state was the only city with

* Corresponding author: Douye Parkinson MARKMANUEL

good access to road hence, there was a massive economic boom and increase in population within the state capital (Yenagoa town and its environs).

Since the Epie Creek and its communities run transversally along the Yenagoa metropolis, the Creek becomes a dumpsite for all kinds of wastes; industrial wastes, household wastes (sewage and garbage) as well as agricultural run-off and petroleum activities (citation of petrol stations near the Creek). Currently, the Creek has become a sink for water hyacinth, snakes, reptile, and other environmental chemical pollutants such as heavy metal, hydrocarbon etc. (Markmanuel and Young 2023; Nathan and Soronnadi-ononiwu et al., 2022 and Seiyabah, 2018).

Heavy metal contamination of aquatic ecosystems (waters and sediments) is alarming and is of a major public health concern as trace to concentrated amounts of these metals are always present in waters and sediments. (Markmanuel and Young, 2023; kiero et al., 2012, Huang et al., 2012). Once these metals are released into the water ecosystem, they persist, bioaccumulate and biomagnify within the food chain and cause detrimental health hazard to living organisms especially man at the apex of the food pyramid (Jordananova et al., 2018, Mortuzu et al., 2009, Fermander and Olahia, 2000).

Recent studies have shown that, sediment serves as a sink for heavy metals (Kieri et al., 2021; Hung et al., 2020; Fang et al., 2019; Ebuete et al., 2019). This is because heavy metals are easily deposited in the sediment and accumulate over time. The accumulation of these metals in the sediment poses threat to the benthos organisms such as shrimps, oysters, crabs, clams, lobsters, periwinkles etc. which later affects higher organisms via food chain (Budu et al., 2018; Ogamba et al., 2017; Markmanuel and Horsefall, 2016; Fu et al., 2014.

The major sources of heavy metal pollution in the riverine ecosystem in the Niger Delta region of Nigeria are often petroleum products and oil related activities (exploration and exploitation), one of such activities that threatens the aquatic life is the proliferation of petrol stations along the water ways. Most often, the wastes generated from these petrol stations are discharged indiscriminately in the aquatic ecosystem without proper treatment. Furthermore, most petrol stations pipe are damaged and as such, petroleum products can easily flow into the water ways since they are sited near the water ways and the Epie Creek has been a victim of this activity since the creation of Bayelsa State. Recent studies have shown that the refined petroleum products show higher toxicity compared to the crude oil itself, because during the process of refining metals, speciation are altered and new metals are added to the products (Ulakpa et al., 2022; Adewuyi et al., 2021; Oluwaseun et al., 2020). Again, most of this waste generated may contain spent catalyst which may trigger the reactivity of these metals in the sediment or suspended water body to cause secondary pollution (Kauidin et al., 2016; Wang etal., 2015) and one recipient and victim of such unfriendly environmental practice is the Epie Creek. Therefore, it is imperative to evaluate the impact of petroleum activities on heavy metal levels and pollution indices in the sediment of Epie Creek, Yenagoa Bayelsa State.

2. Materials and method.

2.1. Study area

The Epie Creek is located geographically at latitude 4^{o} 55’ 23”and longitude 6^{o} 15’ 28” in the Niger Delta Region, Bayelsa State.

Figure 1a Google Map showing the Epie Creek in Yenagoa metropolis

Figure 1b Current Status of Epie

Source: Google Map, 2024

2.2. Sample Collection and Preparation

Surface sediment samples were collected at the depth of 15cm with soil auger from the Epie Creek in three different locations where petrol stations are sited closely to the Creek, these include Total petrol station, UnlessGod petrol station and Barbizone petrol station which are located in Yeneqwe-Epie, Agudama-Epie and Opolo Epie communities in Yenagoa, Bayelsa State along the Epie Creek in Yenagoa metropolis. Also control sediment samples were collected in the upstream of the Creek in Igbogene community where petrol station is not sited near the Creek to determine the background level of the heavy metal in the unaffected sediment with the contaminated sites. All sediment samples were collected in triplicate and packed into air tight polythene bags and labelled appropriately. Samples were transported in the laboratory, air dried to a constant weight, crushed with mortar and pestle and sieve with 2mm mesh into uniform particle size.

