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ECOLOGICAL RISK OF CHEMICAL FRACTIONATION OF HEAVY METALS IN SEDIMENTS FROM OGBA RIVER, BENIN CITY, NIGERIA

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Abstract

Heavy metals have been recognized worldwide for their toxic effects in man and wildlife. The Ogba River in Benin City, Nigeria, has been reported to be contaminated to varied levels by heavy metals as a result of anthropogenic impact. However, there is paucity of scientific data on the chemical fractionation of such metals in sediment which serves as a repository for such contaminants. Specifically, the chemical fractionation of Cadmium (Cd), Copper (Cu), Lead (Pb) and Zinc (Zn) in sediment was thus determined via a five-stage stage (i.e. Exchangeable, Carbonate, Fe-Mn oxide, Organic/sulphide and Residual) sequential extraction procedure while levels of metals were quantified by Atomic Absorption Spectrophotometric technique in order to evaluate the potential ecological risk of these heavy metals. Results from the study revealed that Cd and Pb were predominantly associated with the Fe-Mn oxide fraction of sediment while Cu and Zn were chiefly associated with the residual fraction of sediment. The mean concentrations (mg/kg, dry weight) of the heavy metals in sediment were 0.91±0.18, 7.83±1.57, 4.88±0.98 and 10.84±2.17 for Cd, Cu, Pb and Zn respectively while the environmental risk factor (ERF) revealed that Cd posed a potential threat to aquatic organisms including fish by having a sub-zero value of -14.12. Contamination factors were 14.29, 0.76, 2.52 and 1.46 for Cd, Cu, Pb and Zn respectively, indicating that contamination was low for Cu, high for Cd and moderate for Zn and Pb. Sequel to findings from the research, it was concluded that relevant environmental regulatory agencies should carry out routine monitoring of the sediment from Ogba River in order to ensure a mitigation in the present contaminated status.

Key Words: *Heavy metals, chemical fractionation, contamination, sediment, River*

Introduction

Heavy metals have been defined as metallic elements that have a relatively high density compared to water and are noted for their potential toxicity to man and wildlife (Paul *et al*., 2014). Both natural and anthropogenic activities have been reported to be sources of such metals in water (Wilson and Pyatt, 2007) while anthropogenic activities generate heavy metals in sediment that pollute the aquatic environment (Sanchez-Chardi *et al*., 2007). Sediments are naturally occurring materials that are broken down by processes of weathering and erosion and are subsequently transported by the action of wind, water, or by the force of gravity acting on the particles (Wikipedia, 2019). In the aquatic environment, sediments have been widely used as environmental indicators for the assessment of metal pollution in natural aquatic media (Islam *et al*., 2015). Chemical fractionation entails the determination of the concentration of the physiochemical forms of elements which together makes up its total concentration in samples. The process provides information related to the origin, mobilization and transport of metals. It also provides information on biological availability and potential risk related to the metal content in natural waters (Passos *et al*., 2010). The bioavailability and toxicity of heavy metals to biota will depend on their chemical forms (Ahif *et al*., 2009). Wangboje (2015) observed that chemical fractionation can be used in establishing pre-urban levels of heavy metals, evaluating I-geo indices and enrichment factors in Rivers. In sediments, heavy metals are present in a number of chemical forms and generally exhibit different physical and chemical characteristics in terms of chemical interactions, biological availability and potential toxicity (Sunduray *et al*., 2011). Ogba River is located in Benin City, Edo state, Nigeria. The River plays host to human activities like farming, fishing, bathing, laundry, car/ motorbike washing, disposal of refuse and traditional religious activities. Several studies have been carried out on Ogba River in the past including, heavy metals in water and fish species (Wangboje and Oronsaye, 2001), physiochemical studies (Emeka, 2011), heavy metals in selected tissues of *Clarias gariepinus* (Wangboje *et al*., 2013) and bioaccumulation studies (Obasohan, 2008). Wangboje *et al.* (2016), observed that the Benin Master Drainage system which empties directly into the River, contributes to the pollution of this ecosystem. Based on the aforementioned studies, Cadmium (Cd), Lead (Pb), Zinc (Zn) and Copper (Cu) were observed to be present in significant proportions, hence their adoption in this study. In addition, there is paucity of information on the chemical fractionation of these metals in sediment from Ogba River hence the relevance of this study in order to fill an existing gap in knowledge.

