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Pollution Status of Sediment of Elele-Alimini Stream, Port Harcourt, Nigeria

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Abstract

This study investigated the pollution status and ecological risk of the sediment of Elele-Alimini Stream, Port Hacourt from three stations. Some pollution indices such as contamination factor (CF), pollution load index (PLI), geoaccumulation index (I_{geo}), toxicity unit analysis (TUA) and potential ecological risk (PER) were used to determine the pollution status and ecological risk level of the sediment. The mean concentration (mg/l) of the metals, Cd, Cr, Pb, Ni and Cu in the sediment were respectively 0.069±0.048, 2.089±0.288, 0.223±0.115, 1.289±0.114 and 1.289±0.114 with Cr and Cd having the highest and lowest values. The order of concentration of metals was Cr>Cu>Ni>Pb >Cd. All mean values exceeded the maximum permissible limit (MPL), criterion continous concentration (CCC) indicating pollution. The indices, CF, Igeo and PLI were less than unity indicating lower contamination of sediment by the observed heavy metals. The sum of the toxic unit at different stations less than the standard limit 4 indicating low toxicity while the descending order of pollutants (metals) in the sediment showed low potential ecological risk. It was concluded that sediment of Elele-Alimini Stream had low pollution. However, it is recommended that anthropogenic activities in the area should be monitored to avoid devastation of the area.

Key words: Pollution status, Pollution indices, Sediment, Elele-Alimini Stream, Port Harcourt.

Introduction

Evidently heavy metal pollution has become a great threat to man and aquatic resources, owning to increased global level of anthropogenic activities (1). Notably, trace levels of heavy metals play significant roles in maintaining the natural balance of the aquatic ecosystem on earth. According to (2), and (3), unacceptable high concentration of heavy metals in the aquatic ecosystem causes serious negative ecological changes in the aquatic ecosystem. (4) opined that rapid progress of technological innovations made it virtually difficult if not impossible to do without utilization of metal and their sources thus inundating the environment with excess of these metals leading to the current age of ecological fright. According to (5) increasing water and sediment pollution not only cause water quality deterioration but also threaten human health and the balance of aquatic ecosystem, economic development and social prosperity.

Due to sediment contamination by heavy metals in most of urban rivers, streams etc large number (80%) of the world populations are currently facing increased threat of water security (7-8). Sediment has been considered to be an essential and dynamic part of the aquatic ecosystems with habitat and environment variation which in the aquatic environment have been used as environmental indicators for assessing metal contamination in the natural environment (9-10). Sediments have a high storage capacity for contaminants (3), act as sinks and sources of pollutants to be overlying water column and biota and have toxic and persistent characters (10-13). In the riverine ecosystems, sediments can be polluted with different kinds of hazardous substances and heavy metals through several means such as disposal of liquid effluents, traffic emissions, terrestrial runoff, brick kilns and leaches carrying chemicals originating from urban, industrial and agricultural activities (14-15). Identification of contaminants association with sediments is therefore crucial in ecological management of aquatics ecosystem.

Some studies have assessed the concentration of heavy metals in the water and sediments of Elele-Alimini stream (4,16) but no adequate work has been done on pollution indices especially in pollution quantification study of the stream. This work is therefore aimed at investigating the pollution indices such as contamination factor (CF), pollution loading index (PLI), potential ecological risk (PER), geoaccumulation index (Igeo) and toxic unit analysis (TUA).

Sediment Quantitative Ecological Assessment.

Numerous indices have been developed in calculating the environmental risk of heavy metals surface sediment base on their total content, bioavailability and poisonous nature (8,17). They are as discussed below:

1. Contamination factor (Cf): This is the ratio of concentration of each metal in the sediment by the baseline/background value represented by the formular:

$$Cf = \frac{C \quad heavy\ metal}{C\ background} \quad - \quad - \quad - \quad - \quad - \quad (1)$$

Where

C heavy metal = concentration of heavy metal

C background = concentration of background/baseline value

Cf is classified into four grades for monitoring pollution of a single metal over a period of time (18). Classification of contamination levels is based on their intensities on a scale ranging from 1-6: low degree ($C_f < 1$), moderate degree ($1 < C_f < 3$), considerable degree ($1 \leq C_f \leq 3$), considerable degree ($3 \leq C_f < 6$) and very high degree ($C_f > 6$) (19) Table 1).