2.3. Sample Digestion and Flame Atomic Absorption Spectrometer (FAAS) Analysis

Approximately, one gram (1g) of the homogenized sediment sample was digested with 20 ml aqua regia (conc HNO_3/HCl) in a ratio of 3:1 V/V and 2 mL perchloric acid ($HClO_4$) was also added. After digestion clear solutions were obtained. The digests were cooled, filtered and diluted with 50 mL of distilled water (Ogoyi et al., 2011). The concentrations (mg/kg) of the heavy metals (Pb, Cd, As, Cu, Fe, Zn, Cr, Ni Co and Mn) were determined with Solar-thermal Elemental Atomic Absorption Spectrophotometer (FAAS-S4-71096 model). All chemicals and reagents were of analytical grade. FAAS analysis was carryout in triplicates as recommended by Association of Official Analytical Chemists (AOAC, 1990).

2.4. Evaluation of Pollution Indices of Heavy Metal in Epie Creek

2.4.1. Contamination Factor and Degree of Contamination

The contamination factor and degree of contamination indices were employed in this study to evaluate the contamination status of the sediment in Epie Creek. The contamination of the individual heavy metals in the sediment of Epie Creek was calculated using the formula reported by Edori and kpee (2017) with slight modification as expressed below:

$$CF_i = \frac{I_{mc}}{B_{cm}} ---------------------(1)$$

Where CF_i is the contamination factor index, I_{mc} is the individual metal concentration in the sediment and B_{cm} is their background concentrations. The background concentrations of the metals were taken from world average value in Shale which were; Pb = 20, Cd = 0.3, As = 13, Cu = 45 Fe = 47200, Zn = 95, Cr =90, Ni = 68, Co = 19 and Mn = 850 (Tisha et al., 2021; Kieri et al., 2020; Emmanuel et al., 2018) while, the degree of contamination DC was calculated as the sum total of all metal contamination factors as expressed below:

$$DC = \sum CF_i = CF_{Pb} + CF_{Cd} + CF_{As} + CF_{Cu} + CF_{Fe} ----CF_{Mn} --- (2)$$

Table 1 Recommended Contamination Factors and Degree of Contamination Value and Status

Contamination factor		**Degree of contamination**	
Value	Status	Value	status
$Cf_i < 1$	Low	DC < 6	Low
$1 \leq Cf_i < 3$	Moderate	6 = DC < 12	Moderate
$3 \leq Cf_i < 6$	Considerable	12 = DC < 24	considerable
$Cf_i = 6$	Very high	DC = 24	Very high

Source: Harkumar et al., (2010)

Note, $CF_i = 6$ and $DC = 24$ indicates alarming anthropogenic source pollution of the individual metals and combined effects of all the metals in the sediment.

2.4.2. Geoaccummulation Index (Igeo)

The geoaccumulation index was employed in this study to evaluate the current heavy metal pollution level by comparing them to pre-industrial levels (Muller 1979). The geoaccumulation index (Igeo) have been widely employed by many researchers to evaluate the heavy metal pollution in the sediments because, it could directly reflect the enrichment of anthropogenic source of heavy metals (Huang et al., 2020; Edori and Kpee 2017; Banu et al., 2013; Tran et al., 2013; Karkumar et al., 2010; Andy et al., 2004). Thus, it can be calculated as follows;

$$Igeo = log2\left(\frac{C_{ms}}{1.5C_{gb}}\right) ------------ (3)$$

Where C_{ms} is the concentration of the metals in the sediments,

C_{gb} is the geochemical background concentration of the metals and 1.5 is the background matrix correction factor adopted as a coefficient to compensate sedimentary and lithogenic effects. According to Muller (1981) geoaccumulation index can be classified into six classes. These include; class 0 (Igeo ≤ 0) - practical unpolluted; class 1 (0 < Igeo ≤ 1) - unpolluted to moderately polluted; class 2 (1 < Igeo ≤ 2) moderately polluted; class 3 (3 < Igeo ≤3) moderately to heavily polluted; class 4 (3 < Igeo ≤ 4) heavily polluted; class 5 (4 < Igeo ≤ 5) heavily to extremely polluted and class 6 (Igeo > 5) extremely polluted.