Materials and Methods

The study was carried out between August 2017 and January 2018, representing both wet and dry months as the region falls within the Tropical rain forest belt. Three sampling stations (Fig. 1) namely Ogba Zoo (upstream), Ogba Bridge (intermediate) and Iyekogba (downstream), were established along the stretch of the River based on anthropogenic activities and characteristics of effluents. At the Ogba Zoo, (Zoological garden) the activities carried out here include recreation, fishing, washing and discharge of solid waste. At the Ogba Bridge station, bathing, fishing, traditional worshiping, swimming, laundry and sand excavation are observable while at the Iyekogba station, fishing, bathing, laundry, car wash and swimming take place. Sediment samples were collected monthly at approximately 20 cm depth, using an Ekman® grab device and placed in Polythene receptacles that had been previously treated with 5% Nitric acid and rinsed with distilled water. Samples were transported to the laboratory within 24 hours in a Thermolineo® ice chest and thereafter stored at - 5°C in a Polystar®

PV-CF 300L freezer, prior to chemical fractionation.

Samples of sediment were thawed at room temperature (25 ± 2 °C) overnight and subsequently dried in a Uniscope® SM 9023 oven (Surgifield medicals, England) at 85ºC until aconstant weight was attained. Dried samples were ground with a porcelain mortar and pestle and homogenized with a stainless steel spatula. One (1) g of dried sample was placed into a 50 ml centrifuge tube and a five-stage (i.e. Exchangeable, Carbonate, Fe-Mn oxide, Organic/sulphide and Residual) sequential extraction procedure was applied as detailed by Tessier *et al.* (1979), Abu-Kukati (2001), Lin *et al.* (2009) and Wangboje *et al.* (2014). The various analytical fractions were each directly aspirated for heavy metal analysis in a flame (acetylene) Atomic Absorption Spectrophotometer (Unicam® 969 series, England), using appropriate wavelengths. Concentrations of metals were expressed in mg/kg (dry weight). Blanks, spiked samples and duplicate analyses were performed for all analytes as part of the quality assurance procedures. All reagents (e.g. Hydrochloric acid, Nitric acid, and Perchloric acid) were of analytical grade (BDH, Poole, England).

