

Evaluation of potentially toxic metals load and risk assessment in sediments from coastal areas of Lagos State

Majolagbe A. O.*, Anko S. O., Yusuf K. A. and Ayodele A. A.

Department of Chemistry, Lagos State University, Ojo, Nigeria.

*Corresponding author. Email: abdulrafiu.majolagbe@lasu.edu.ng; Tel: +2348023589871.

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ABSTRACT: Trace metal pollution is of global concern due to its adverse effects on human health. Sediments in water bodies are a repository of pollutants, including trace metals, and since they are non-biodegradable, they have negative impact on the ecosystems. Trace metals are due to both anthropogenic and natural sources. Sediments are monitors of trace metal pollution. The study, therefore, aims at assessing the trace heavy metals (THM) in the surface sediments of coastal areas in Lagos State. Forty (40) sediments samples (top and sub-sediment soil) were collected from five coastal communities: Langbasa, Itumaro, Ibeshe, Epe and Badagry, analyzed for pH and trace metals using Atomic Absorption Spectrometry (AAS). Ecological tools: pollution classification, pollution index, and geo accumulation index were further used along with application of sediments quality guidelines to reveal trends and variations in sediment investigated. The pH values range from 4.7- 6.4, while the trace metals concentration ranges from 1.6 - 6.42, 36.2 - 104.5, 0.05 - 63.6, 0.00 - 0.17, 32.1 - 266.3, 3.7 - 5.94, 0.00 - 0.00 mg/kg for Zn, Fe, Cu, Pb, Ca, Mg and Ni respectively. The order of concentration of the metals was Ca > Fe > mg > Cu > Zn > Pb. The monomial and overall ecological potential risks for the trace potentially toxic metals investigated (lead, iron, zinc and copper) in the study area posed low potential risk (<40) and (< 110) respectively. The order of deteriorations (potential risk) in the study area is Badagry > Ibeshe > Epe > Itumaro > Langbasa. Continuous monitoring of trace heavy metals is important to ensure health safety and sustainable environment.

Keywords: Coastal area, ecological potential risks, Langbasa, trace metals, sediments, sediment quality guidelines.

INTRODUCTION

Sediment, a natural sink and a repository for contaminants in water bodies has been extensively reported by environmental researchers (Viers *et al.*, 2009; Sutherland and Tolosa, 2000; Aduwo and Adeniyi, 2018; Fathollahzadeh *et al.*, 2014). Various chemical contaminants that are preserved in sediment include organic compounds: pesticides, polyaromatics and polycarbonbiphenyls etc, (Bigus *et al.*, 2014). Trace heavy metals (THM) constitute another major chemical contaminants in sediments (aquatic environments). Trace heavy metals in sediments can originate from both natural and anthropogenic sources (Algül and Beyhan, 2020; Kostka and Leśniakm, 2021). The metallic elements occur naturally in the basement rock and ore minerals in the geologic formation of bottom sediment of the water bodies. Alternatively, the other major source of metals is from

processes of man-made activities or its by products (Masindi and Muedi, 2018) including discharges from industries, urban runoff, leachates from landfill (Teta and Hikwa, 2017; Essien *et al.*, 2022), runoff from farms (applications of fertilizers and chemical) (Alengebawy *et al.*, 2021; Wu and Ge, 2019), mining (Hadzi, 2022; Fashola *et al.*, 2016) and ship yard activities (Su *et al.*, 2019). Heavy metals that are not essential: Hg, As, Pb, and Cd are of serious adverse effect to man even in low level while some that are essential: Fe, Cu, Mo, and Zn etc will also become health compromising at a very high concentration. Toxicity, non-degradability, and ubiquitousness are factors that make heavy elements consequential in an environment aside bio magnification, bio accumulation and bio transfer that contribute to the adverse effect of the presence of heavy metals in an environment (Ali *et al.*,

2019; Jaishankar *et al.*, 2014). These trace heavy metals have been implicated in a number of diseased conditions. Heavy metal toxicity can lower energy levels and damage the functioning of the brain, lungs, kidney, liver, blood composition and other important organs (Jaishankar *et al.*, 2014). Nickel has been linked to respiratory failure, chronic bronchitis and birth defects (Horsfall and Spiff, 2005). Sediments are in constant movements under the influence of various dynamics and this concept changes the contamination status of water and sediment bed. The change in sediment transport can come from changes in water flow, water level, weather events and human influence (Dudgeon *et al.*, 2006; Graf *et al.*, 2016). Dredging involves the removal of sediments layers from the bottom of water bodies. It is of socioeconomic importance and geared towards infrastructural development in a nation: building waterways (Adekunbi *et al.*, 2018), sediments soil for the construction of roads, housings etc. Environmental dredging is form of dredging involving removal of contaminated sediment. Environmental dredging is performed to reduce the risk of effects of contaminated sediment and associated risks to human health and the environment. Environmental dredging is becoming common in both developed and developing countries, for the sole purpose of cleaning up the water body, thereby minimizing the spread of contaminants. US Army Corps of Engineers make use of dredging in maintaining navigation channels for recreation, national defense and commercial purposes (NRC, 2008).