2.4.3. Evaluation of Potential Ecological Hazard Factor and Hazard Index (HI)

The potential ecological hazard factors and hazard index (HI) was employed to ascertain the gravity of the ecological hazard of the individual heavy metal and the combine toxicity index of all the studied heavy metals in the sediment of Epie Creek (Hakanson, 1980). The HI expressed the combine ecological and environmental toxicity which provide an overall assessment of the potential hazard of the study heavy metals in the sediment. Potential ecological hazard Factor was expressed as follows:

$$E_h^i = T_h^i \frac{C_{ms}}{C_{bm}} ------------(4)$$

Where E_h^i is the potential ecological hazard factor, andT_h^i is the toxicity response factor of the studied heavy metals, while C_{ms} and C_{bm} are the measured and background concentrations of the metals respectively. The toxicity hazard factor T_h^i values for the metals were: Pb, Cd, As, Cu, Fe Zn Cr, Ni, Co and Mn were; 5, 30, 10, 5, 1, 2, 5, 5 and 1 (Huang et al., 2020; Teng et al., 2014) while, Hazard Index was expressed as follows:

$$HI = \sum E_h^i ----------------(5)$$

where $\sum E_h^i$ is the sum total of all the ecological hazard index of the individual studied heavy metal (Hakason, 1980)

2.5. Statistical Analysis

The mean values of the heavy metal concentrations (mg/kg), standard deviation and Spearman Correlation Analysis were statistically performed with statistical package for social science (SPSS-version -24) in Microsoft Excel 2020

3. Results and Discussion

3.1. Mean Concentrations (mg/kg) of the Heavy Metal (Pb, Cd, As, Cu, Fe, Zn, Cr, Ni, Co and Mn) From the Sediment of Epie Creek

The mean concentrations (mg/kg) of the studied heavy metals; Pb, Cd, As, Cu, Fe, Zn, Cr, Ni, Co and Mn in the different locations from Epie Creek are presented in table 2 and these values were also compared to standard guidelines average values in shalve. The relationship between the metals were evaluated using Spearman Correlation Coefficient and the results are presented in table 3.

Table 2 Heavy Metals Concentrations (mg/kg) in Sediments from Epie Creek in Comparison to the World Average Value in Shalve

Heavy metal	Statistics	Station 1(Yenegwe)	Station 2 (Agudama Epie)	Station 3 (opolo)	Control Igbogene	World Average value in Shalve
Pb	Range	8.320-8.321	6.919-12.649	12.646-12.647	5.102-5.105	
	Mean ± SD	8.320 ±0.001	8.828±3.307	12.647±0.001	5.103±0.002	20
	SE	0.001	1.909	0.000	0.001	
Cd	Range	0.356-0.350	1.301-1.361	2.360-2.361	0.419-0.420	
	Mean ± SD	0.358±0.002	1.322±0.034	2.361±0.001	0.420±0.001	0.3
	SE	0.001	0.020	0.001	0.000	
As	Range	1.636-1.637	1.969-1.971	3.102-3.104	0.198-0.199	13
	Mean ± SD	1.636±0.001	1.970±0.001	3.103±0.001	0.198±0.001	
	SE	0.001	0.001	0.001	0.000	
Cu	Range	23.604-23.605	27.409-27.410	34.619-34.620	9.122-9.124	
	Mean ± SD	23.604±0.001	27.410±0.001	34.620±0.001	9.123±0.001	45
	SE	0.000	0.001	0.001	0.000	
Fe	Range	16.271-16.281	10.874-10.877	13.509-13.510	5.097-5.100	
	Mean ± SD	16.218 ± 0.001	10.876 ± 0.002	13.510 ± 0.000	5.098 ± 0.002	47200
	SE	0.000	0.001	0.000	0.001	
Zn	Range	10.865-10.866	6.925-6.930	8.095-8.097	6.620-6.624	
	Mean ± SD	10.865 ± 0.001	6.928 ± 0.003	8.096 ± 0.001	6.621 ± 0.002	95
	SE	0.000	0.002	0.001	0.001	