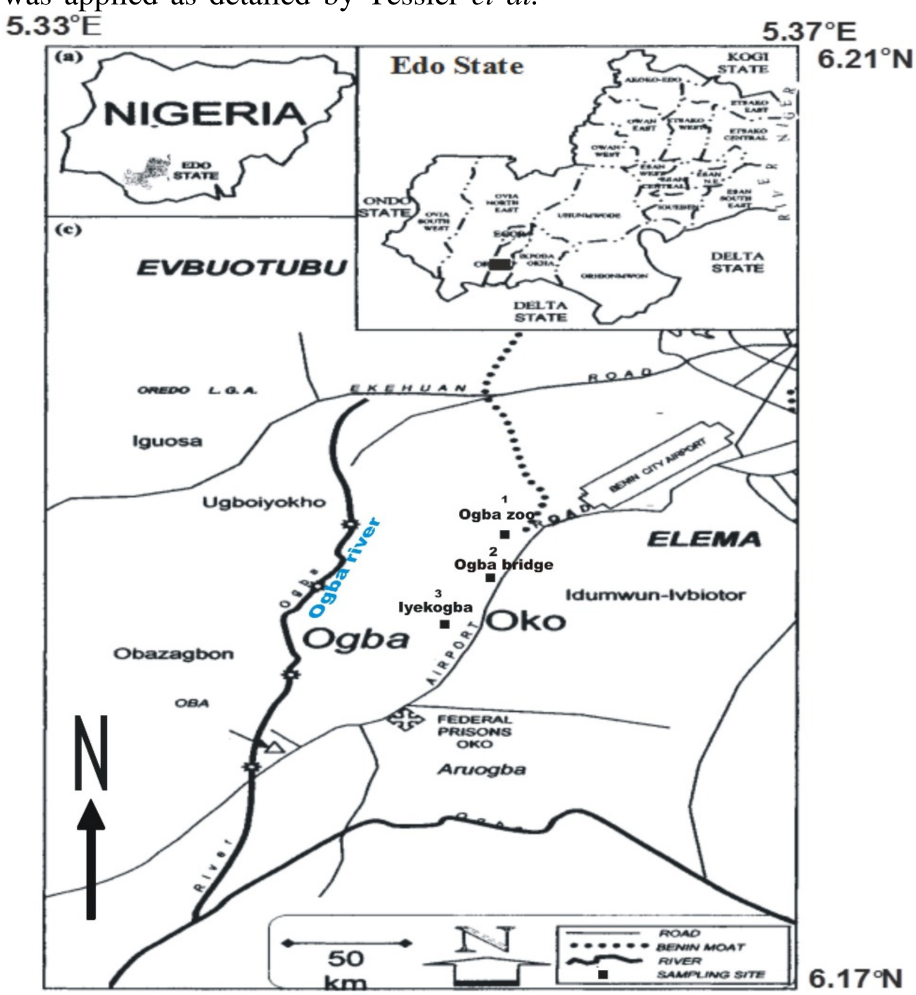

Fig. 1: Map of Ogba River and position of stations
Source: Google Map, 2017

Data Analysis

Environmental Risk Factor (ERF) for Heavy Metals

The ERF was applied to determine environmental risk in order to establish potential threat of heavy metals to aquatic organisms (Saenz *et al*., 2003).

ERF= $CSQV - Ci/CSQV$

Where: CSQV= Concentration sediment quality value (Heavy metal concentration in residual fraction of sediment which is equivalent to the background /pre-industrial concentration);

Ci= Heavy metal concentration in the first four fractions of sediment.

ERF < 0 = Potential threat to aquatic organisms indicated; ERF > 0 = No potential threat to aquatic organisms indicated.

Contamination Factor (CF) for Heavy Metals

CF = Metal concentration in sediment/Background concentration of metal in sediment (Wangboje *et al*., 2014).

$$CF = F1 + F2 + F3 + F4/F5$$

Where; F1 to F5 = Analytical fractions of sediment.

Generated data were subjected to statistical analysis using GENSTAT® computer software (Version 12.1 for Windows). Analysis of variance (ANOVA) was used to determine significant differences (P<0.05) between mean concentrations of heavy metals in sediment while significant means were separated using Duncan multiple range test (DMRT). Microsoft Excel (for Windows 2010) was used for all graphical presentations.

