Article Number: BF1DB40

A Paper presented at the 39th CSN Annual International Conference, Workshop and Exhibition, Rivers State University of Science and Technology, Port Harcourt, Nigeria.
18th – 23rd September 2016

http://www.proceedings.academicjournals.org/

ACADEMIC JOURNALS
expand your knowledge

Conference Proceedings

Full Length Research Paper

Using index models for heavy metal pollution estimation of sediments from Bomu and Oginigba rivers

Marcus, A. C. and Edori, O. S.*

Department of Chemistry, Ignatius Ajuru University of Education, P.M.B. 5047, Rumuolumeni, Port Harcourt, Nigeria.

Sediments collected from Bomu and Oginigba rivers were treated according to recommended standards and subsequently analyzed for heavy metals and further tested with index models. The results showed that all the metals examined were higher than the recommended upper limits in sediments by China and USEPA except lead in the Oginigba River and cadmium in both rivers. In both rivers, all the metals, copper (Cu), nickel (Ni), chromium (Cr) and zinc (Zn) fell within the category of heavily polluted, lead (Pb) in the sediment from the Oginigba River was moderately polluted and cadmium (Cd) showed no indication of contamination/pollutionin any of the sediments from the rivers. The order of the concentration of the heavy metals in the sediments was Zn> Ni > Cr >Cu>Pb>Cd. Contamination factor (Cf) analysis showed that the sediments from both rivers were free from Cd pollution, slightly polluted with Cu and Cr and moderately polluted with Ni, Zn and Pb. Pollution load index (PI) results showed that Bomu River sediments were moderately polluted while Oginigba river sediments were slightly polluted by the metals. Geo-accumulation index (I-geo) measurements showed that sediments from both rivers are free from pollution by the metals. Ecological risk factor and ecological risk assessment of the sediments from both rivers indicated that both aquatic environments are free from ecological risk. However, the results suggested that there is the possibility of a near future or long run pollution. Therefore, adequate measures should be put in place to monitor thes environments.

Key words: Heavy metals, pollution, index models, Bomu River, Oginigba River, sediments.

INTRODUCTION

The prevalence of pollution has become a matter of public debate all over the world. The increase in pollution primarily resulted from human activities aimed at making life on earth worthwhile. Pollution is diverse and therefore comes in different ways and forms. It has a fairly negative consequence on our health and thus affects every other part of human existence. Among all the pollutions, heavy metal is one that should be given much attention by

*Corresponding author. E-mail: onisogen.edori@yahoo.com.

individuals, cooperate bodies and the government. When adequate attention is paid to the contamination of the environment, then possible ways of improving the environment through pollution reduction can be put in place.

Industrialization and agricultural activities which are the routes for economic growth have diversified the pathways through which heavy metals are introduced into air, water, soils and sediments. Soil is as the ultimate sink for heavy metals and other pollutants discharged into the environment (Banat et al., 2005). Heavy metals, which may be essential (useful) and non-essential (harmful) to human system are very significant in the study of ecology and toxicology. They are persistent in the environment and possess potential toxicity to living organisms in the environment. The concentrations of heavy metals in aquatic ecosystems are monitored by measuring their concentration in water (Ebrahimpour and Mushrifah, 2008), sediments and life forms in the aquatic environment. Sediment as an important component of the aquatic environment gives vital information on the pollution status of the marine ecosystem (Casas et al., 2003). The sediment which acts as the carriers and sinks for contaminants provides information on the history of pollution, the extent of pollution or contamination of the river concerned (Singh et al., 2005) and also provides a data bank on that ecosystem which further studies could be compared with. In the aquatic environment, there are three ways in which heavy metals are retained. These ways are water, sediment and biological organisms (aquatic plants and animals) (Saha et al., 2001). The analysis of the sediment of any aquatic system gives information on the impact of human activities and natural processes that may have impacted on that environment over time (Goorzad et al., 2009; Olubunmi and Olorunsola, 2010).

The accumulation of heavy metals in river sediments involves adsorption processes (physical and chemical) which depends on the nature of the sediment matrix (simple or complex) and the characteristics of the compounds entrained in the sediments (Ankley et al., 1992).

This study was therefore carried out to examine the effect of oil exploration activity at Bomu on the Bomu River and the effect of industrial activity on the Oginigba River with reference to the concentration of heavy metals in these rivers.