Assessment and monitoring of trace potentially toxic metals in sediments have been reported extensively the last few decades (Sutherland and Tolosa, 2000; Zhang *et al.*, 2015; Olaniyi and Popoola, 2021; Yuan *et al.*, 2019). Laboratory instrumental determination of metals in the assay (Sediments samples) is common. The concentration of the metals determined is often compared to standards by international regulatory bodies or background values. Various ecological and statistical tools are introduced to further explain trends and variations in the laboratory data obtained. The ecological tools include contamination factor, pollution index, pollution classification, geo accumulation index and pollution load index while statistical include correlation coefficient, cluster and factor analyses.

Application of sediments quality guidelines (SQG) is employed in further analyzing sediments contamination/pollution profiles. Sediment quality guidelines (SQGs) were developed in Australia and New Zealand in 2000 to predict the adverse biological effects caused by contaminated sediments (ANZECC/ARMCANZ, 2002 as cited in Preda and Cox, 2002). These tools were based on the ecotoxicology of environment. So many SQGs have been developed in various provinces, countries and research bodies. SQGs known include the National Standard of China (*Marine Sediment Quality*) SEPA, 2002, Swedish Environmental Sediment Quality Guideline, Portuguese Legislation Classification of Sediment in Coastal region and Washington Department

of Ecology (WDOE), Interim Sediment Quality Guideline for Hong Kong (Praveena *et al.*, 2008).

This study was therefore designed to evaluate the trace metals load and associated ecological risk assessment in sediment from five coastal communities in Lagos State, thereby enhancing the required policies towards the safety of man and sustainable environment.

EXPERIMENTAL

Study area

Five coastal communities in Lagos State constitute this study area: Langbasa, Ibeshe, Epe, Itumaro and Badagry are located in five different local government councils namely Lekki, Ojo, Epe, Apapa and Badagry Local Government Councils respectively. The geographical coordinates longitude/ latitude ranging from N6°30'27'/E3°34'42 to N6°30'30'/E3°34'45 (Langbasa), N6°24'27'/E3°15'11 to N6°24'27'/E3°15'13 (Ibeshe), N6°34'55'/E3°59'24 to N6°34'49'/E3°59'6 (Epe), N6°25'5'/E3°21'44 to N6°25'8'/E3°21'43 (Itumaro) and N6°24'57'/E2°52'33 to N6°24'54'/E2°24'55 (Badagry). The coordinates of the study area (each of the five communities) were used to draw the sample locations map in Figure 1. The communities in the study area are occupied with local sand/sediment dredging, fishing, and water transportation.

Samples and sampling collection

Forty (40) sediment samples (top and sub-sediment soil) were collected using a soil auger near the bank of the river bodies in the investigated five coastal communities using soil auger: Langbasa (LSS), Ibeshe (ISS), Epe (ESS), Itumaro (TSS) and Badagry (BSS). Four composite sediments were taken from each community of the study area for this research, including top-sediment soil (1-15 cm) and sub-sediment soil (15-30 cm).

The soils were collected into a double-labelled black polythene bag and transported to the laboratory, where they air dried for four days. The dried samples were pulverized with a pre-cleaned mortar and a pestle, and sieved through a 2 mm sieve.

Analytical procedure

The physiochemical analyses conducted on the sediment samples in this study include pH using a pH meter, and potentially toxic metals analysis using Atomic Absorption Spectrophotometric method following standard procedure.

Data analyses

A descriptive analysis of the data generated was performed using Graph Pad Prism (version 5.00). The data



Figure 1. Map of sampling locations.

were also subjected to various ecological assessments, including pollution index (Pi), pollution classification (Pc) and geo-accumulation index. Potential Ecological Risk assessment of the metals in the environment was also determined.

Pollution Index (Pi)

The pollution index is the extent of pollution of soil with reference to a specific metal. Liu *et al.* (2007) obtained Pi as a ratio of metal concentration in a contaminated soil sample and its concentration in the control sample. Pollution index is synonym to contamination factor (CF). However, Diatta *et al.* (2003) obtained Pi as a ratio of the metal concentration in a contaminated soil sample and the local Maximum Allowable Limit (MAL) values of the metal/background value. Values considered as MAL of trace heavy metals vary from place to place and depend on local background values (Kloke, 1980).

$$Pi = \frac{C_{in}}{C_{ib}}$$

Where: C_{in} is the concentration of the i th soil pollutant, and C_{ib} is the relative metal concentration of pollutant in the control sample or background value in $mgkg^{-1}$. Contamination categories are as follows:

- Low contamination $CF < 1$
- Moderate Contamination $1 \leq CF < 3$
- Considerable contamination $3 \leq CF < 6$
- Very high contamination $CF > 6$.

