Evaluation of heavy metal contamination in sediment of Gbalegbe River, Ughelli, Delta State, Nigeria

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Abstract: The pollution of surface water in recent time impairs its quality. Deleterious effect of sediment contamination with heavy metals could be associated with their toxicity and accumulative capacity in biota. Information on sediment pollution with heavy metals of Gbalegbe River is limited. This study therefore seeks to evaluate the degree of sediment contamination of Gbalegbe River through the application of sediment pollution indices. Spatially, Gbalegbe River (12.5 km) was stratified into eight stations (S1, S2, S3, S4, S5, S6, S7, and S8) based on proximity to key anthropogenic activities. At each station, three sampling points were randomly chosen. Temporal stratification covered wet (March - October) and dry (November – February) seasons. Sediment samples were collected from each station forth – nightly for 24 months following standard methods. Sediment samples were analysed for Cadmium, Nickel and Chromium according to standard methods. Pollution load index (PLI), modified degree of contamination (mC_d) and geoaccumulation (Igeo) were calculated. Data were analysed by using descriptive statistics and ANOVA at $\alpha_{0.05}$.Spatially, Cadmium ranged from 0.10±0.01 to 0.34±0.12; Nickel (0.06±0.01, 0.24±0.04) in S 1 and S 6, while highest (0.34±0.01) and least (0.06±0.02) concentrations of Chromium were recorded in S 2 and S 1, respectively. Seasonally, Cadmium ranged from 0.15±0.12 to 0.27±0.01; Nickel (0.12±0.05, 0.13±0.05) in dry and wet seasons, while Chromium ranged from 0.13±0.02 to 0.14±0.01 in wet and dry seasons, respectively. Spatially, the values of PLI and mC_d were 0.121 and 0.150. Seasonally, the highest (0.140) and least (0.110) of PLI; mC_d (0.350, 0.210) were recorded in dry and wet seasons. Spatially, Igeo ranged from -0.502 to 0.163 for Zinc and Chromium, while the highest (0.970) and least (0.060) were recorded for Lead and Chromium in wet and dry seasons, respectively. Hence, Gbalegbe River rich fauna abundance and diversity could be threatened.

Keywords: Contamination factor, heavy metal, sediments, pollution indices, surface water.

Introduction

Heavy metals are persistent and stable pollutants in waters and sediments (Ewutanure & Olaifa, 2018a). A rise in the levels of heavy metals in surface water could threaten the existence of aquatic flora and fauna because of their toxicity and non – biodegradable nature (Ewutanure and Olaifa, 2021b). The presence of heavy metals in surface water affects the totality of the aquatic biota through geochemical recycling (Al – Haidarey *et al.* 2010).

Heavy metals bio – accumulate in benthic fauna that are in contact with affected sediments (Olaifa and Ewutanure, 2019). This could cause their transfer into the aquatic food chain to induce metabolic and physiological disorders (Kumar *et al*,. 2012). Eating of foods items contaminated with heavy metals could cause inhibition of some essential nutrients in the body of organisms, which could lead to disabilities associated with malnutrition, impaired psycho-social behaviour, reduction inimmunological defences, intrauterine growth retardation, and rise in upper gastrointestinal cancer (Arora, 2008).

Sediments have the capacity to retain and release heavy metals into the water column through various methods of remobilization (Marchland *et al*., 2006; Mingorance *et al*., 2007). The uppermost layer of sediment contains the largest concentration of heavy metal pollutants in surface water (Barakat *et al.,* 2012). An increase in anthropogenic effluent in surface water is directly proportional to the concentration of heavy metal contents in sediment (Ewutanure and Olaifa, 2018a).

In Nigeria, various studies have been conducted to assess the degree of contamination of sediment of inland water such as Great Kwa River, (Bassey and Ifedayo, 2014); KwaIboe-River Estuary, (Uwahet *al.*, 2013); Kubanni River, (Butu and Iguisi 2013);Roro Bay, (Majolagbe *et. al*, 2012); Agbabu sediment (Olubunmi and Olorunsola, 2010); Lagos Lagoon, (Aderinola *et al*., 2009). But information of sediment pollution of Gbalegbe River is limited. Therefore, this study was undertaken to assess the level of sediment contamination of Gbalege River through the application of sediment pollution indices.