MATERIALS AND METHODS

Sediment samples were collected at low tide from three locations from each river using Eckman Grab Sampler. The samples were put in clean black polythene bags and then transported to the Chemistry Laboratory of the Ignatius Ajuru University of Education Port Harcourt.Sediment samples were air-dried at ambient temperature in the laboratory to constant weight. The dried samples were powdered in a ceramic mortar without crushing stones and pebbles and other hard materials such as pieces of wood and leaves of vegetables. The powdered samples were then then sieved with 0.5 mm sieving mesh. Two grams (2 g) of the air-dried and powdered sediment samples were weighed using a high precision balance and was transferred into 100 ml conical flask. The digestion process for sediment samples was done at 60°C for 3 h to near dryness with a mixture of HCl, HNO_3 and H_2SO_4 acids in in the ratio of 1:3:1 in a water bath. Precisely 20 cm^3 of deionized water was added after which the digest was allowed to cool to room at temperature and was then filtered into a 50 ml volumetric flask using Whatman No.1 filter paper. The digest was made up to mark of 25 ml with distilled water and the concentrations of the trace metals were determined by a Buck Scientific model 200 Å Spectrophotometer equipped with air-acetylene flame. The data obtained were subjected to mathematical index models on pollution. These models are used in the interpretation of the extent of contamination/pollution of the environment by heavy metals.

Contamination factor/ pollution index

The contamination factor is expressed as: Contamination Factor (C_f) = Cm/C_b

The Pollution Index (PI) is mathematically expressed as:

Pollution Index (PI) = $n\sqrt{(C_f1 x C_f2 x C_f3 x \ldots x C_fn)}$

Where, C_F = contamination factor, n = number of metals, Cm = metal concentration in polluted sediments, Cb = background value of that metal.

The significance of intervals of contamination factor/ pollution index indicates that values < 1 indicates contamination of the sediment while values > 1 is an indication of pollution (Lacatusu, 2000). The world average concentration values for the metals are Cu (45 mg/ kg), Ni (68 mg/ kg), Cd (0.3 mg/ kg), Zn (95 mg/ kg), Cr (90 mg/ kg) and Pb (20 mg/kg) were used as the background value.

Geo-accumulation index (I-geo)

Geo-accumulation index was calculated according to the equation given by(10). Mathematically, I-geo = log 2 (Cn / 1.5 Bn)
Where, Cn = Concentration of heavy metal in the sediment and Bn = Geochemical background value in average shale of the metal.
The factor 1.5 is used for the possible variations of the background data due to lithological variations.

The classification of the I-geo shows that values < 1 are not polluted, while values > than 1 ranges from slight pollution to extreme pollution (Muller, 1969).

Ecological risk factor (E_f)/ potential ecological risk (RI)

Ecological risk factor (E_f) was used to express the potential ecological risk of a given contaminant, while the potential ecological risk assesses the effect of multiple metal pollutions in the sediments from the aquaticenvironment (Håkanson, 1980).

Mathematically, $E_f = Tr \times C_f$ and $RI = \sum E_f$
Where, Tr = the toxic-response factor for a given element and C_f= the contamination factor of the element.
The toxic response values of the heavy metals are: Cu = Ni = Pb = 5, Cd = 30, Cr =2 and Zn =1.
The terms used to describe the ecological risk factor (E_f) and potential ecological risk (RI) are given in Table 1 to 3.

Table 1. Terminologies used for ecological risk factor (E_f) and potential ecological risk (RI)

Factor	Low risk	Moderate	Considerable	High risk	Very high risk
E_f	<40	$40\leq E_f<80$	$80\leq E_f<160$	$160\leq E_f<320$	$E_f\geq320$
RI	<150	150≤RI<300	300≤RI<600	-	RI>600

Table 2. Heavy metal concentrations of sediments from Bomu and Oginigba

Metal	Bomu	Oginigba	Standard deviation
Cu	66.301 ±38.152	74.610 ± 27.152	5.657
Ni	148.919±84.793	151.219 ± 34.473	1.627
Cd	<0.001	<0.001	0.00
Cr	129.731 ±30.483	109.297 ± 21.843	14.449
Zn	203.513 ±63.101	213.315 ± 60.214	6.931
Pb	60.301 ±38.152	43.307 ± 21.521	12.017

Table 3. World average and standards Limits for trace metal contamination of sediments in mg/Kg.

