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Environmental and Ecological Risk Assessment of Heavy Metal in Dredged Sediments in Lagos, Nigeria: An index Approach Analyses

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Abstract:

Introduction: Bio magnification and accumulation of trace heavy metals in the environment has been worrisome, causing gradual but high level of environmental degradation, particularly as a result of its non-degradable nature. Therefore, the need to monitor the trace metal loads in the environment.

Aims: The present study investigated the distribution of Heavy metals (Cadmium, Copper, Zinc, lead and Nickel) and potential ecological risk associated in surface sediments samples from six coastal communities (Ajah, Imore, Ilado, Ajindo, Ojo and Gbelejo) in Lagos, Nigeria

Materials and Methods: Composite samples were collected from ten (10) different locations in each of the communities and analysed of heavy metals using employing Atomic Absorption Spectrophotometer (AAS). The interim Sediment Quality Guidelines (ISQG) was applied to characterize the dredged sediments and assessment of the potential ecological risk on the environment through multivariate quality indices such as pollution index (Pi), pollution classification (Pc), geo accumulation index (I geo) and potential ecological risk index (RI) was also carried.

Results: The concentration of zinc was observed higher in the sediments from commercially dredge areas (Ajah and Imore). The results obtained classified entire study area as polluted with respect of Pb and Ni, and as contaminated with respect to other trace heavy metals (Cd, Cu, and Zn) investigated. The ecological risk for the six study areas revealed moderate potential risk ($110 \leq RI < 200$), except Imore and Gbelejo which showed low potential risk ($RI < 110$).

Conclusion: Though the present levels of Pb and Ni in the study area is becoming noticeable, but the overall ecological risk for the entire study areas still fall within moderate potential risk. Hence, the need for regular monitoring by the relevant agencies to ensure safety of lives and sustainable environment.

Keywords: Ecological Risk Index, Dredged Sediment, Interim Sediment Quality Guidelines, Heavy Metals

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1. INTRODUCTION

Lagos, Nigeria is a maritime hub [1]. The state is made up of over seventy five percent (75%) coastal communities and serves as economic base for Nigeria, the most populous black nation in the world.

Estuarine in coastal areas have long been recognized as being of both ecological and economic importance [2]. Sediment in the estuarine area are constantly under the dynamic influence of multiple anthropogenic, or and naturally occurring stress induced factors originating from various sources such as agricultural, urban runoff, municipal sewage, industrial effluents and waste water and sometimes oil spillage [3,4].
Dredging and excavation are the two common methods of removing sediments from a water body. Both methods involve moving sediment removed to a new transits location either for treatment, or and disposal. Sediment is regularly dredged by US Army Corps of Engineer thereby maintaining navigation channels for the purpose of recreation, national defence and commercial purposes [5]. Environmental dredging is also gaining momentum in developed countries, in which sediment is removed for the sole purpose of cleaning up the water body. Environmental dredging is intended to remove sediment contaminated above certain action levels, while minimizing the spread of contaminants to the surrounding environment during dredging [5].
Sutherland and Tolosa [4] reported the three factors that influence the magnitude and distribution of resuspended sediment in the near-field water column: (a) the physical properties of the sediments being dredged (quantified by grain size and distribution and specific gravity relative to the overlying waters); (b) the condition of the in situ sediments as reflected by in situ bulk density, void ratio, and other similar physical measurements; and (c) the physicochemical characteristics of the sediment or the overlying waters (e.g., salinity), which might affect the cohesiveness and consequently the flocculation and settling of sediment particles.
Dredging of sediment is now very rampant in Lagos, especially in the coastal area either for ecological and economic purposes. The dredging operations include the locals who deal in surface sediment and not too deep-water body using canoe and locally fabricated tools (shovel, basket), as well as the commercial licensed dredging companies that explore bottom sediment from deep water bodies. The dredged materials are transported to a transit station, from where it is disposed.
Sediment is the sink of various contaminants in a water body, including organic chemical, heavy and trace metals [6]. Heavy metals contamination remains a major environmental problem, particularly due to its non- biodegradability, its toxicity, multiple sources in the environment and its accumulative tendency. Heavy metal distribution in the marine sediments is influenced by texture, clay-minerals, organic matter, oxides, oxyhydroxides of iron and manganese and calcium carbonate [7].
The sediments have capacity to hold and release the adsorbed metals when the chemical conditions change, particularly the pH, thereby leading to secondary metal pollution [8]. Sediment therefore could be a potential source of trace and heavy metals that originate from natural and anthropogenic processes and could have an adverse effect on the drinking water quality and human health. Although, Spatial distribution of heavy metals and other pollutant in sediment have been reported [9], which vary with time and site, metals such as copper, lead, mercury, or zinc and organic compounds such as pesticides, PCBs, and PAHs are the major contaminant constituents [10]. The use of sediments quality guidelines (SQG) to evaluate the potential adverse effect of pollutants in the sediment in the environment, among other things are well documented [11, 12].
This study was therefore designed to (i) determine the level of trace and heavy metals in dredged sediments in various part of coastal area of Lags state. (ii) apply Sediment Quality Guidelines (SQG) to characterize the dredged sediments and (iii) conduct the ecological risk assessment on the environment. The data generated will obviously aid the environmental managers and relevant agency in ensuring sustainability of the coastal areas of the state.