Pollution classification (Pc)

This helps in establishing the distinction between conta-

mination and pollution range in soil. Pc values above 1.0 indicate the pollution range, while those below 1.0 indicate the contamination range. The pollution index obtained can be used to compute the Pc of an area using the formula of the Dutch system (Lacatusu 1998; Poh *et al.*, 2006).

$$Pc = \frac{C_{in} - C_{ib}}{Pi}$$

Where: C_{in} is the concentration of the i th soil pollutant, C_{ib} is the relative metal concentration of pollutant in the control sample or background value in $mgkg^{-1}$ and Pi is the pollution index.

Geo accumulation index (Igeo)

The Igeo of heavy metals in the sediment helps in determining the extent of heavy metal accumulation in sediments (Zhang *et al.*, 2015; Chakravarty and Patgiri, 2009). Igeo can be calculated through the mathematical relationship,

$$Igeo = \frac{\log_2 [C_{metal\ sample}]}{1.5 [C_{ib}]}$$

Where: $C_{metal\ sample}$ is the concentration of the heavy metal in the sediment samples. C_{ib} is the background or control sample value. The degree of metal pollution is assessed in terms of seven contaminant categories based on the increasing value of the index as follows:

- Igeo = 0 means unpolluted;
- $0 < Igeo < 1$ means unpolluted to moderately polluted;
- $1 < Igeo < 2$ means moderately polluted;
- $2 < Igeo < 3$ means moderately to strongly polluted;

Table 1. Grades of individual and overall ecological potential risks.

Eir value	Grades of ecological risk of metals	RI value	Grades of the environment
Eir < 40	Low ecological potential risk	RI < 110	Low ecological potential risk
40 ≤ Eir < 80	Moderate ecological potential risk	110 ≤ RI < 200	Moderate ecological potential risk
80 ≤ Eir < 160	Considerable ecological potential risk	200 ≤ RI < 400	Strong ecological potential risk
160 ≤ Eir < 320	High ecological potential risk	400 ≤ RI	Very strong ecological potential risk
320 ≤ Eir	Significant very ecological potential risk		

- e. $3 < I_{geo} < 4$ means strongly polluted;
- f. $4 < I_{geo} < 5$ means strongly to very strongly polluted;
- g. $I_{geo} > 5$ means very strongly polluted.

Potential Ecological Risk Assessment Index (RI)

The Potential Ecological Risk Index (RI) introduced by Hakanson (1980) helps in assessing the degree of heavy metal pollution in soil shown in Table 1. RI could evaluate ecological risk caused by toxic metals comprehensively. The calculating methods of RI are:

$$F_i = \frac{C_{in}}{C_{io}}$$

$$E_{ir} = T_{ir} \times F_i$$

$$RI = \sum_{i=1}^n E_i$$

Where F_i is the single metal pollution index; C_{in} is the concentration of metal in the samples; C_{io} is the reference value for the metal. E_{ir} is the monomial potential ecological risk factor; T_{ir} is the metal toxic response factor according to Hakanson (1980). The T_{ir} for Zn = 1, Cr = 2, Cu = Ni = Pb = 5, As = 10 and Cd = 30. RI is the potential ecological risk caused by the overall contamination.

RESULTS AND DISCUSSION

The statistical analysis of data generated for pH and trace metals evaluation of sediments samples analyzed in this study are presented in Table 2. Potentially toxic metals investigated include Zn, Fe, Ni, Pb, Cu, Mg, and Ca. The pH values ranged from 4.7 ± 0.67 to 6.4 ± 0.27 indicating the acidic state of the sediment. pH influences the distribution and dispersion of metals in the aquatic environment. pH also affects the capacity of sediment to hold and release metals leading to secondary pollution (Segura *et al.*, 2006). The acidic range of pH in this study differs from the neutral to the alkaline range of pH value in another study in Lagos (Majolagbe *et al.*, 2017). However, the pH in this study is similar to the Abuja study for the acidic range of the sediment (Ilechukwu *et al.*, 2020).