Materials and Methods

Description of the study area

According to Ewutanure and Olaifa, (2018b), Gbalegbe River (12.5 Km) is located on latitudes 5°10'N and 5°17'N of the Equator and Longitudes 5°56'E and 5°13'E of the Greenwich meridian (Ewutanure and Olaifa, 2018a). It has its source from Asaba - Ase River, Delta State (Ewutanure and Olaifa, 2018). The study area consist of tropical climate with temperatures ranging from 23.5 °C to 32 °C and double peaks of rainfall in June/July and September with about 2,700 mm of rain annually (Ewutanure and Olaifa, 2018b). Its annual relative humidity ranged from 69 to 92% with characteristics of evergreen vegetation. The area has topography of about 100 m above sea level and it is composed of sedimentary rock deposits containing lime stones, sand stones and shales (Aweto, 2002).

Sampling techniques

Gbalegbe River was spatially stratified into eight stations (S1 – S8) based on key human activities such as Sand mining, Glass production and Rubber factory (Ewutanure and Olaifa, 2021a). Three replicate samples per station were collected to standard methods as described by American Public Health Association, APHA, (1992). Time stratification covered wet season (March – October) and dry season (November – February). Sediment samples were forth – nightly collected from each station for two years, while the exact locations of all sampling stations were recorded by using Garmin GPSMAP eTrex 10 type sensors (Ewutanure and Olaifa, 2018a). The sampling stations were S1, S2, S3, S4, S5, S6, S7 and S8, respectively.

At each station, sediment samples were collected from depths ranging from 0 – 10 cm by using a van Veen bottom grab sampler, drained off water *in – situ*, packed in a well – labelled Teflon (to avoid contamination), taken to the laboratory and aired dried at room temperature for 21 days before usage(van Veen, 1933; ASTM, 2006). The drying was done to remove moisture and organic matter contents.

After drying, individual samples were ground and mechanically sieved through a net of mesh size 2mmplastic sieve to remove plant roots, animal shells, large debris and gravel – sized materials (Ewutanure & Olaifa, 2018a). It has been reported that Finer fraction of sediment accommodate organic matter, clay minerals and exhibit very great capacity to bind particle reactive trace metal pollutant compared with coarser particles size (>2 mm) (Ewutanure and Olaifa, 2021b).

Digestion of sediment sample

About 1.00g of air – dried sediment sample was weighed by using a sensitive weighing balance, grounded in a mortar and heated to reddish brown in a furnace. Thereafter, it was cooled and moistened by using de – ionised water. About1 mL of 60% perchloric acid and 20 mL of 40% hydrofluoric acid were added. The content was heated to dryness in a sand bath at temperature of 180^{o}C. It was cooled and 15 ml of 10% hydrochloric acid added. The mixture was thereafter heated in a crucible to dryness, while the concentrations of the heavy metals were determined by using Atomic Absorption Spectrophotometer (AAS) according to the method described by American Public Health Association – APHA, (1992).

Pollution indicators of sediment ofGbalegbe River

Contamination factor (C^i_f)

$Cif = \frac{Ci}{Cin}$, Kryzysztof *et al*., (2004);

The study of sediment contamination of Gbalegbe River was carried out using the contamination factor (Table 1). The sum of contamination factors for all heavy metals determined is equivalent to the $C^i_f$and it is classified into four classes (Hokanson, 1980).

Table 1. Interpretation of contamination factor (C^i_f) for sediment and soil

C^i_f levels	Interpretations
C^i_f <1	Low contamination factor (showing low contamination)
1≤ C^i_f<3	Moderate contamination factor
3≤ C^i_f<6	Considerable contamination factor
6≤ C^i_f	Very high contamination factor

Sources: Hokanson, (1980); Syed *et al*., (2012).

Pollution load index (PLI)

Syed *et al.*, (2012) reported that PLI was established by Tomlinson *et al.*, (1980) for the determination of pollution that allows spatial and temporal comparison of pollutants in a study location. The PLI was estimated as a concentration factor for respective heavy metals with reference to their established or background concentrations in sediment or soil. The world mean values of heavy metals reported forshale were used as the background values in this study (Tomlinson et al. 1980). According to Hokanson (1980), ranges of pollution load index were PLI>1 (immediate action to reduce pollution), PLI=1 (more detailed study is needed) and PLI<1 (drastic remediation measures not needed).

$PLI = n\sqrt{cf_1 * cf_2 * \ldots * cf_n}$ Tomlinson *et al.*, (1980).