2. MATERIAL AND METHODS

2.1 Study area

Six coastal communities from five different Local Government Area Councils in Lagos states formed the study area. These communities are densely populated with fishing, dredging and water transportation as their major preoccupations. There are no serious industrial activities in these communities, so they are largely free from direct exposure to industrial effluent except probably the Gbelejo coastal community which bound (about 20km) eastern side of Apapa, an industrial hub. The detail of the study area is captured in Table 1.0.and Figure 1.0.

2.2 Samples and Sampling Technique

Ten (10) different composite samples were collected from dredged sediments in the study area: Ajah (AJH), Imore (IMR), Ojo (OJO), Ilado (ILD), Ajindo (AJD) and Gbelejo (GJO). Composite sediment samples were collected with the aid of improved core sampler stored in a transparent polythene bag, marked and transported to laboratory for further analyses.

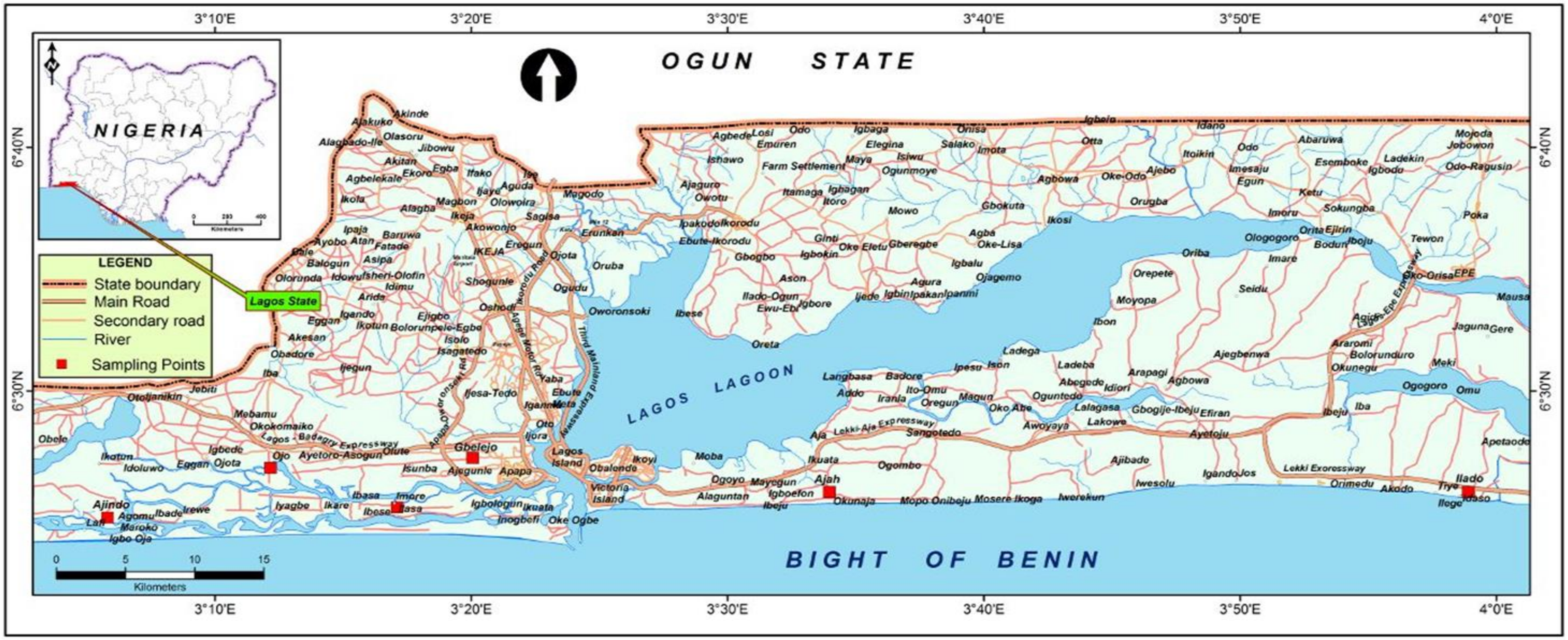

Fig. 1. Lagos State map showing the sampling locations

The stainless auger was cleaned thoroughly in between sampling to avoid possible cross contamination.

Table 1. Details of sampling locations in coastal communities in Lagos

S/N	Study Area	Local Govt. Area	GPS	Types of dredging activities
1	Ajah	Lekki	$6^0$25'51"N $3^0$33' 8"E	Commercial
2	Imore	Amuwo odofin	$6^0$25' 13" N; $3^0$17' 06."E	Commercial
3	Ojo	Ojo	6^0 25'51" N; $3^0$33'56" E	Local
4	Ilado	Badagry	6^0 25'51" N; $3^0$58'54" E	Local
5	Ajindo	Badagry	6^0 24' 48" N; $3^0$05'48"E	Local
6	Gbelejo	Apapa	6^0 27'15"N; 3^0 20'03"E	Local

2.3 Sample Pretreatment and Analyses

The samples were air dried and pulverized into a uniform size using laboratory mill which was ensured clean in between each sample as a quality assurance measure. The pulverized sample were made to pass 2 mm mesh sieve and stored in acid washed dried polythene bottles with plastic screw cap prior to the analysis.

2.3.1 Determination of pH

10.0 g of the sieved sediment samples was weighed into a 250 ml beaker and 10 ml of distilled water was added. The mixture was vigorously shaken and allowed to stand for 1 hour. A blot dried pH meter (Mettler Toledo IP67 model) that has been pre-calibrated with buffer solutions of 4, 7 and 9, was dipped into the mixture and pH value was taken [13,14].