Various sources of heavy metals of both natural and man-made origins have been identified (Chatterjee *et al.*,

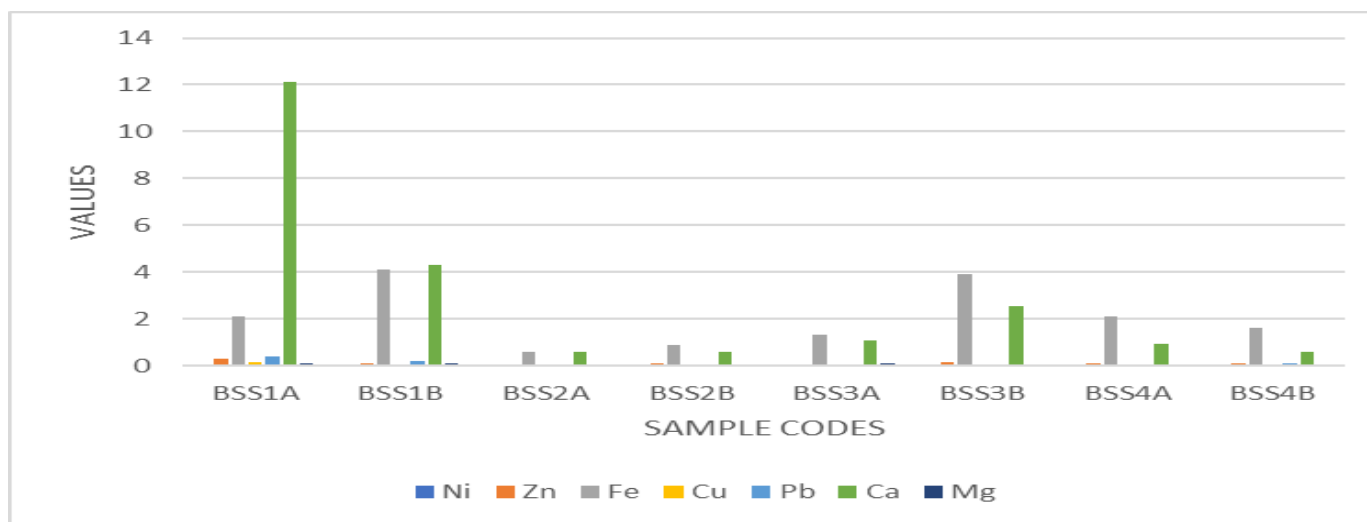
2007; Wang *et al.*, 2012). The anthropogenic sources include mining, modern agricultural practices, urban runoff and industrialization (Wang *et al.*, 2012; Harikrishnan *et al.*, 2017). Pollution threats also come from urban run-off, effluent discharges, oil spills, and as well as local sand dredging (Majolagbe *et al.*, 2012). The levels of metals investigated in Table 2 revealed generally low concentrations of metals across the five sub-components in the study area. This observation may be due to very low levels of human activities, hence the low heavy metal trends observed in this study may probably point at only natural sources including mineralogy and geo formation of the study area (Algül and Beyhan, 2020).

All metals investigated were observed in the study area except nickel and lead (Pb was present only in the Badagry sample). The general decreasing order of concentration of metals observed is $Ca > Fe > Cu > Mg > Zn > Pb$. The high levels of magnesium and calcium in this study could be attributed to the geological formation of the area.

Valiela *et al.* (2005) linked the presence of the high level of magnesium as a baseline rock in aquatic environment. As chemical or by-chemical products are released into the aquatic environment through either natural or anthropogenic activities. They partition into the particulate phase. These particles/substances may be deposited into the bed sediments and accumulate over time (CEQG, 2003). These deposited and bedded sediment (DBS) refers to mineral and organic particles that settle out of the water column. This settling often occurs when water flow slows down or stops, and heavy particles can no longer be supported by the bed turbulence and with favourable geochemical conditions heavy metals can occur in sediments or precipitate into them. Other common sediment contaminants in sediment contamination are pesticides, PCBs, PAHs, and to a lesser extent dissolved phase chlorinated hydrocarbons. Heavy metals distribution in marine sediments is influenced by texture, clay-minerals, organic matter, oxides, oxy hydroxides of iron and manganese and calcium carbonate (Vilela *et al.*, 2004). So many health threats have been traced to trace metals through the food chain. The fauna and flora in the aquatic environment particularly in big water bodies are involved in bio-accumulation, bio-magnify and bio-transfer of heavy metals thereby elevating the concentration of trace/heavy metals in the environment and its attendant health effect in man (Rajeshkumar and Li, 2018). A number of health conditions have been linked to high

Table 2. Descriptive statistics of pH and heavy metals (mg/kg) in sediment in coastal communities in Lagos.