Cr	Range	28.917-28.918	36.210-36.211	43.698-43.701	18.431-18.433	
	Mean ± SD	28.917 ± 0.001	36.211 ± 0.001	44.699 ± 1.733	18.432 ± 0.001	90
	SE	0.000	0.000	1.001	0.001	
Ni	Range	5.630-5.634	7.119-7.120	9.050-9.055	3.809-3.819	
	Mean ± SD	5.631 ± 0.002	7.120 ± 0.001	9.053 ± 0.003	3.813± 0.001	68
	SE	0.001	0.000	0.001	0.003	
Co	Range	4.217-4.220	1.816-1.817	3.698-3.699	0.119-1.200	
	Mean ± SD	4.219 ± 0.002	1.816 ± 0.001	3.698 ± 0.001	0.837± 0.622	19
	SE	0.001	0.000	0.000	0.359	
Mn	Range	2.485-2.487	5.100-5.105	8.360-8.362	1.852-1.856	850
	Mean ± SD	2.486 ± 0.001	5.102 ± 0.002	8.361 ± 0.001	1.853 ± 0.001	
	SE	0.001	0.002	0.001	0.001	

Table 3 Spearman's Correlation Coefficient between the Heavy Metals in the Sediments from Epie Creek

	Pb	**Cd**	**As**	**Cu**	**Fe**	**Zn**	**Cr**	**Ni**	**Co**	**Mn**
Pb	1.000									
Cd	-0.520	1.000								
As	-0.261	0.824	1.000							
Cu	-0.026	0.789	0.961	1.000						
Fe	0.290	0.210	0.721	0.735	1.000					
Zn	0.806	-0.912	-0.605	-0.490	0.103	1.000				
Cr	-0.156	0.889	0.954	0.982	0.600	-0.634	1.000			
Ni	-0.360	0.981	0.798	0.819	0.217	-0.838	0.911	1.000		
Co	0.037	0.245	0.745	0.677	0.958	-0.023	0.559	0.195	1.000	
Mn	-0.431	0.989	0.894	0.872	0.351	-0.849	0.946	0.978	0.369	1.000

As indicated in table 2, the mean concentrations of the heavy metals in the four locations ranged from 5.103 - 12.647 mg/kg (Pb); 0.358 - 2.361mg/kg (Cd); 0.198 - 3.102 mg/kg (As); 9.122 - 34.619 mg/kg (Cu); 5.100 - 16.217 mg/kg (Fe); 6.621 - 10.865 mg/kg (Zn); 18.432 - 44.699 mg/kg (Cr); 3.813 - 9.053 mg/kg (Ni); 0.837 - 4.219 mg/kg (Co) and 0.837 - 4.219 mg/kg (Mn) respectively.

Generally, the mean concentrations of the heavy metals in the control sample (table 2) were lower than the mean values of the heavy metals in the three location (1-3) where filling stations are sited close to the Epie Creek ($P < 0.05$). This result indicates that the petrol stations significantly influenced the concentrations of the heavy metals in the sediment. Also, it is eminent to note that station 3 recorded the highest mean values for most of the heavy metals (table2). This may be attributed to the activities of petrol station and indiscriminate disposal of wastes from the modern market (Opolo market) sited closed to the Creek. The average mean levels of the heavy metals in the four locations showed a decrease order of Cr > Cu > Fe > Pb > Zn > Ni > Mn > Co > As > Cd respectively. However, the mean concentrations of the studied heavy metals were all lower than their average values in shalve (the background concentrations of the metals in the World Surface Rock Average – WSRA) except for Cd (table 2).

The source and the relationship between the heavy metals were investigated using Spearman Correlation Coefficient (table 3). And most of the metals demonstrated strong positive relationship with each other. For example, Cd- As (0.824), Cd- Cu (0.789), Cd- Cr (0.889), Cd- Ni (0.981) and Cd -Mn (0.989); As- Cu (0.961), As-Fe (0.721) As-Cr (0.954), As-Co (0.721) and As-Mn (0.894); Cu-Fe (0.735), Cu-Cr (0.954), Cu-Ni (0.819), Cu-Co (0.677) and Cu-Mn (0.872); Fe-Cr (0.600), and Fe-Co (0.958); Cr-Ni (0.911), Cr-Co (0.559) and Cr-Mn (0.946), and Ni-Mn (0.978). This strong positive correlation demonstrated by these heavy metals are strong indication that these metals are from the same anthropogenic pollution source which could have been triggered by the activities of the petrol station sited close to the Epie Creek. The concentration of the heavy metals in this study is similar to the values reported by Kieri et al., (2020) from silver bed river, Bayelsa state except for Fe. Also, the reported values of Fe, Cu, Mn and Pb in the sediment of river Benue is higher than the findings of this study but the values of As, Cd, Cr, and Zn are similar to the reported values of Emmanuel et al., (2018).