Note: C_n = Measured concentrations of heavy metals in sediment, B_n and C^i_n = geochemical background value/ pre – industrial concentrations of heavy metals in sediment, 1.5 accounts for natural fluctuations and very small anthropogenic influences, C_d = Sum of contamination factors for all metals determined, C^i_0 = mean contents of metals from all 8 stations, n = number of contamination factors while cf_1, cf_2,---cf_n = contamination factors.

Degree of Contamination factor (C_d)

The sum of the calculated C^i_f is referred to as the degree of contamination factor (C_d) for the pollutant species specified (Krzysztof *et al.* 2004). The C_d is concerned with the extent of the grand contamination of surface layers of sediment samples from specific sampling stations (Bhuiyan *et al*., 2011).It uses the various concentrations of heavy metals in the earth's crust as a reference point. The C_d is further sub – divided into four classes (Table 2).

Table 2.Degree of contamination (C_d) for soil and sediment

C_d<8	Low degree of contamination
8≤ C_d<16	Moderate degree of contamination
32≤ C_d<8	Considerable degree of contamination
16≤ C_d<32	Very high degree of contamination

Source: Hokanson, (1980).

$C_d = \sum_{i=1}^{n} \left(C_f^i\right)$ Hokanson, (1980)

Modified degree of contamination (mC_d)

According to Syed et al., (2012), an improved and generalized form of the Hokanson, (1980)equation for the computation of the overall degree of contamination at a given sampling station

was done by Abraham and Parker, (2008)with the following conditions: (1) The modified formula is generalized by stating the degree of contamination (mC_d)as the sum of all the contamination factors (C^i_f) for a given set of aquatic ecosystem pollutants divided by the number of analysed pollutants; (2) An average value of any heavy metal (pollutant) is predicated on the analysis of a minimum of three samples and (3) The baseline levels are estimated from recommended or established earth or benthic materials. According to Ahmed ***et al.,*** (2001), this generalized formula permits the inclusion of many heavy metals as may be analysed during the study without an upper limit. Seven groups are recognised for the classification and description of the mC_d (Table 3).

Table 3. Modified degree of contamination (mC_d)

mC_d Class	Interpretation
mC_d <1.5	Nil to very low degree of contamination
1.5≤ mC_d<2	Low degree of contamination
2≤ mC_d<4	Moderate degree of contamination
4≤ mC_d<8	High degree of contamination
8≤ mC_d<16	Very high degree of contamination
16≤ mC_d<32	Extremely high degree of contamination
mC_d≥32	Ultra high degree of contamination

Source: Abrahim and Parker, (2008).

$$mC_d = \sum_{i=1}^{i=n} \left(C_f^i\right)$$ Abrahim and Parker, (2008)

Index of geo – accumulation (I_{geo})

$$Igeo = log2\frac{Cn}{1.5Bn},$$ (Muller, 1969)

The constant, 1.5 accounts for the extent of natural dynamics in a given environmental material and minutes anthropogenic perturbation. Geo – accumulation (Igeo) index is used in the evaluation of contamination through the comparison of the present and pre – industrial levels originally applied to benthic sediment (Muller, 1981). According to Luo *et al.*, (2012), Igeo indices recognised the extent of metal pollution in seven classified enrichment classes based on the increasing concentrations (Table 4).In this report, the major concern is between the concentration obtained and the concentration of heavy metals contained in the Earth's crust as recommended.

Table 4. Standard range of contaminants for geo-accumulation index in soil or sediment

I_{geo} Class	I_{geo} Value	Interpretation of I_{geo}
0	I_{geo}≤0	Uncontaminated
1	0< I_{geo}<1	Uncontaminated/moderately contaminated
2	1< I_{geo}<2	Moderately contaminated
3	2< I_{geo}<3	Moderately/strongly contaminated
4	3< I_{geo}<4	Strongly contaminated
5	4< I_{geo}<5	Strongly/ extremely contaminated
6	5< I_{geo}	Extremely contaminated

Sources: Muller, (1981); Syed *et al.* (2012).

Results and discussion

The mean concentrations of heavy metals recorded during the study period among stations and seasons are presented in Tables 5 and 6. Spatially, the trend in the concentrations of heavy metals was: Zn > Cd > Cr > Ni > Cu > Fe >Mn>Pb. In the wet season, the trends were: Cd > Ni >> Cr > Fe >Mn> Cu >Pb> Zn, while in the dry season the trend were: Cu > Cd >Mn> Fe > Cr > Ni >Pb> Zn. Fluctuation of heavy metal levels in Gbalegbe River could be due to the nature of anthropogenic effluents and its constant flow (Ewutanure and Olaifa, 2018a). A relatively higher concentration of the standard deviations obtained during the study period is an indication of a slight increase n the input and distributions of heavy metal from different sources of pollutants into Gbalegbe River (Ewutanure and Olaifa, 2021).