Site	pH		Zn		Fe		Cu		pb		Ca		Mg		Ni
	Mean± SD	CV	Mean± SD	CV	Mean± SD	CV	Mean± SD	CV	Mean± SD	CV	Mean± SD	CV	Mean± SD	CV	
Badagry	6.1±0.56	-	6.42±0.078	60.7	104.5±1.29	61.835.5	63.6±0.4	-	0.17±0.001	-	158.3±1.08	29.9	3.45±0.04	56.5	ND
Epe	4.7±0.67	-	2.8±0.009	17.5	41.7±0.479	57.6	0.15±0.479	88.3	ND	-	251.1±2.1	40.4	5.94±0.02	15.9	ND
Itumaro	6.4±0.27	-	6.45±0.079	61.2	104.5±0.079	8.78	0.05±0.002	54.1	ND	-	266.3±3.25	60.25	5.5±0.023	21.3	ND
Langbasa	4.9±0.91	-	1.6±0.002	7.31	36.2±0.31	43.3	0.05±0.001	90	ND	-	32.1±0.09	14.4	3.7±0.01	9.73	ND
Ibeshe	6.2±0.16	-	6.45±0.08	61.3	104.5±1.29	62.1	63.6±0.05	4.01	ND	-	142.9±3.71	129.9	4.65±0.002	21.3	ND
BV			34.01		139.9		11		11.6						4.7
CCMe			120				16		31						16

**Figure 2.** A line chart showing the metals in Badagry coastal area.

concentrations of many trace metals (Jaishankar *et al.*, 2014). The toxic health effect includes on various human organs include gastrointestinal and kidney dysfunction, nervous system disorders, immune system dysfunction, and cancer (Rice *et al.*, 2014; Cobbina *et al.*, 2015; Balali-Mood *et al.*, 2021; Zhang *et al.*, 2015; Luo *et al.*, 2020).

The decreasing order of Zn, Fe, Cu, Ca and Mg in each of the five sites of the study area is as follows: Itumaro > Ibeshe > Badagry > Epe > Lamgbasa; Itumaro > Ibeshe > Badagry > Epe > Lamgbasa; Ibeshe > Badagry > Epe > Itumaro > Lamgbasa; Itumaro > Epe > Badagry > Ibeshe > Ibeshe; and Epe > Itumaro > Ibeshe > Lamgbasa >

Badagry respectively. The trends in each of the four composite locations in each five sites are illustrated by the following line charts (Figures 2 to 6).

The pollution index, pollution classification and geo accumulation index of this study are summarized in Table 3. The pollution index in respect of zinc, iron and lead is low contamination in all sites as well

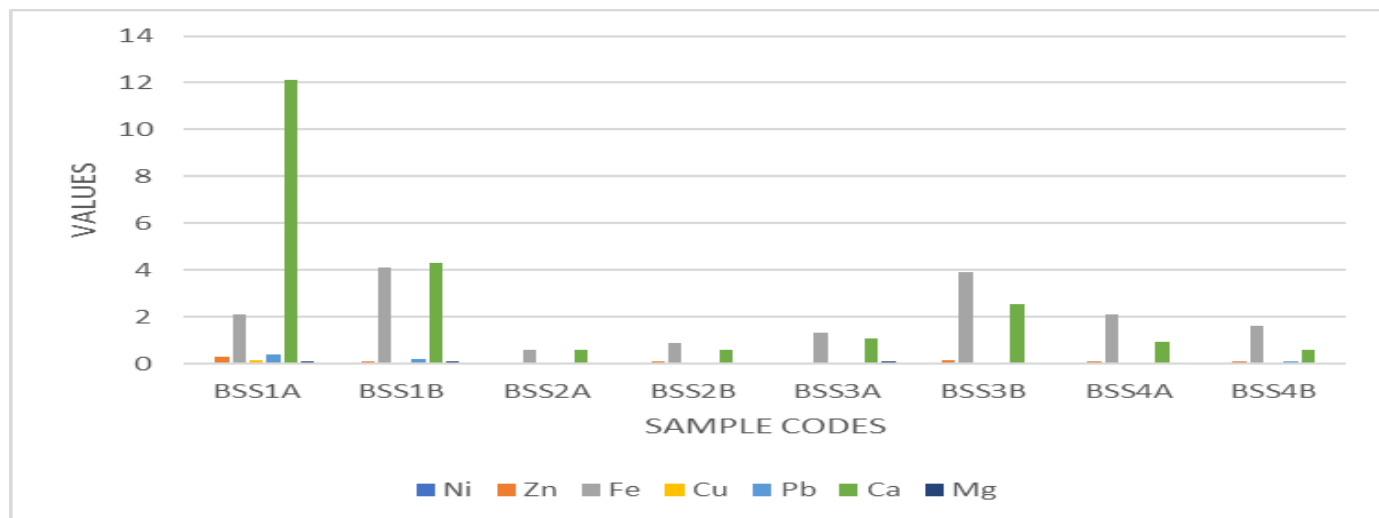


Figure 2. A line chart showing the metals in Badagry coastal area.