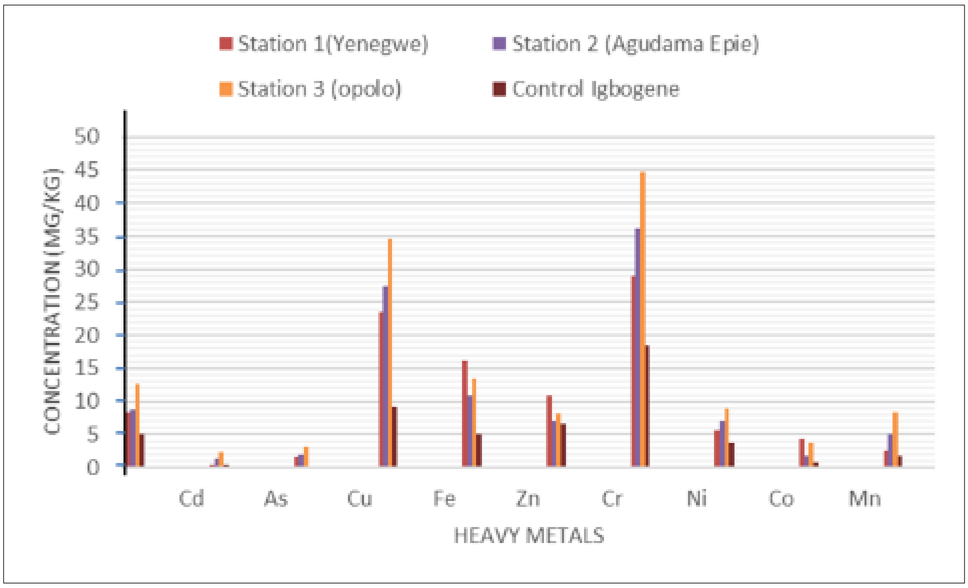

Figure 1c The Mean Concentrations of the Metals in the Three Locations and the Control Sample

3.2. Pollution Indices of the Heavy Metals in Epie Creek

Four pollution indices were employed in this study to determine the impact of the petroleum activities and other anthropogenic influence on the sediments of Epie Creek. These include; contamination factor (CF_i), degree of contamination (DC), Igeoaccumulation index (Igeo), potential ecological hazard factor (E_h^i) and hazard index (HI). The CF_i, Igeo, and E_h^i were employed to evaluate the pollution indices of the individual heavy metals in the sediment while, DC and HI expressed the combined interactive toxicity effects of the heavy metals on the comprehensive quality of the sediment. The results of the heavy metal pollution indices from this study are presented in table 4, 5 and 6 respectively.

Table 4 Contamination Factor (CF_i) and Degree of contamination (DC) of the Heavy Metal from Sediment of Epie Creek

Contamination factor (CF_i) Value				
Metals	**Location 1 Yenegwe**	**Location 2 Agudama-epie**	**Location 3 Opolo**	**Location 4 control Igbogene**
Pb	0.416	0.441	0.632	0.255
Cd	1.193	4.407	7.890	1.667
As	0.126	0.121	0.239	0.152
Cu	0.525	0.611	0.769	0.203

Fe	0.000	0.000	0.000	0.000
Zn	0.114	0.073	0.085	0.069
Cr	0.321	0.402	0.497	0.205
Ni	0.053	0.105	0.139	0.056
Co	0.222	0.096	0.195	0.044
Mn	0.003	0.006	0.009	0.002
Degree of contamination (DC)	2.974	6.262	10.455	2.653

Table 5 Geoaccumulation Index (Igeo) of the Heavy Metals from Sediment of Epie Creek