2.3.2 Heavy Metal Analysis in Sediment Samples

A mixture of 36 ml HNO3, 12 ml 50% HF and 2 ml HCl (Analar grade) was added into 250 ml round bottom flask containing 10.0 g sediment sample. It was refluxed for 2 hours until no brown fumes were given off by the sample [2]. The sample was washed, rinsed with double distilled water, filtered using Whatman No. 1 filter paper and the filtrate made up in 100 ml standard volumetric flask. Heavy metal determination was done with Atomic Absorption Spectrometer (Pye Unicam Philips Model 900 X).

Calibration curve was prepared with standard solution of pure metals of concentration ranging from 0.0 – 40.0 mg/L at 5.0 mg/L increment. Duplicate determinations were carried out for each of the samples to test for the reproducibility of the method. Blank sample was also analysed to correct any variation that may result from purity of the reagents used for digestion.

2.4 Data Analyses

Descriptive analyses of data generated were carried out using Graph Pad Prism (version 5.00). Correlation coefficient was performed in a pair wise fashion employing Pearson correlation coefficient. The data were subjected to various multivariate indices which include pollution index (Pi) and pollution classification (Pc). The data were also used in determining the Geo-accumulation Index and Potential Ecological Risk Index of the metals in the environment.

2.4.1 Pollution Index (P_i)

Pollution index is a degree of soil pollution of soil with reference to a specific metal, and it has been used to assess urban soil pollution. Liu et al., [15] obtained P_i as a ratio of metal concentration in a contaminated soil sample and its concentration in control sample. However, Diatta et al., [16] obtained P_i as a ratio of the metal concentration in a contaminated soil sample and the local Maximum Allowable Limit (MAL) values of the metal. Values considered as MAL of heavy metals vary from place to place and depend on local background values [17]. Pollution index had also been calculated as ratio of metal concentration in sample to background concentration [18].

$$P_i = C^i_n / C^i_b$$

Where:

C^i_n is the concentration of the ith soil pollutant, and C^i_b is the relative metal concentration of pollutant in control sample or background value in mgkg-1.