Table 5. Mean concentrations of heavy metals in sediment at different stations

	Cu (mg/Kg)	Pb (mg/Kg)	Ni (mg/Kg)	Cd (mg/Kg)	Fe (mg/Kg)	Zn (mg/Kg)	Mn (mg/Kg)	Cr (mg/Kg)
Station 1	0.07 ± 0.02^{c}	0.03 ± 0.01^{b}	0.06 ± 0.01^{b}	0.10 ± 0.01^{b}	0.09 ± 0.01^{b}	0.02 ± 0.01^{b}	0.02 ± 0.01^{d}	0.06 ± 0.02^{c}
Station 2	0.19 ± 0.04^{a}	0.08 ± 0.02^{a}	0.25 ± 0.04^{a}	0.18 ± 0.12^{b}	0.15 ± 0.02^{a}	0.06 ± 0.04^{a}	0.16 ± 0.02^{c}	0.34 ± 0.10^{a}
Station 3	0.12 ± 0.03^{b}	0.06 ± 0.03^{a}	0.12 ± 0.04^{a}	0.30 ± 0.09^{a}	0.12 ± 0.04^{a}	0.06 ± 0.02^{a}	0.12 ± 0.02^{b}	0.14 ± 0.09^{b}
Station 4	0.12 ± 0.03^{b}	0.07 ± 0.03^{a}	0.12 ± 0.03^{a}	0.28 ± 0.11^{a}	0.11 ± 0.03^{a}	0.06 ± 0.02^{a}	0.11 ± 0.03^{b}	0.13 ± 0.02^{b}
Station 5	0.15 ± 0.11^{a}	0.07 ± 0.02^{a}	0.14 ± 0.03^{a}	0.25 ± 0.09^{a}	0.12 ± 0.02^{a}	0.06 ± 0.03^{a}	0.13 ± 0.02^{b}	0.12 ± 0.04^{b}
Station 6	0.12 ± 0.02^{b}	0.06 ± 0.03^{a}	0.24 ± 0.04^{a}	0.34 ± 0.12^{a}	0.14 ± 0.06^{a}	0.05 ± 0.03^{a}	0.13 ± 0.02^{b}	0.12 ± 0.04^{b}
Station 7	0.13 ± 0.02^{b}	0.06 ± 0.03^{a}	0.13 ± 0.02^{a}	0.27 ± 0.11^{a}	0.12 ± 0.03^{a}	0.06 ± 0.03^{a}	0.16 ± 0.01^{a}	0.13 ± 0.02^{b}
Station 8	0.16 ± 0.16^{a}	0.05 ± 0.02^{a}	0.13 ± 0.05^{a}	0.28 ± 0.09^{a}	0.13 ± 0.02^{a}	0.06 ± 0.02^{a}	0.14 ± 0.08^{b}	0.17 ± 0.01^{b}
WHO, (2004)	16	40	16	0.6	30	110	30	25

Means with the same superscripts along rows were not significantly different at p>0.05.
Cu=copper, Pb= lead, Ni=nickel, Cd=cadmium, Fe=iron, Zn=zinc, Mn=manganese, Cr=chromi

Table 6. Mean concentrations of heavy metal in sediment between seasons

Heavy metals	Wet season	Dry season	P – value	WHO (2004) (mg/Kg)
Cu (mg/Kg)	0.12±0.02	0.17±0.08	0.04**	16
Pb (mg/Kg)	0.07±0.02	0.09±0.04	0.07**	40
Ni (mg/Kg)	0.13±0.05	0.12±0.05	0.56**	16
Cd (mg/Kg)	0.27±0.10	0.15±0.12	0.01*	0.6
Fe (mg/Kg)	0.13±0.01	0.14±0.06	0.98**	30
Zn (mg/Kg)	0.05±0.03	0.06±0.02	0.13**	110
Mn (mg/Kg)	0.12±0.03	0.15±0.05	0.054**	30
Cr (mg/Kg)	0.13±0.02	0.14±0.01	0.064**	25

Note: * = There were significant differences at $p<0.05$
** There were no significant differences at $p>0.05$
Cu=copper, Pb= lead, Ni=nickel, Cd=cadmium, Fe=iron, Zn=zinc, Mn=manganese and Cr=chromium.