Heavy metal	Location 1 (yenegwe)	Location 2 (Agudama)	Location 3 (Opolo)	Location 4 control
Pb	0.083	0.089	0.127	0.051
Cd	0.239	0.884	1.583	0.334
As	0.025	0.024	0.048	0.031
Cu	0.105	0.123	0.154	0.041
Fe	6.394	4.624	5.743	2.167
Zn	0.023	0.015	0.017	0.014
Cr	0.064	0.081	0.099	0.041
Ni	0.011	0.021	0.028	0.011
Co	0.045	0.019	0.039	0.009
Mn	0.001	0.001	0.002	0.000

Table 6 Potential Ecological Factor and Hazard Index of the Heavy Metals from Sediment of Epie Creek

Heavy metal	Location 1 (yenegwe)	Location 2 (Agudama)	Location 3 (Opolo)	Location 4 control
Pb	2.080	2.207	3.162	1.276
Cd	35.800	132.200	236.700	50.000
As	1.258	1.208	2.387	1.523
Cu	2.623	3.056	3.847	1.014
Fe	0.000	0.000	0.000	0.000
Zn	0.114	0.173	0.085	0.069
Cr	0.643	0.805	0.993	0.409
Ni	0.267	0.529	0.699	0.280
Co	1.110	0.478	0.973	0.220
Mn	0.003	0.006	0.010	0.002
Hazard index HI	43.898	140.562	248.855	54.793

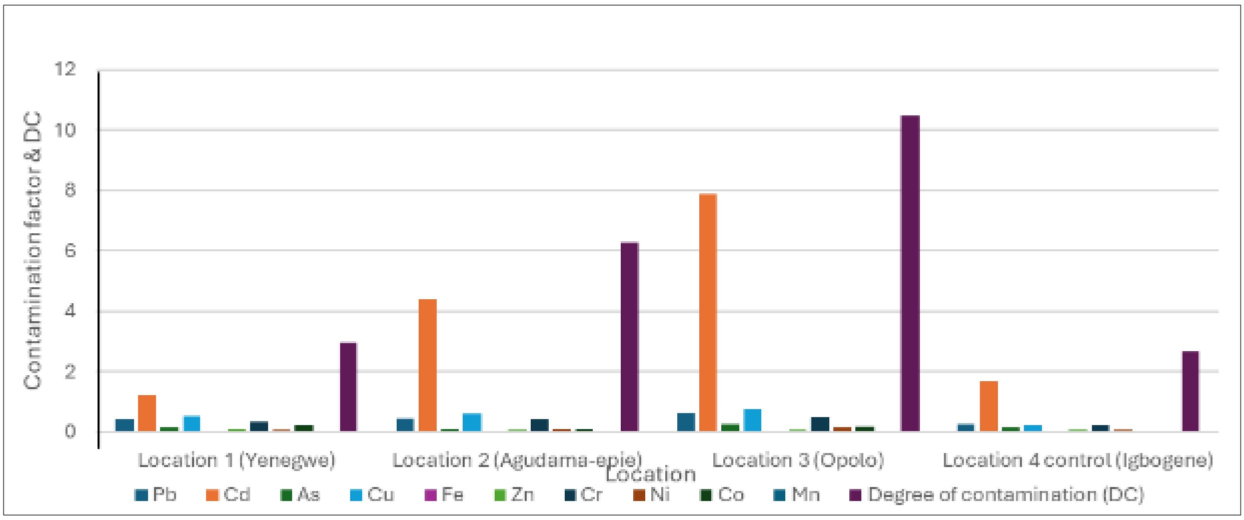

Figure 2 Contamination Factor and Degree of Contamination in the Three Locations and the Control Sample