2.4.2 Pollution Classification (P_c)

This helps to establish the distinction between soil contamination and soil pollution range. P_c Values above 1.0 depicts the pollution range, while those below 1.0 indicate the contamination range. Pollution index obtained can be used to compute P_c of an area using the formula of the Dutch system [18, 19]. Pollution classification (P_c) was calculated as reported by Chee et al., [19]:

$$Pc = \frac{C^i_n - C^i_b}{P_i}$$

Where:

C^i_n is the concentration of the ith soil pollutant, and C^i_b is the relative metal concentration of pollutant in control sample or background value in mgkg-1 and Pi is pollution index

2.4.3 Geo accumulation Index (Igeo)

The Igeo of heavy metals in the sediment helps in determining the extent of heavy metal accumulation in sediments, and it has been reported by various studies [20, 21, 14]. I_{geo} can be calculated through the mathematical relationship,

$$I_{geo} = \text{Log2} \frac{[C_{metal}\ \text{sample}]}{1.5\ [C^i_b]}$$

Where, C_{metal} sample, is the concentration of the heavy metal in the sediment samples. C^i_b is the geochemical background value or control sample value. The factor 1.5 is incorporated in the relationship to account for possible variations in the background or control which may be attributed to lithogenic variations in the soil [22]. The degree of metal pollution is assessed in terms of seven contaminant categories based on increasing value of the index as follow: I_{geo} = 0 means unpolluted; 0 < = I_{geo} < 1 means unpolluted to moderately polluted; 1< = I_{geo} < 2 means moderately polluted; 2 < = I_{geo} < 3 means moderately to strongly polluted; 3< = I_{geo} <4 means strongly polluted; 4< = I_{geo} < 5 means strongly to very strongly polluted and I_{geo} > =5 means very strongly polluted.

2.4.4 Potential Ecological Risk Index (RI)

The Potential Ecological Risk Index (RI) was originally introduced by Hakanson [23]to assess the degree of heavy metal pollution in soil, according to the toxicity of metals and the response of the environment. RI could evaluate ecological risk caused by toxic metals comprehensively. The calculating methods of RI are listed below:

$$F_i = C^i n / C^i o$$
$$E^i_r = T^i r \times F_i$$
$$RI = \sum_{i=1}^{n} E$$

where F_i is the single metal pollution index; $C^i n$ is the concentration of metal in the samples; $C^i o$ is the reference value for the metal; E^i_r is the monomial potential ecological risk factor; Tir is the metal toxic response factor according to [23]. The values for each element are in the order Zn = 1 < Cr = 2 < Cu = Ni = Pb = 5 < As = 10 < Cd = 30. RI is the potential ecological risk caused by the overall contamination. There are four categories of RI and five categories of Eir as shown in Table 2.0.

Table 2. Grades of single and overall Ecological Potential Risks

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

3. RESULTS AND DISCUSSION

The descriptive statistics of pH and heavy metals concentration in dredge sediments collected from study areas is presented in Table 3.0, while Figures 2.0 and 3.0 show the bar chats presentation of metals in commercial and local dredging areas respectively.

The pH is an important parameter that affect the mobility of metals in the aquatic environment.

The pH values observed for sediment samples analysed ranged between 7.4 - 8.2, 7.6 – 8.2, 7.6 – 8.1, 7.2 – 7.5, 7.6 – 8.0 and 7.7 -8.2 for Ajah, Imore, Ojo, Ilado, Ajindo and Gbelejo areas respectively.

The pH values observed was in alkaline region irrespective of the type of dredging (commercial or local). The pH appeared a function of mineralogy makeup of the ocean bed. A number of studies have reported variation of pH values in sediment [24,25].

The concentration of metals investigated in this study was compared to Canadian Council of Ministers of the Environment Guidelines for the Protection of Aquatic Life (CCME). CCME derives two guidelines; the lowest effect level, (LEL) or threshold effect level (TEL) of interim sediment quality guidelines (ISQG), which represent concentration of contaminants below which there is a very low probability of effects on the biota and the severe effect levels (SEL) or probable effect level (PEL) which represent concentrations above which there is a high (> 50%) probability of adverse effect on the biota.

Heavy metals distribution in the marine sediments is influenced by texture, clay-minerals, organic matter, oxides, oxyhydroxides of iron and manganese and calcium carbonate in the sediment [7].

Zinc and copper are essential metals but becomes toxic when present in excessive concentration. Zinc level in this study was higher in commercial dredging areas (Ajah and Imore) compared to local dredging areas.