2.Geoaccumulation Index (Igeo): This refers to the degree of contamination from which the trace metals could be assessed by determining the geoaccumulation index (Igeo). Igeo has been widely used in the assessment of contamination (20). In characterizing the level of pollution in the sediment, Igeo index values were calculated from the equation:

Igeo = Log 2 (cn.1.5Bn). - - - - - (2)

Where:

Cn is the measured concentration of metal n in the sediment.

Bn is the geochemical background value of element n in the background sample (21).

1.5 is used to minimize the possible variations in the background values which may be attributed to lithogenic effects.

Igeo valves were interpreted as:

Igeo $\leq$ 0 – Practically uncontaminated

0 $\leq$ Igeo $\leq$ 1 - Uncontaminated to moderately contaminated

1 $\leq$ Igeo $\leq$ 2 - Uncontaminated to moderately contaminated

2 $\leq$ Igeo $\leq$ 3 - Moderately contaminated

3 $\leq$ Igeo $\leq$ 4 - Moderately to heavily contaminated

$4 \leq$ Igeo ≤ 5 - Heavily to extremely contaminated

$5 \leq$ Igeo - Extremely contaminated

3. **Pollution Load Index (PLI)**: This is an integrated approach used in assessing the sediment quality of heavy metals. (22) opined that pollution load index can be assessed using the five hazardous elements, Cd, Cr, Ni, Cu, and Pb.

Pollution load index (PLI) was determined using the element, Cd, Cr, Cu, Ni and Pb from the formular:

$$PLI = Cf_1 \times Cf_2 \times Cf_3 \times \ldots\ldots\ Cf_n)^{1/n} \quad - \quad - \quad - \quad - \quad (3)$$

Where:

Cf is contamination factor for each simple metal

n is number of heavy metals (5 in this case)

PLI show the overall toxicity status of heavy metals in the sediment.

4. **Potential Ecological Risk (PER)**: This determines the degrees of hazardous chemical contamination in sediments. (19) proposed the equation below in calculating PER of hazardous chemical contamination:

$$\frac{C^n f = C^n}{C^1 n} Cd = \frac{\sum^{n} C^n f}{1=1} \quad - \quad - \quad - \quad - \quad - \quad (4)$$

$$t_f - T^1 r \times C^d.\ PER = \frac{\sum^{n} E^d r}{1=1}$$

Where:

$C^1 f$ = Single element contamination factor

C = Concentration of the element in samples.

Cn = Background value of the element

In this study Cn value for Cr, Ni, Cu, Cd and Pb were respectively 90, 68, 45 0.092 and 23 mg/kg (23).

Summation of C_f for all metals gives pollution degree (Cd) of the environment. Er is the potential ecological risk index which represents the biological toxic factor of an individual element. The toxic response factors (TRF)for Cr, Ni, Cu, Cd and Pb were respectively 2, 6, 5, 30 and 5 (10,18,24).

PER is the comprehensive potential ecological risk index which is the sum of Er. It shows the sensitivity of a biological community to toxic substance indicating the PER caused by the overall contamination.

5. **Toxic unit analysis (TUA)**: This refers to the ratio of the assessed concentration of hazardous elements in sediment to probable effect level (PEL) (25). The sum of all the toxic units (ETUs) is known as potential acute toxicity of hazardous elements in sediment samples. A moderate to serious toxicity of hazardous elements remain in sediment when the ETUs for all the samples is higher than 4 (ETUs > 4) (26).

TU for each metal is calculated using the formular:

TU = (Cm/PEL) - - - - - -(5)

Where

Cm = Concentration of heavy metal (Cm) in sediment

PEL = Probable effect levels value of heavy metals in sediment

ETUs: TUm_1 x Tum_2 x Tum_3 x …….. Tumn - - - - (6)

Where

ETUs is the product of toxic units for heavy metals in sediments.

Statistical Analysis

The values obtained from the laboratory were subjected to statistical analysis using the SPSS package, version 20 to obtain the mean, standard deviation, ANOVA etc.

Results

Table 1 showed the spatial mean value of sediment, average shale/background values and toxicity response factor (TRf) of heavy metal studied in Elele-Alimini Stream.