Results and Discussion

Station-wise for the carbonate-bound metal fraction, the mean concentrations of heavy metals ranged from 0.12 mg/kg (Cd) at Ogba Zoo to 8.65 mg/kg (Zn) at Ogba Bridge with significant differences (P<0.05) in the mean concentrations of Zn between stations (Table 1) while monthly-wise, the mean concentration of metals ranged from 0.08 mg/kg (Cd) in September to 14.17 mg/kg (Zn) in November with significant differences (P<0.05) in the mean concentrations of Pb and Zn between months (Table 2). In the exchangeable metal fraction, the mean concentrations of metals ranged from 0.01 mg/kg (Cd) at Iyekogba to 4.55 mg/kg (Zn) also at Iyekogba with significant differences (P<0.05) in the mean concentrations of Pb between stations (Table 3) while monthly-wise, the mean concentration of metals ranged from 0.01 mg/kg (Cd) in August to 7.43 mg/kg (Pb) in November with significant differences (P<0.05) in the mean concentrations of Pb and Zn between months (Table 4). In the Fe-Mn oxide metal fraction, the mean concentrations of metals ranged from 1.36 mg/kg (Cd) at Iyekogba to 14.03 mg/kg (Zn) at Ogba Bridge with significant differences (P<0.05) in the mean concentrations of Zn between stations (Table 5) while monthly-wise, the mean concentration of metals ranged from 0.72 mg/kg (Cd) in August to 16.04 mg/kg (Zn) in November with significant differences (P<0.05) in the mean concentrations of all the metals between months (Table 6). In the organic/ sulfide metal fraction, the mean concentrations of metals ranged from 0.48 mg/kg (Cd) at Ogba Zoo to 11.43 mg/kg (Cu) at Iyekeogba with significant differences (P<0.05) in the mean concentrations of Pb between stations (Table 7) while monthly-wise, the mean concentration of metals ranged from 0.24 mg/kg (Cd) in August to 16.33 mg/kg (Zn) in November with significant differences (P<0.05) in the mean concentrations of Cu, Pb and Zn between months (Table 8). In the residual metal fraction, the mean concentrations of metals ranged from 0.08 mg/kg (Cd) at Ogba Zoo to 26.06 mg/kg (Zn) at Iyekeogba with significant differences (P<0.05) in the mean concentrations of Cu, Pb and Zn between stations(Table 9) while monthly-wise, the mean concentration of metals ranged from 0.05 mg/kg (Cd) in October to 30.03 mg/kg (Zn) in November with significant differences (P<0.05) in the mean concentrations of Cu, Pb and Zn between months (Table 10).

Table 1: Mean concentration of heavy metals in sediment (mg/kg) across stations for carbonate-bound metal fraction

Stations	Cd	Cu	Pb	Zn
Iyekogba	0.13a	0.31a	0.37a	7.01b
Ogba Bridge	0.13a	0.33a	0.14a	8.65a
Ogba Zoo	0.12a	0.31a	0.59a	8.55a
LSD (0.05)	1.82	1.82	1.82	1.82
SEM	0.64	0.64	0.64	0.64

Means followed by the same letter(s) in the same column are not significantly different (P>0.05)

Table 2: Mean concentration of heavy metals in sediment (mg/kg) across months for carbonate-bound metal fraction

Months	Cd	Cu	Pb	Zn
August	0.09a	0.22a	0.15b	5.53f
September	0.10a	0.25a	0.66a	6.06e
October	0.08a	0.25a	0.11b	5.52df
November	0.20a	0.40a	0.81a	14.17a
December	0.17a	0.39a	0.35a	10.14b
January	0.12a	0.38a	0.16b	7.02c
L.S.D (0.05)	1.09	1.09	1.09	1.09
SEM	0.37	0.37	0.37	0.37

Means followed by the same letter(s) in the same column are not significantly different (P>0.05)

Table 3: Mean concentration of heavy metals in sediment (mg/kg) across stations for exchangeable metal fraction

Stations	Cd	Cu	Pb	Zn
Iyekogba	0.01a	0.61a	4.06a	4.55a
Ogba Bridge	0.03a	0.63a	3.32ab	4.15a
Ogba Zoo	0.02a	0.59a	2.77b	3.84a
L.S.D (0.05)	1.30	1.30	1.30	1.30
SEM	0.46	0.46	0.46	0.46

Means followed by the same letter(s) in the same column are not significantly (P>0.05)

Table 4: Mean concentration of heavy metals in sediment (mg/kg) across months for exchangeable metal fraction

Months	Cd	Cu	Pb	Zn
August	0.01a	0.47a	2.12c	3.26c
September	0.02a	0.52a	2.05c	4.38b
October	0.05a	0.47a	1.97c	2.89c
November	0.02a	0.76a	7.43a	7.07a
December	0.09a	0.73a	4.76b	4.66b
January	0.02a	0.70a	1.98c	2.83c
L.S.D (0.05)	0.94	0.94	0.94	0.94
SEM	0.32	0.32	0.32	0.32