Lower concentrations of heavy metals recorded in sediment of Gbalegbe River compared with established values could be attributed to its continuous flow, dilution effects from rainfall and removal through bioaccumulation by aquatic macrophytes (WHO, 2004; Islam *et al*., 2009) Though, heavy metal concentrations recorded during the study period were lower than the recommended values, Zn recorded the highest concentration among stations in sediment.

Mean concentration of heavy metals detected in sediment during the wet season were higher than in dry season. This could be as a result of heavy rainfall, increased anthropogenic activities and surface effluents run off (Ewutanure and Olaifa, 2021b). Highest concentration of Cd recorded during the wet season in sediment could be attributed to increase in Cd containing effluent flowing into the study area (Shamar *et al.* 2008). This could results in the contamination of the sediment structure thereby imposing threat to its benthic community (Ewutanure and Olaifa, 2021a).

Generally, the concentrations of heavy metals in the study area were higher during the wet season than in the dry season. Values recorded in dry season were relatively lower than in wet season. In the wet season, the rate of aquatic pollution was higher due to increase volume of effluent from anthropogenic activities (Chen *et al.* 2005). This could be adduced to increase in effluent discharge in the wet season than in the dry season (Ewutanure and Olaifa, 2018a). Therefore, long term exposure of benthic Macroinvertebrate abundance in the study area could cause hazardous toxicological effects (Olubunmi and Olorunsola, 2010).

Contamination factor, pollution load index, degree of contamination, modified degree of contamination and geo – accumulation index

Contamination factor (C_i^f), pollution load index (PLI),degree of contamination (C_d), modified degree of contamination (mC_d) and geo – accumulation index (Igeo) among stations and between wet and dry seasons are presented in Tables 7 and 8, respectively. Spatially, the highest (0.443) and least (0.012) concentration of Contamination factor (C_i^f) where recorded in Stations 6 and 2, while it ranged from 0.020 to 0.380 in wet and dry seasons, respectively.

Table 7. Spatial variation in means of C^i_f, C_d, mC_d and PLI of Gbalegbe River sediment

Stations	Index	Cu	Pb	Ni	Cd	Fe	Zn	Mn	Cr
Station 1	C^i_f	0.099	0.013	0.063	0.130	0.090	0.012	0.034	0.056
Station 2	C^i_f	0.268	0.035	0.260	0.442	0.150	0.035	0.271	0.167
Station 3	C^i_f	0.169	0.026	0.125	0.390	0.120	0.035	0.203	0.130
Station 4	C^i_f	0.169	0.031	0.125	0.364	0.110	0.035	0.186	0.120
Station 5	C^i_f	0.211	0.031	0.146	0.325	0.120	0.035	0.220	0.111
Station 6	C^i_f	0.169	0.026	0.250	0.443	0.140	0.029	0.220	0.111
Station 7	C^i_f	0.183	0.026	0.135	0.351	0.120	0.035	0.271	0.120
Station 8	C^i_f	0.225	0.022	0.135	0.364	0.130	0.035	0.237	0.157
	PLI	0.121							
	C_d	1.493	0.210	1.240	2.805	0.980	0.247	1.644	0.972
	$_mC_d$	0.150							
	Igeo	0.006	0.0840	0.076	0.097	-3.816	-5.602	-2.877	0.1626

Note: C^i_f = Contamination factor, PLI = Pollution load index, C_d = Degree of contamination, mC_d = Modified degree of contamination andIgeo = geo-accumulation index

Table 8. Seasonalvariation in means of C^i_f, C_d, mC_d and PLI of Gbalegbe River sediment

	Cu	Pb	Ni	Cd	Fe	Zn	Mn	Cr
C^i_f (Wet season)	0.180	0.020	0.140	0.370	0.130	0.030	0.200	0.120
PLI	0.110							
C_d	0.370	0.050	0.260	0.770	0.250	0.060	0.410	0.240
$_mC_d$	0.210							
I_{geo}	0.020	0.970	0.530	0.020	0.790	-5.710	0.080	0.030
C^i_f(Dry season)	0.230	0.030	0.310	0.380	0.110	0.029	0.270	0.120
PLI	0.140							
C_d	0.440	0.070	0.440	0.771	0.240	0.080	0.510	0.250
$_mC_d$	0.350							
I_{geo}	0.040	0.020	0.010	0.100	0.040	0.030	-2.560	0.060

Note: C^i_f = Contamination factor, PLI = Pollution load index, C_d = Degree of contamination, mC_d = Modified degree of contamination andIgeo = geo-accumulation index.