Table 1. Mean (mg/kg) and Ranges of Heavy Metals in Elele-Alimini Stream with their BV and TRFs

HM/Stn	1	2	3	Mean	Range	BV	TRF
Cd	0.052±0.045	0.087±0.063	0.0740±0.016	0.069±0.048	0.015-1.00	0.920	30
Cr	2.030±0.160	2.300±0.300	1.933±0.0570	2.089±0.288	1.90-2.000	90	2
Pb	0.157±0.129	0.333±0.088	0.1800±0.072	0.223±0.115	0.10-0.200	23	5
Ni	1.300±0.100	1.383±0.075	1.1830±0.076	1.289±0.114	1.100-1.45	68	6
Cu	1.300±0.100	1.183±0.076	1.1830±0.076	1.289±0.114	1.100-1.45	45	5

HM=Heavy Metals, Stn=Station, BV=Background Value, TRF= Toxicity Response Factor

The range of values for the respective metals, Cd (0.015-1.00), Cr (1.90-2.00), Pb (0.10-020), Ni (1.10-1.45) and Cu (1.10-1.45) were considered narrow. The magnitude of concentration of heavy metal in sediment was Cr > Cu > Ni > Pb > Cd.

Table 2 shows the contamination factors (Cf) of all the metals in the stations in the study area. The highest contamination factors (Cf) for Cd (0.087), Cr (0.026) Pb (0.0145), Ni (0.0203) were in station 2 which is the midstream but that of Cu (0.0289) was found in station 1.

Table 2. Contamination Factor (CF) of the Sediment of Elele-Alimini Stream

HM/Stn	1	2	3	Mean	CD
Cd	0.0570	0.0870	0.0800	0.0750	0.224
Cr	0.0230	0.0260	0.0220	0.0237	0.071
Pb	0.0068	0.0145	0.00783	0.0097	0.029
Ni	0.0191	0.0203	0.01740	0.0189	0.057
Cu	0.0289	0.0263	0.02630	0.0272	0.082

HM=Heavy Metals, Stn= Station

Table 3 showed the results of the geoaccumulation index (geo) of the area based on average shale/background value. The Igeo of the studied metals in decreasing order was Ni> Pb>Cd> Cu> Cr with values less than 1 (<1) indicating that the sediment is uncontaminated to moderately contaminated.

Table 3. Geoaccummulation index (Igeo) of Sediment of Elele-Alimini Stream

HM/Stn	1	2	3	Mean
Cd	0.01100	0.01600	0.01480	0.01390
Cr	0.00455	0.00431	0.00466	0.00451
Pb	0.00137	0.00157	0.00195	0.00163
Ni	0.00385	0.03490	0.02680	0.02190
Cu	0.00580	0.00528	0.00545	0.00550
Degree of Contamination	0.02660	0.06210	0.05370	0.04740
Contamination Level (<1	Low	Low	Low	Low

Table 4 showed the pollution load index (PI) of the area. From the table, the stations had PLI of less than I (PLI < 1) with station 2 having the highest PLI.

Table 4. Pollution Load Index Per Station of Sediment of Elele-Alimini Stream

Pollution Load Index ($PLI^{1/5}$)	**Value**
1.	0.0000000492
2.	0.000000175
3.	0.0000000631
Mean	0.00000000883

Tables 5 showed the potential ecological risk index (PEF) of metals in the sediment from the study area. From the table the PER in the area ranged between 2.050 (station 1) and 2.989 (station 3) with cadmium having the highest value. This result showed low degree of risk in the area.

Table 5. Potential Ecological Risk (PER) of Sediment of Elele-Alimini Stream

HM/Stn	1	2	3	Mean	E_f
Cd	1.7100	2.6100	2.2400	2.1870	6.5600
Cr	0.0460	0.0520	0.0470	0.0480	0.1450
Pb	0.0340	0.0725	0.0490	0.0520	0.2075
Ni	0.1150	0.1220	0.1140	0.1170	0.3510
Cu	0.1400	0.1320	0.1360	0.1380	0.5510
Degree of Contamination	2.0500	2.9890	2.5860	2.5420	
Contamination Level (<1	Low	Low	Low	Low	

Table 6 showed the toxic unit analysis (potential acute toxicity) of pollutants in sediment samples of the area. The toxicity value of the metal decreased in the order, Cr>Ni>Cu>Pb>Cd. It could be observed from the result that station 2 had the highest toxicity level among the stations studied.