Means followed by the same letter(s) in the same column are not significantly different (P>0.05), SEM= Standard error of means

Table 5: Mean concentration of heavy metals in sediment (mg/kg) across stations for Fe-Mn oxide metal fraction

Stations	Cd	Cu	Pb	Zn
Iyekogba	1.36a	6.18a	6.97a	12.47b
Ogba Bridge	1.81a	5.39a	8.26a	14.03a
Ogba Zoo	1.77a	6.08a	8.05a	12.69ab
L.S.D (0.05)	1.67	1.67	1.67	1.67
SEM	0.83	0.83	0.83	0.83

Means followed by the same letter(s) in the same column are not significantly different (P>0.05)

Table 6: Mean concentration of heavy metals in sediment (mg/kg) across months for Fe-Mn oxide metal fraction

Months	Cd	Cu	Pb	Zn
August	0.72b	4.76b	5.21c	11.09e
September	1.10bc	5.33b	5.67c	12.17d
October	0.95bc	5.03b	5.24c	10.82e
November	2.77a	6.76a	14.1a	16.04a
December	2.57ac	6.71a	9.67b	14.71b
January	1.76c	6.70a	6.66c	13.54c
L.S.D (0.05)	1.66	1.66	1.66	1.66
SEM	0.58	0.58	0.58	0.58

Means followed by the same letter(s) in the same column are not significantly different (P>0.05)

Table 7: Mean concentration of heavy metals in sediment (mg/kg) across stations for organic/ sulfide metal fraction

Stations	Cd	Cu	Pb	Zn
Iyekogba	0.74a	11.43a	8.34a	9.85a
Ogba Bridge	0.50a	9.55a	6.44ab	9.57a
Ogba Zoo	0.48a	9.25a	5.05b	8.62a
L.S.D (0.05)	3.04	3.04	3.04	3.04
SEM	1.07	1.07	1.07	1.07

Means followed by the same letter(s) in the same column are not significantly different (P>0.05)

Table 8: Mean concentration of heavy metals in sediment (mg/kg) across months for organic/ sulfide metal fraction

Months	Cd	Cu	Pb	Zn
August	0.24a	8.36b	3.08d	6.83c
September	0.71a	9.71bc	3.16d	7.44c
October	0.37a	8.63b	2.68d	6.19c
November	0.78a	11.80a	14.61a	16.33a
December	0.71a	11.24a	11.50b	11.33b
January	0.67a	10.72ac	4.62c	7.97c
L.S.D (0.05)	3.22	3.22	3.22	3.22
SEM	1.13	1.13	1.13	1.13

Means followed by the same letter(s) in the same column are not significantly different (P>0.05)

Table 9: Mean concentration of heavy metals in sediment (mg/kg) across stations for residual metal fraction

Stations	Cd	Cu	Pb	Zn
Iyekogba	0.32a	17.93b	8.06a	26.06a
Ogba Bridge	0.10a	24.29a	7.96a	21.59b
Ogba Zoo	0.08a	24.51a	5.59b	23.64b
L.S.D (0.05)	2.29	2.29	2.29	2.29
SEM	0.81	0.81	0.81	0.81

Means followed by the same letter(s) in the same column are not significantly different (P>0.05)

Table 10: Mean concentration of heavy metals in sediment (mg/kg) across months for residual metal fraction

Months	Cd	Cu	Pb	Zn
August	0.06a	20.27b	5.29b	21.15b
September	0.60a	20.83b	7.18b	21.91b
October	0.05a	20.07b	5.43b	20.6b
November	0.09a	26.27a	10.58a	30.03a
December	0.09a	24.40a	8.33b	25.76
January	0.09a	21.63b	6.38b	23.13
L.S.D (0.05)	4.70	4.70	4.70	4.70
SEM	1.56	1.56	1.56	1.56