Metal	World average	China	USEPA		
			Not polluted	Moderately polluted	Heavily polluted
Cu	45	35	< 25	25-50	> 50
Ni	68	-	< 20	20-50	> 50
Cd	0.3	0.5	-	-	> 6
Cr	90	-	< 25	25-75	> 75
Zn	95	150	< 90	90-200	> 200
Pb	20	60	< 40	40- 60	> 60

RESULTS AND DISCUSSION

Heavy metal concentration

The concentrations of the heavy metals in the sediments of Bomu and Oginigba Rivers are given in Table 2. All the metals assessed in the sediments from the two rivers were higher than the world average value for each metal and the limit value set by China except for cadmium. Further examination of the concentrations of the heavy metals in the sediments revealed that the sediments are heavily polluted by the individual metals except lead which was moderately polluted in the Oginigba River and cadmium with no pollution threat. The high values of heavy metals concentrations in sediment is traceable to anthropogenic activities or interferences which in this case are the oil exploration and exploitation in Bomu in Ogoni and the industrial activities in the Port Harcourt Trans Amadi Industrial layout of most of the industries discharge their effluents treated and untreated into the river. This observation corroborates the findings of (Rabee et al., 2011), who observed that toxic metals are derived from waste arising from industries and from fuel sources used in these industries. Accordingly, they argued that most of these metals are also derived from the disintegration or corrosion launches abandoned by the factories along the river shore. This situation was observed in the Oginigba River where many launch boats were lying unattended to by the shores of the river.

The variation of heavy metals concentrations in sediments depends on rate at which particles sediments, the rate at which of heavy metals are deposited, the size of the particles generated and organic matter presence in the sediments (Mwamburi, 2003). Other factors that contribute to heavy metal concentration in sediments includes the type of industry present, the rate of discharge of effluents, the available quantity of particulate matter present in the river or the aquatic environment and others such as the landscape which can facilitate runoffs into the aquatic environment.

Contamination factor/pollution load index of heavy metals

In the present study the contamination factor of Cd

Table 4. Contamination Factor/Pollution Load Index of heavy metals in sediments from Bomu and Oginigba Rivers.

Station	Metals						
	Cu	Ni	Cd	Cr	Zn	Pb	Pollution index
Bomu	1.473	2.190	0.00	1.414	2.142	3.315	2.0048*
Oginigba	1.658	2.224	0.00	1.214	2.245	2.165	1.8515*

*Cadmium value not added in the pollution index calculation.

Table 5. Geo-accumulation Index (Igeo) ofheavy metals in sediments from Bomu and Oginigba Rivers.

Station	Metals					
	Cu	Ni	Cd	Cr	Zn	Pb
Bomu	0.294	0.440	0.00	0.289	0.430	0.665
Oginigba	0.333	0.446	0.00	0.244	0.451	0.435

Table 6. Ecological Risk Factor(E_f) and Potential Ecological Risk Assessment (RI) of heavy metals in sediments from Bomu and Oginigba Rivers.

Station	Metals						
	Cu	Ni	Cd	Cr	Zn	Pb	RI
Bomu	7.365	10.95	0.00	2.828	2.142	16.575	39.859
Oginigba	8.29	11.12	0.00	2.428	2.245	10.825	34.908

(0.00) in the sediments were found in the category of no contamination. The sediments were slightly polluted with Cu and Cr whose values in the sediments ranged from 1.214-1.658 in the sediments, while the sediments were moderately polluted by Ni, Zn and Pb metals. The pollution index status of the sediment showed that Bomu sediment was moderately polluted, while Oginigba sediment was slightly polluted (Table 4).

Contamination index is a quick tool used to examine the pollution status of the individual metal in water, sediments and soils while Pollution load index examines the combined effects of all the individual metals examined and its variation along the sites (Adebowale et al., 2009). The pollution of these sediments is an indication of external influence, which in this case is the industrial activity. The result of the contamination index and the pollution load index based on the (Lacatusu, 2000) contamination and pollution index is a confirmation that the Bomu and Oginigba rivers are facing environmental pollution problems which need urgent attention of the government and relevant agencies.

Geo-accumulation index

The geo-accumulation index of the sediments by the metals from the two rivers all fall into the category or class 0, Class 0 = Igeo ≤ 0, practically uncontaminated (Table 5). This is based on the classification proposed by (Muller, 1969). Geo-accumulation is a measure of the extent of pollution of aquatic sediments which is categorized into seven levels. From the results obtained in this work, it follows that the heavy metals in sediments from these rivers are within the background level or little above the background value from world average in shale.

Ecological Risk Factor (E_f) and Potential Ecological Risk Assessment (RI)

Based on the equation of ecological risk factor (E_f) and potential ecological risk assessment (Ri) the analysis of factors were found to be in the category of low risk. All E_f results for the metals were far < 40 and Ri results were all < 150 (Table 6). Based on the classification in Table 1 as proposed by (Håkanson, 1980), the metals in the sediments do not show any form of risk to the aquatic environment.