Table 6. Toxicity Unit Analysis (TUA) of Sediment of Elele-Alimini Stream

HM/Stn	1	2	3	Mean
Cd	0.00173	0.00267	0.00229	0.00223
Cr	1.01650	1.15000	1.04400	1.07020
Pb	0.03140	0.06660	0.00447	0.03420
Ni	0.26000	0.27700	0.25800	0.26500
Cu	0.26000	0.23700	0.24500	0.24700
Degree of Contamination	1.58500	1.73300	1.55400	1.61900
Contamination Level (<1	Low	Low	Low	Low (<4)

Discussion

The mean values of the heavy metals studied exceeded the maximum permissible limit (MPL), (27), criterion maximum concentration (CMC) (28) and Criterion Continuous Concentration (CCC) (28) indicating pollution. The metal values when compared with the average Shale value widely used by (29) are considered low indicating less pollution. The use of average Shale value as a standard in comparism with the mean concentration of heavy metals in this study is in line with the finding of (30) in Kwata Yobe in Dumba. The high concentration of all the metals studied could be attributed to natural and anthropogenic activities ranging from industrial to municipal activities in the area. The high concentrate of chromium than any other metal studied could be due to natural concentration of Cr– bearing minerals and anthropogenic (industrial activities such as tanneries and discharge of Cr-based oxidants.

The mean CF of the heavy metals considering the average CF was Cd >Cr>Cu>Ni>Pb with values less than 1 suggesting lithogenic sources. Contamination factor of less than 1 obtained in the study is in line with the finding of (1) in Elechi creek, Port Harcourt Nigeria. Elele-Alimini Stream therefore has low degree of pollution which is in line with the assertion that sediment with contamination level less than 1 (cf<1) is classified as low degree (19). The result of the overall contamination factor for all the elements in this study (CF<1) is in line with the finding of (31) in Louhajang River, Bangladesh. The highest contamination degree (CD) observed in station 2 in this study could be due to extensive discharge of municipal and industrial wastes from petrochemical activities in the area. The degree of contamination (CD) of Elele-Alimini stream according to (18) classification is considered low since Cd<8. (32) opined that concentration factor is an indicator of sediment contamination which is popularly used in assessing pollution in an aquatic environment.

The result of the geoaccumulation index (Igeo) of Elele-Alimini stream sediment was less than 0.42 which suggest unpolluted area as opined by (33). According to(34) Igeo is used to estimate metals contamination in sediments by comparing current concentrations in with pre-industrial period.

The PLI value in this study is in agreement with the finding of (1) in Elechi creek, Port Harcourt considered not polluted at different stations. This result however is in disagreement with the finding of (6) where all the sampling points were considered polluted and deteriorating progressively. The PLI value obtained in this study is also in disagreement with the finding of (35) in Urban River in Philippines. PLI according to (9) can provide valuable information concerning the pollution status of an area which helps decision makers in taking decision. (29) opined that an area with PLI value less than 1 shows no pollution.

According to (36) and (18) an area with PER (er) < 95 is considered low risk which is in line with the result of the study. Cadmium had the highest potential ecological risk considering individual element (E_f = 6.560) indicating moderate risk ($40 \leq E_i < 80$). The high PER and E_f obtained for Cd in this study is in line with the findings of (37) who disclosed that Cd contribution to potential ecological risk index of an environment is very significant.

The mean toxic unit values of the metals in sediment which ranged between 0.00223 and 1.0702 and the sum of the toxic units at differing stations which was below 4 showed a low toxicity of heavy metals to sediment dwelling fauna in the area as opined by (36).

Conclusion /Recommendation

Based on the findings, it could be concluded that although the heavy metal concentration in the sediment of Elele-Alimini stream exceeded the standard permissible limits of World Health Organisation (WHO), criterion maximum concentration (CMC), USEPA and Criterion Continuous Concentration (CCC) (USEPA,) indicating pollution, but based on the various pollution indices studied (CF, lgeo, PLI, PER and TUA) the stream is moderately polluted or contaminated. Considering the individual metal, Cd had the highest potential ecological risk for most of the sites of the study area. To obtain a comprehensive risk assessment, either the biological and toxicological data or bioaccumulation data in the benthic environment of the studied stream in Elele-Alimini should be considered in further studies.

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