Means followed by the same letter(s) in the same column are not significantly different (P>0.05)

The mean heavy metal concentrations in sediment for the river system ranged from 0.91 mg/kg (Cd) to 10.84 mg/kg (Zn), as presented in Table 11. The contamination factor values for heavy metals in sediment ranged from 0.76 (Cu) to 14.29 (Cd) as shown in Figure 2. The geochemical forms of heavy metals showed that Cd and Pb were chiefly associated with the Fe-Mn oxide fraction of sediment while Cu and Zn were chiefly associated with the residual fraction of sediment (Table 12). The environmental risk factor for heavy metals in sediment ranged from -14.12 (Cd) to 22.30 (Zn), as shown in Figure 3.

Table 11: Mean heavy metals concentration (mg/kg) in sediment

Heavy metals	Ogba Zoo	Ogba Bridge	Iyekogba	River mean	USDOE-ISQG* (1997) PEC LEVEL	CBSQG** (2003) PEC LEVEL
Cd	1.70 ± 0.34	0.52 ± 0.10	0.52 ± 0.10	0.91 ± 0.18	11.70	5.0
Cu	8.15 ± 1.63	8.04 ± 1.61	7.29 ± 1.46	7.83 ± 1.57	77.70	150
Pb	4.41 ± 0.89	4.68 ± 0.94	5.56 ± 1.11	4.88 ± 0.98	396	130
Zn	9.84 ± 1.97	10.95 ± 2.19	11.74 ± 2.35	10.84 ± 2.17	1532	460

*United State Department of Energy Integrated Sediment Quality guidelines

**Wisconsin Consensus Based Sediment Quality guidelines; PEC = Probable Effect Concentration

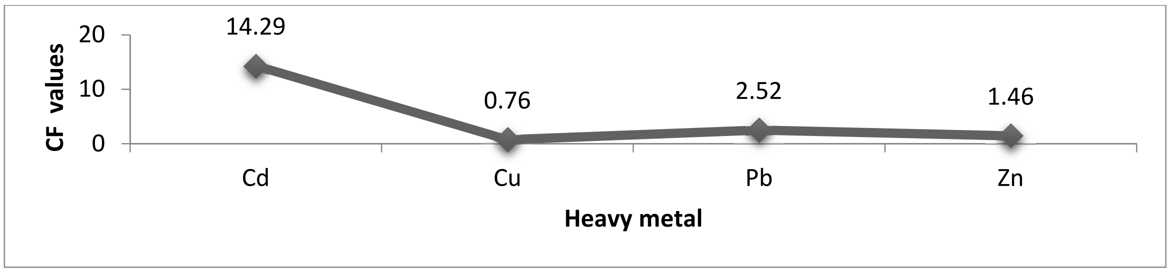

Fig. 2: Contamination factor (CF) for heavy metals in sediment

Key: CF <1= Low contamination; 1<CF <3=Moderate contamination; CF > 6 =High contamination

Table 12: Geochemical forms of heavy metals in sediment

Fractions (F)	Cd (mg/kg) mean		Cu (mg/kg) mean		Pb (mg/kg) mean		Zn (mg/kg) mean	
	Mean	%	Mean	%	Mean	%	Mean	%
F1(Exchangeable)	0.07	2.69	0.61	1.56	3.39	13.38	4.18	7.15
F2(Carbonate)	0.13	5.00	0.32	0.82	0.37	1.46	8.07	13.81
F3(Fe-Mn oxide)	1.65	63.46	5.88	14.20	7.76	30.64	13.06	22.36
F4(Organic sulphide)	0.58	22.31	10.08	25.70	6.61	26.10	9.35	16.00
F5(Residual)	0.17	6.54	22.33	56.94	7.20	28.42	23.76	40.67
Total	2.60		39.22		25.33		58.42	

Where F1 + F2 + F3 + F4 = Heavy metal concentration in sediment; F5 = Residual/ Background concentration of heavy metal in sediment