Different guidelines are used to monitor the quality of sediments and protect aquatic organism (plants and animals) from the dangerous, harmful and toxic effects that comes along with sediment bound contaminants

(McCready et al., 2006). The reasons behind these guidelines is to examine the extent that the sediment-bound chemical status has affected aquatic animals and plants and also to give adequate ranking of sediment pollution and also allow time for further investigations and make necessary recommendations (Dias et al., 2011).

Conclusion

The activities of oil exploration and exploitation in Bomu in Ogoni and the industrial activities in the Trans Amadi Industrial Layout in Port Harcourt all in Rivers State Nigeria has slightly impacted negatively on the rivers within the areas. The heavy metals assessed were all slightly higher than the recommended limits for heavy metals in sediments by the relevant bodies cited. Even though the assessment by the different index models showed little or no threat to the environment, yet consistent activity on these rivers for a long time can pose detrimental effects on the later years.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Banat FKM, Howari M, Al-Hamada AA (2005). Heavy Metals in Urban Soils of Central Jordan: Should We Worry about Their Environmental Risks? Environmental Research 97:258-273.

Ebrahimpour M, Mushrifah I (2008). Heavy metal concentrations in water and sediments in TasikChini, a freshwater lake, Malaysia. - Environmental Monitoring and Assessment 141: 297-307.

Casas JM, Rosas H, Sole M, Lao C (2003). Heavy metals and metalloids in sediments from the llobregat basin, Spain. Environmental Geology 44(3):325-332.

Singh KP, Mohan D, Singh VK, Malik A (2005). Studies on distribution and fractionation of heavy metals in Gomti River sediments – a tributary of the Ganges, India. Journal of Hydrology 312(1-1.4): 14-27.

Saha SB, Abhijit SB, Choudhury A (2001). Status of sediment with special reference to heavy metal pollution of a brackish water tidal ecosystem in northern Sundarbans of West Bengal. Tropical Ecology 42(1):127-132.

Goorzadi A, Vahabzadeh G, Carbassi AR (2009). Assessment of heavy metals pollution in Tilehbon River sediments. Iran Journal of Applied Science 9(6):1190-1193.

Olubunmi FE, Olorunsola OE (2010). Evaluation of the status of heavy metal pollution of sediment of Agbabu Bitumen deposit area, Nigeria. European Journal of Scientific Research 41(3):373-382.

Ankley GT, Lodge K, Call DJ, Balcer MD, Smith BJ (1992). Heavy metal concentrations in surface sediments in a near shore environment, Jurujuba Sound, Southeast Brazil. Environmental Pollution 109 p.

Lacatusu R (2000). Appraising Levels of Soil Contamination and Pollution with heavy Metals. European Soil Bureau Research Report 4:393-402.

Muller G (1969). Index of geoaccumulation in sediments of the Rhine River. Geology Journal 2:109-118.

Håkanson L (1980). An Ecological Risk Index for Aquatic Pollution Control: A Sedimentological Approach. Water Research 14 975-1001.

Rabee AM, Al-Fatlawy YF, Abdown AN, Nameer M (2011). Using Pollution Load Index (PLI) and Geoaccumulation Index (I-Geo) for the Assessment of Heavy Metals Pollution in Tigris River Sediment in Baghdad Region. Journal of Al-Nahrain University 14(4):108-114.

Mwamburi J (2003). Variations in trace elements in bottom sediments of major rivers in Lake Victoria's basin, Kenya Lakes & Reservoirs. Research and Management, 8:5-13.

Adebowale KO, Agunbide FO, Olu-Owolabi B (2009). Trace metal concentration, site variations and partitioning pattern in water and bottom sediments from coastal area: A case study of Ondo Coast, Nigeria. Environmental Research Journal 3(2):46-59.

McCready S, Birch GF, Long ER (2006). Metallic and organic contaminants in sediments of Sydney Harbour, Australia and vicinity- a chemical dataset for evaluating sediment quality guidelines. Environment International 32:455-65.

Dias De Alba M, Galindo-Riano MD, Casanuueva-Marenco MJ, Garcia-Vargas M, Kosore CM (2011). Assessment of the metal pollution, potential toxicity and speciation of sediment from Algeciras Bay (South of Spain) usingchemometric tools. Journal Hazard Materials 190:177-87.