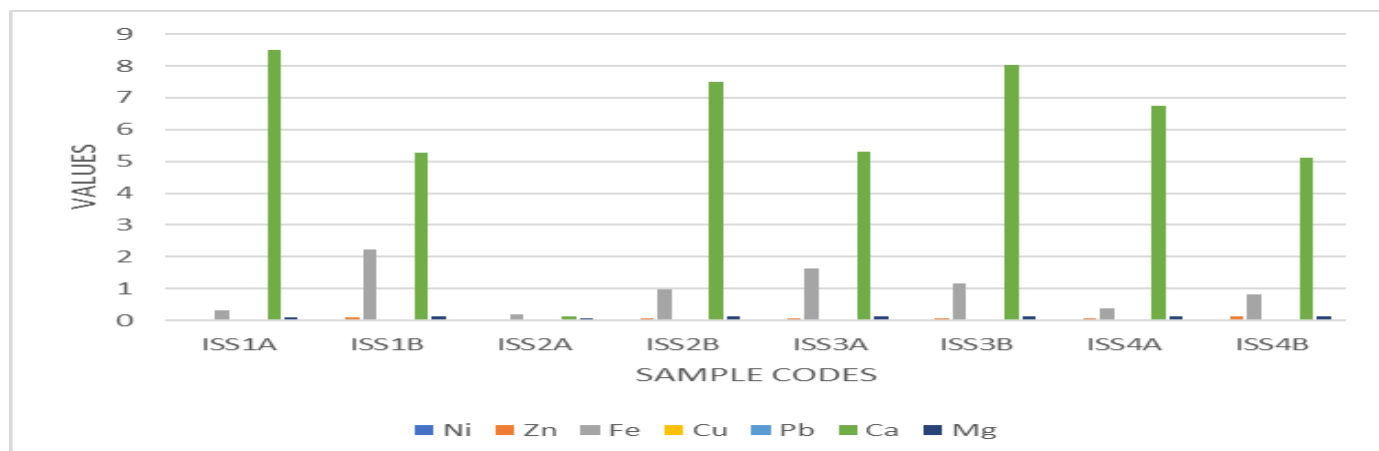


Figure 3. A line chart showing the metals in Ibeshe coastal area.

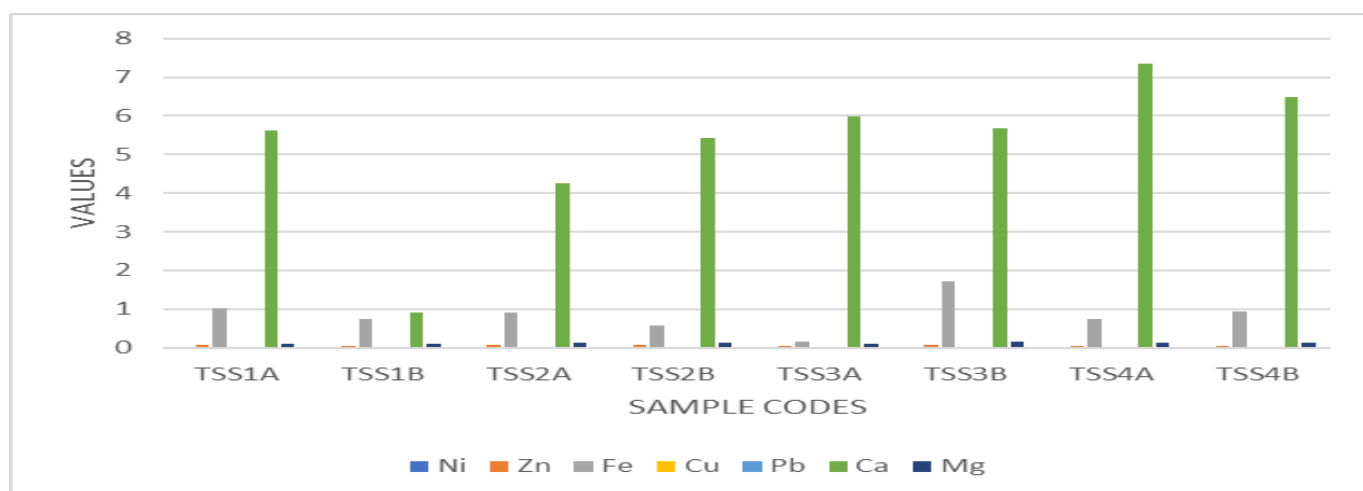


Figure 4. A line chat showing the metals in Itumaro coastal area.