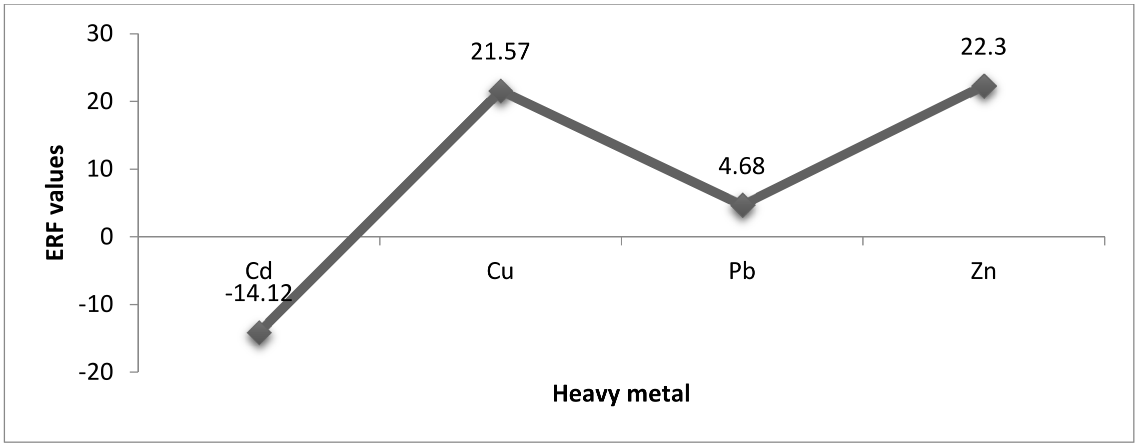

Fig. 3: Environmental risk factor (ERF) for heavy metals in sediment

The chemical form, in which a metal is found in the environment, provides predictive insights on the mobility, bioavailability and the ultimate fate of such metal. Metal species associated with organic/sulphide metal fraction and residual metal fraction are not readily bioavailable. This is attributed to the fact that the metal species associated with these metal fractions are tightly bound thus, their consequent release into water will depend on the strong depletion of the mineral content in sediment as well as the decomposition and oxidation of organic matter (Ikhuoria *et al*., 2010). The mean concentration of Cd was 0.91 mg/kg (Table 11) in sediment with a mean background concentration (BC) value of 0.17 mg/kg (Table 12) and a contamination factor (CF) value of 14.29 (Fig. 2). The CF value indicates that the sediment is highly contaminated with Cd because the value exceeded unity. Cd was predominantly associated with Fe-Mn oxide metal fraction of the sediment indicating that the metal is readily bioavailable to aquatic organisms including fish. The mean concentration of Cd was however lower than the established Probable Effect Concentration (PEC) limits for sediment reported by the United State Department of Energy (USDOE) and the Wisconsin Consensus based sediment quality guidelines (CBSQG) value of 5 mg/kg, indicating that sediment dwelling organisms are not under immediate threat by the metal. The mean concentration of Cd in sediment was however exceeded by the value of 1.58 mg/kg reported by Wangboje *et al.* (2014) in sediment from Ikpoba reservoir in Edo state, Nigeria, and a value of 1.32 mg/kg reported by (Ekeanyanwu *et al*., 2011) in sediment from Okumeshi River in Delta state, Nigeria. The observed mean concentration value of Cd was however higher than the value of 0.80mg/kg reported by Saha and Hossain (2011) in sediment from Buriganga River in Bangladesh. Sources of Cd include; batteries, plastic, fossil fuel, fertilizers and pigments (Annabi *et al*., 2013). The mean concentration of Cu was 7.83 mg/kg in sediment with a mean background concentration (BC) value of 22.33 mg/kg and a contamination factor (CF) value of 0.76. The CF value indicates low contamination of the sediments by the metal. Copper was predominantly associated with residual metal fraction of the sediment implying that the metal is tightly bound and not readily bioavailable.