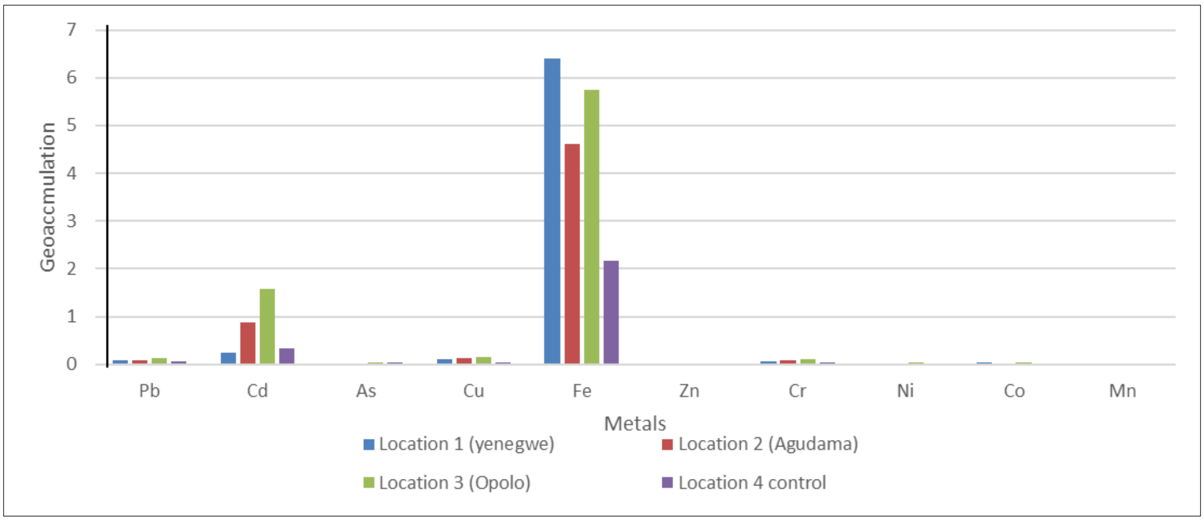

Figure 3 Geoaccumulation index in the Three Locations and the Control Sample

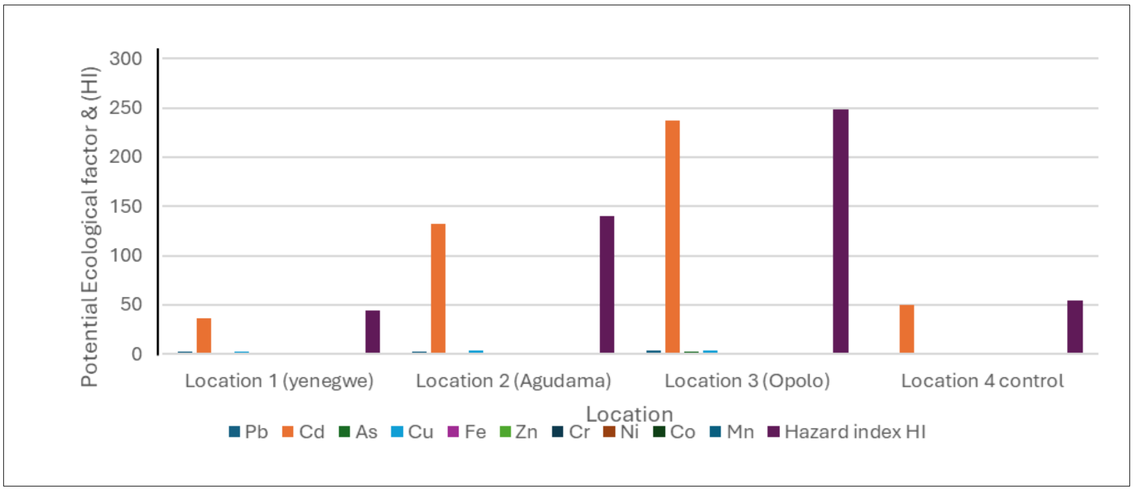

Figure 4 Potential Ecological Factor and Hazard Index in the Three Locations and the Control Sample

3.2.1. Contamination Factor (CF_i) and Degree of Contamination (DC)

From table 4, the calculated values for each heavy metals shows low contamination status (CF_i < 1). Except for Cd. Cd showed very high contamination factor in location 3 (Opolo), considerable contamination in location 2 (Agudama-Epie) and moderate contamination in location 1 (Yenegwe)and location 4 (control- Igbogene).

This result indicates that the sediment of Epie Creek is highly contaminated with Cd. Cd has no known biological role in living organisms rather it is highly toxic to aquatic fauna and flora. Also, due to its persistence and bioaccumulation nature within the environment, it could be easily transferred within the food chain. For example, accumulation of Cd in sediment could pose risk to the benethos organisms such as crabs, lobster, periwinkles, shrimps and fishes (Ogamba et al 2017; Markmanuel et al., 2016). This result showed the impact of anthropogenic sources on concentration of Cd in the sediment of Epie Creek This result is similar to the finding of Harikumar et al., (2010) where Cd recorded the highest contamination factor in all locations. Table 4 also illustrates the degree of contamination of the heavy metals in studied locations and the results showed that location 1 (Yenegwe) and 4 (control) recorded low degree of contamination and the control location recorded the lowest. While location 2 showed moderate degree of contamination and location 3 recorded considerable degree of contamination respectively.