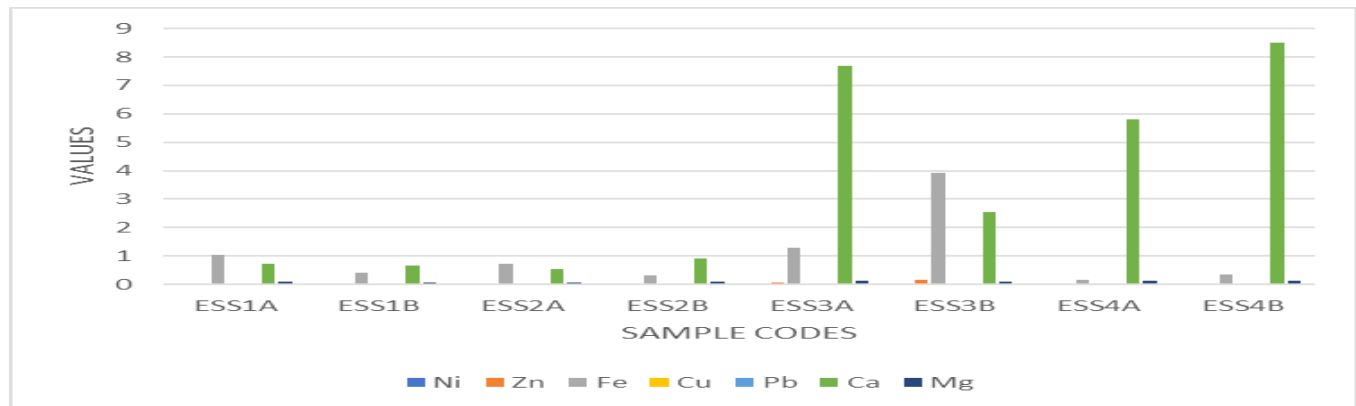


Figure 5. A line chart showing the metals in Epe coastal area.

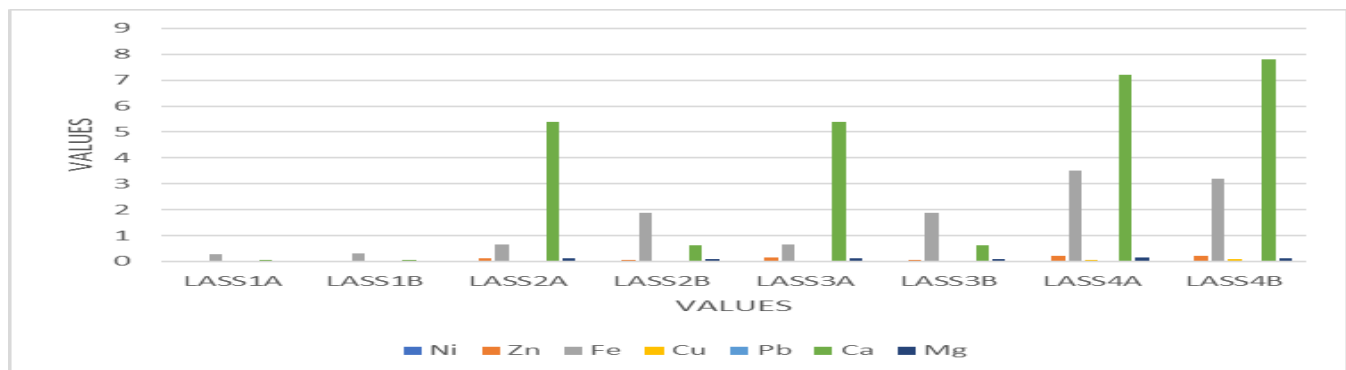


Figure 6. A line chart showing the metals in Langbasa coastal area.

Table 3. Pollution Index (P_i), Pollution Classification (P_c) and Geo Accumulation Index (I_{geo}) in sediment in coastal communities in Lagos.

This study	Zn			Fe			Cu			Pb		
	P_i	P_c	I_{geo}	P_i	P_c	I_{geo}	P_i	P_c	I_{geo}	P_i	P_c	I_{geo}
Badagry	0.189	-174.8	0.037	0.763	-47.1	0.149	5.8	9.02	1.156	0.015	-762	0.03
Epe	0.082	-380.5	0.016	0.304	-323	0.059	0.13	-83.5	0.003	-	-	-
Itumaro	0.189	-174.8	0.037	0.763	-47.1	0.149	0.004	-2e3	0.001	-	-	-
Langbasa	0.047	-689.4	0.009	0.264	-392	0.051	0.004	-2e3	0.001	-	-	-
Ibeshe	0.189	-174.8	0.037	0.763	-47.1	0.149	5.8	9.02	1.156	-	-	-

as copper in Epe, Itumaro and Langbasa, while copper in Badagry and Ibeshe is of moderate contamination. This observation is similar to another Lagos study (Majolagbe *et al.*, 2017). The pollution classification status of this study reveals 'contamination' status for all the areas in the present study except for Badagry and Ibeshe in respect of copper. The Geo accumulation index in sediment samples analysed shows similar trends as P_i and P_c where only Badagry and Ibeshe in respect of copper are moderately polluted while the remaining parts of the entire study area are unpolluted according to the I_{geo} . Values as shown in Table 3. The individual (monomial) ecological potential risk

for all the trace potentially toxic metals investigated (lead, iron, zinc and copper) in the study area revealed low potential risk (<40). The overall ecological risk for the five studied sites also showed low potential risk, (< 110) as stipulated in Table 4. This reflects the low level of anthropogenic activities in the study area, hence low levels of deterioration of the environment. This is in contrast to the results shown in another Lagos study (Majolagbe *et al.*, 2017). The order of deterioration (potential risk) in five sites in the study area is Badagry > Ibeshe > Epe > Itumaro > Langbasa.