The mean concentration of Cu was lower than the established PEC limits for sediment presented by USDOE of 77.70 mg/kg and CBSQG value of 150 mg/kg. The mean concentration of Cu in sediment was lower than the value of 27.10 mg/kg reported by Madiseh *et al.* (2009) in sediment from Khuzestan coastal water in Northern Persian Gulf, higher than the value of 4.75 mg/kg reported by Obasohan *et al.* (2007) in sediment from Ikpoba River in Edo state, Nigeria and exceeded by the value of 50.40 mg/kg reported by Banu *et al.* (2013) from Turag River in Bangladesh. Sources of Cu include paints, pipes, pesticides and wire. Lead had a mean concentration of 4.88mg/kg in sediment with a mean background concentration (BC) value of 7.20 mg/kg and a contamination factor (CF) value of 2.52. The CF value indicates that the sediment is moderately contaminated with Pb. Lead was predominantly associated with Fe-Mn oxide metal fraction of the sediment indicating that the metal is readily bioavailable. The mean concentration of Pb was lower than the PEC limits for sediment established by USDOE of 396 mg/kg and CBSQG value of 130 mg/kg. The mean concentration of Pb in sediment was exceeded by the value of 32.78 mg/kg reported by Banu *et al.* (2013) in sediment from Turag River in Bangladesh and higher than the value of 0.45kg/mg reported by Ekeanyanwu *et al.* (2011) in sediment from Okumeshi River in Delta state, Nigeria. Sources of Pb include; batteries, alloys and solders, fossil fuel, refineries, plastic and pesticides (Wangboje *et al*., 2014). Lead interferes with a variety of body processes and is toxic to many organs and tissues including the heart, bones, intestines, kidneys, reproductive and nervous systems (Monisha *et al*., 2014). Zinc had a mean concentration of 10.84mg/kg in sediment with a mean background concentration (BC) value of 23.76mg/kg and a contamination factor (CF) value of 1.46. The CF value indicates that the sediment is moderately contaminated by Zn. Zinc was predominantly associated with residual metal fraction of the sediment implying that the metal will not be easily released into solution and so will be less bioavailable to the aquatic organisms including fish. The mean concentration of Zn was 10.84 mg/kg which was lower than the recommended PEC limits for sediment established by USDOE of 1532 mg/kg and CBSQG value of 460 mg/kg. The mean concentration of Zn in sediment was surpassed by the value of 502.3 mg/kg reported by Saha and Hossain (2011) in sediment from Buriganga River in Bangladesh. Zn can be sourced from refineries, fertilizers, batteries, pesticides, alloys and electrical component (Wangboje *et al*., 2014). The ERF values for heavy metals (Fig. 3) indicated that Cd has a potential threat to aquatic organisms including fish. The high values observed for Zn, Cu, Pb (ERF>0) are an indication that there is no immediate potential threat to aquatic organisms compared to Cd. It has been observed that availability of heavy metals in sediment is largely affected by the sediment properties and hydrological conditions in wetlands while the toxicity of such metals depends on factors such as concentration, speciation and bioavailability (Hu *et al*., 2015). The occasional significant differences ($P<0.05$) observed in the mean concentrations of metals in the sediment fractions between stations and between months may be attributed to the dynamics of the influx of these metals at the stations and the influence of seasonal variations respectively. Furthermore sediments have been recognized as repositories for heavy metals whose concentrations are not static but could vary according to anthropogenic impact (Tang *et al*., 2014; Singh *et al*., 2017).

Conclusion

It was revealed that the investigated heavy metals were either chiefly associated with the Fe–Mn oxide or residual fractions and that Cd which had a sub-zero ERF value was the metal that posed the greatest potential threat to aquatic organisms, thereby positing it as the metal of immediate ecological concern in Ogba River. The contamination factor revealed that the sediment was contaminated to various levels by heavy metals thus making it pertinent for relevant environmental regulatory agencies to carry out routine monitoring of the sediment of Ogba River in order to ensure a reduction in the present contaminated level.

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