3.2.2. Geoaccumulation Index of the Heavy Metal

The geoaccumulation index of the studied heavy metal (Pb, Cd, As, Cu, Fe, Zn, Cr, Ni, Co and Mn) are presented in table 5. The calculated geoaccumulation index values for the metals showed that (Pb, Cd, As, Cu, Zn, Cr, Ni, Co and Mn) are practically unpolluted in the location 1, 2, 3 and 4 (control) while Cd is unpolluted in location 3. However, Fe showed moderately polluted in location 4 (control), heavily polluted location 2 (Agudama-Epie), heavily to extremely polluted in location 3 (Opolo) and extremely polluted in location 1 (Yenegwe). This result clearly demonstrates the impact of anthropogenic activities on the concentrations of Fe in the sediment of Epie Creek.

3.2.3. Potential Ecological Hazard Factor (E_h^i) and Hazard Index HI

The calculated potential ecological index factor E_h^i and hazard index (HI) values of individual heavy metals and the combined toxicity of the heavy metals are presented in table 6. The toxicity response status are expressed as follow if E_h^i < 45 HI < 150, it implies low potential ecological hazard; if 45 < E_h^i< 90, 150 < HI < 300, it implies moderate potential ecological hazard, if 90 ≤ E_h^i < 180, 300 < HI < 600, it implies considerable potential ecological hazard, if 180 ≤ E_h^i < 360, it implies high potential ecological hazard, and if E_h^i ≥ 360, HI > 600, it indicates very high potential ecological hazard for the environment and it biota (Chen et al., 2022). As indicated in table 6, the potential ecological hazard for the heavy metals (Pb, As, Cu, Fe, Zn, Cr, Ni, Co and Mn) were all lower than 45, indicating very low potential ecological risk at the moment. However, Cd showed low potential ecological hazard in location 1 (Yenegwe), moderate potential ecological hazard in location 4 (control), considerable potential ecological hazard in location 2 (Agudama-Epie) and high potential ecological hazard in location 3 (Opolo) respectively. Chen et al., (2022) also reported high potential ecological risk of Cd in the sediment of Hunangshui River in Northwest China. The comprehensive potential ecological hazard index (HI) in the four locations were; 43.898 (location 1- Yenegwe); 140.562 (location 2- Agudama); 248.855 (location 3- Opolo) and 54.793 (location 4- control). Again location 3- Opolo has high hazard index value, indicating serious ecological hazard risk. This could be attributed to the massive indiscriminate disposal of anthropogenic wastes from the modern market sited close to the Creek plus the impact of the filling station. Generally, the potential ecological hazard for each heavy metal in the four locations are in order of Cd > Cu > Pb > As > Co > Cr > Ni > Zn > Mn > Fe; while the HI value for the four location follows; location 3 > location2 > location 4 (control) > location 1($P < 0.05$) respectively.

4. Conclusion

This study evaluated the impact of petroleum activities and pollution indices on heavy metals levels in the sediment from Epie Creek. The average mean levels of the heavy metals in the sediment collected from four different locations were in the order of Cr > Cu > Fe > Pb > Zn > Ni > Mn > Co > As > Cd. However, this was a revise of the pollution indices study were Cd pose the greatest hazard risk in most of the evaluated indices. Thus, the potential ecological hazard factor was in the order Cd > Cu > Pb > As > Co > Cr > Ni > Zn> Mn > Fe. Among the four studied locations, the results revealed that location 3 (Opolo) has the highest metal concentrations and pose the greatest hazard index risk. Generally, the study shows that the three-locations 1, 2, 4 (including the control location) is contaminated while location 3 (Opolo) is highly polluted. Therefore, government of Bayelsa state should enact laws to stop indiscriminate disposal of wastes into Epie Creek and regular monitoring programme should put in place to improve the water ecosystem the of Epie Creek

Compliance with ethical standards

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