The application of sediment quality guidelines in

Table 4. Ecological Potential Risk of heavy metals of sediment in coastal communities, Lagos.

Site	Monomial ecological risk for metals				RI
	Zn	Fe	Cu	Pb	
Badagry	0.189	0.763	29	0.075	30.027
Epe	0.082	0.304	0.65	-	1.036
Itumaro	0.189	0.763	0.02	-	0.972
Langbasa	0.047	0.264	0.02	-	0.331
Ibeshe	0.189	0.763	29	-	29.952

Table 5. Application of SQGs to classify the present study based on concentration of metals (mg/kg) (Praveena, 2005).

SQG	Fe	Cu	Zn	Pb
Badagry	104.5±1.29	63.6±0.4	6.42±0.078	0.17±0.001
Epe	41.7±0.479	0.15±0.479	2.8±0.009	-
Itumaro	104.5±0.079	0.05±0.002	6.45±0.079	-
Langbasa	36.2±0.31	0.05±0.001	1.6±0.002	-
Ibeshe	104.5±1.29	63.6±0.05	6.45±0.08	-
Swedish Environmental Sediments Quality Guideline				
Effect range low		34	150	46.7
Effect range medium		270	218	218
Portuguese Legislation Classification of Sediment in Coastal region				
Class 1: Clean dredge materials		<35	<100	
Class 2: Trace contaminated sediment		35 - 160	100 - 600	
Class3: Lightly contaminated sediment		150 - 300	600 - 1500	
Class 4: Contaminated sediment		300 - 500	1500 - 5000	
Class 5: Highly contaminated sediment		>500	>5000	
Washington Department of Ecology (WDOE)				
Non Polluted		<25	<90	
Moderately Polluted		25 - 75	90-200	
Heavily Polluted		>75	>200	

assessing and classifying the status of sediments has been extensively reported (Praveena *et al.*, 2008; Farkas *et al.*, 2007; Gao *et al.*, 2015). This study made use of the Swedish Environmental Sediment Quality Guideline, Portuguese Legislation Classification of the Sediment in Coastal region and Washington Department of Ecology (WDOE) as shown in Table 5.

Four (4) trace potentially toxic metals (Zn, Cu, Fe and Pb) analysed were assessed with the use of sediments quality guidelines. Zinc values in the entire study area, copper in Itumaro, Langbasa and Epe as well as lead in Badagry fall in effect range low (ERL) indicating a small proportion of the concentration is likely to have adverse effects on animals that live in the sediment. The Cu concentration in Badagry and Ibeshe falls into the effect range medium (ERM) indicating that these contaminants will have adverse effects on animals living in the sediments under investigation.

Portuguese Legislation Classification of Sediment in

Coastal region classifies Zinc values in the entire study area, copper in Itumaro, Langbasa and Epe as well as lead in Badagry into Class 1: Clean dredge materials while Cu level in Badagry and Ibeshe fall into Class 2: Trace contaminated sediment. The entire study area was classified as non-polluted by the Washington Department of Ecology (WDOE) in respect of the metals analyzed but put Badagry and Ibeshe in respect of copper as moderately polluted

Conclusion

Sediments from five (5) different coastal areas in Lagos were evaluated for trace potentially toxic metals load and the associated ecological risk. The areas were Langbasa, Itumaro, Ibeshe, Epe and Badagry. The decreasing order of concentration of the metals analysed in sediments investigated was Ca > Fe > Mg > Cu > Zn > Pb with the

pH in the acidic region (4.7 - 6.4). The P_i , P_c , and I_{geo} put only copper in Badagry and Ibeshe into moderate contamination while the remaining study area had low contamination. The monomial ecological potential risk for all the trace potentially toxic metals investigated (lead, iron, zinc and copper) in the study area revealed low potential risk (<40). The overall ecological risk for the five investigated sites also showed low potential risk, (<110). The order of deterioration (potential risk) in five sites in the study area is Badagry $>$ Ibeshe $>$ Epe $>$ Itumaro $>$ Langbasa. All the sediments quality guidelines applied point generally at the study area as relatively non-polluted and reflection of low anthropogenic activities. Continuous monitoring is important to ensure health safety and sustainable environment in line with goals six (6) and eleven (11) of sustainable development goals (SDG)

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

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