These concentrations obtained are within the Class 1 of C_i^f with recommended value as $C_i^f < 1$ (Hokanson, 1981) signifying low contamination of Gbalegbe River by heavy metals. The pollution load index (PLI) recorded among stations was 0.121, while it ranged from 0.110 to 0.140 in wet and dry seasons, respectively. The PLI obtained during the study period were within the recommended range of PLI < 1 (Tomlinson *et al.* 1980; Yaylali – Abanuz, 2011). This implies that the level contamination of Gbalegbe River is relatively low; hence, drastic remediation effort may not be required (Mondol *et al*. 2011). Spatially, heavy metal with highest (1.644) and least (0.210) concentrations of C_d where manganese and lead, while it ranged from 0.050 to 0.771 for lead and cadmium in wet and dry seasons, respectively.

The value of C_d obtained was relatively low. When compared with the recommended value of $C_d < 8$ (Hokanson, 1981), it could be deduced that Gbalegbe River has a relatively low degree of contamination (Hokanson, 1981). Spatially, the concentration of mC_d recorded was 0.150, while it ranged from 0.210 to 0.350 in wet and dry seasons, respectively. Comparatively, the concentration recorded during the study period falls within class 1 of the established value of $mC_d < 1.5$, which ranged from nil to low degree of contamination (Abraham and Parker, 2008). Spatially, the highest (0.163) and least (- 5.710) Igeo – accumulation were recorded for Cr and Zn, while it ranged from 0.060 to 0.970 for Cr and Pb, respectively. The concentration of Igeo – accumulation obtained from this study was within the recommended concentration for class 1 (0 <Igeo< 1). This also indicated that Gbalegbe River is moderately contaminated with heavy metals. The Igeo values fluctuates moderately and this indicates that the sediment of Gbalegbe River was moderately contaminated as observed from the analysed heavy metals (Khan *et al*. 2011). The Igeo showed that all the samples examined in wet and dry seasons and among stations are within class 1— moderately contaminated (Angula, 1996; Khanam *et al*. 2011). The overall assessment of contamination of Gbalegbe River sediment was based on Cif.In the wet and dry seasons, the sediment was classified as been moderately polluted with lead, zinc and chromium.

The mC_d applied in the present study is predicated on integrating and taking means of analysed data for a set of sediment samples (Abraham & Parker, 2008). Hence, this modified method provides a combined assessment of the overall enrichment and contamination impact of the pollutants as evaluated in the sediment (Muller, 1981). Although the spatio – temporal values of PLI obtained did not indicate immediate intervention to reducing the pollution in the study area, it calls for a constant monitoring so as to avoid sudden build – up of pollutants since the values are greater than zero Hokanson, 1980). This means that, the natural states of heavy metals in the sediments of Gbalegbe River have been altered. The natural background values of heavy metal concentrations in sediment were from Taylor and Mclennan, (1995); Syed *et al*., (2012).

Conclusions and Recommendation

River sediments are major career of geochemical pollutants and natural buffer for the transfer of chemical materials in the aquatic environment. Hence, it serves as the most essential part of the aquatic environment. Due to the essentiality of sediment in surface water, any disastrous alterations of its components could damage its overall quality of its benthic macroinvertebrates.

The impact of anthropogenic effluents on sediment of Gbalegbe River indicated that the study area was relatively contaminated by different concentrations of heavy metals. The various concentrations of heavy metals recorded in sediments of Gbalegbe River originate from anthropogenic activities which can be attributed to unrestrained and untreated or poorly untreated effluents industrial facilities located around it.

Contamination factors, degree of contamination and geo-accumulation indices have been widely used to assess the contamination status of sediments of rivers. Indication from both the contamination factor and degree of contamination is that all the measured heavy metals exhibit low contamination status in the sediment. Based on geo-accumulation index, the sediments are generally classified as moderately contaminated with respect to the heavy metals evaluated.

It is recommended that legislative measures should be put in place to control sediment pollution that will legally compel individual industries and opposed to the release of untreated or poorly treated industrial effluents. Regular monitoring of heavy metals in the sediment is required to check the environmental quality. Various remediation measures should be adequately taken to reduce existing metal contamination. Effluents from the study area could be recycled for the remediation of pollution in a sustainable and eco – specific manner.

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