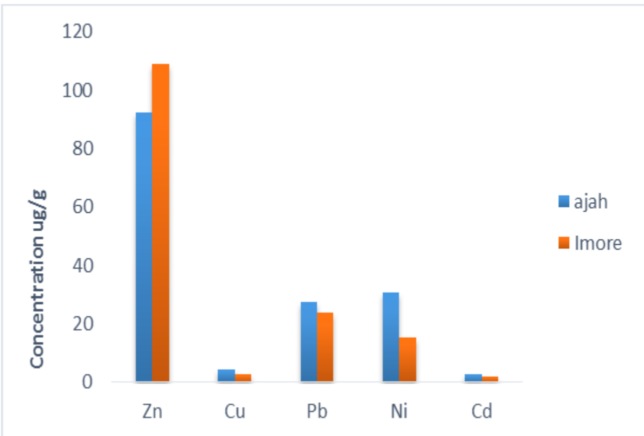

Fig. 2. Bar chart representation of commercially dredge sediment from Ajah and Imore areas

Table 3. Descriptive statistics of pH and heavy metals (µg/g) in sediment in coastal communities in Lagos

Site	pH			Zn			Cu			Pb			Ni			Cd		
	Mean ± SD	SEM	CV	Mean ±SD	SEM	CV	Mean ±SD	SEM	CV	Mean ± SD	SEM	CV	Mean ± SD	SEM	CV	Mean ± SD	SEM	CV
Ajah	7.74a ± 0.1	0.03	1.4	92.3a ± 34	11	38	4.24a±2.5	0.8	58	27.4a± 2.9	0.9	10	30.6a±1.8	0.6	60	2.87a±0.2	0.1	8.0
Imore	7.94b±0.1	0.01	0.7	109a±30	9.7	27	2.58a± 0.5	0.5	0.2	23.8b± 2.1	0.7	8.8	15.5b±1.4	0.5	9.2	1.89b±0.3	0.1	17
Ojo	7.93b ±0.08	0.03	1.0	35.4b ± 2.3	1.03	6.5	3.6b± 0.34	0.15	9.4	43.0c± 7.2	3.2	17	31.9a±2.9	1.3	9.1	2.62a± 0.3	0.03	1.0
Ilado	7.35c±0.1	0.08	1.5	39.5c± 0.2	0.15	0.4	5.05c± 0.6	0.4	11	32.3d± 11	7.9	35	41.5c±0.4	0.25	0.8	4.13c± 0.7	0.36	12
Ajindo	7.81d± 0.1	0.1	1.8	36.5d± 1.4	0.8	3.8	4.8d± 0.3	0.23	6.6	24.0b± 1.5	1.1	6.1	24.3d±2.5	1.8	10	3.45c± 0.6	0.45	18
Gbelejo	7.82d± 0.06	0.07	1.1	35.4d± 3.1	3.1	5.3	4.2a± 0.7	0.4	10	23.3b± 6.2	0.8	11	28.5a±2.2	0.7	13	4.8c± 0.3	0.5	11
BV				175.3			11.0			11.6			4.7			1.2		
CCME				120			16			31			16			0.6		
TEL																		
PEL				820			110			250			75			10		

BV – Background value same alphabet in each column indicates no significant difference

The possible sources of zinc in aquatic environment include industrial effluent discharges, run-off from agricultural fields, mineralogy of sea beds and the use of zinc nodules in ship building and repair. Zinc nodules are important materials employed in cathodic protection and coats painting of ships [12]. The concentrations of zinc observed in this study were below the limits of TEL and PEL values.

The order of levels of zinc across the study areas is Imore > Ajah > Ilado > Ajindo > Gbelejo > Ojo. They bio accumulate, bio magnify in the living tissues and are known to be non-degrading. Toxic metals generally interfere with functioning of metabolic reactions in living cells, thereby responsible for a number of disease condition [26, 27, 28] The mean concentration of Pb was found higher than the TEL value of 31.0 mg /Kg in both Ojo and Ilado areas only, while the nickel and cadmium concentrations observed was higher than the TEL value of 16 and 0.6mg/ Kg respectively in all the study areas but lower than the PEL limits. This suggests the need for regular monitoring because of the effect of bioaccumulation and magnification of metals in the environment.

The pollution index, pollution classification and geo accumulation index in the sediments analysed are shown in Table 4.0. The trend of variation of pollution index across the study areas are as follow; Cu < Zn < Pb < Cd < Ni for Ajah; Cu < Zn < Cd < Pb < Ni for Imore; Zn < Cu < Cd < Pb < Ni for Ojo and Zn < Cu < Pb < Cd < Ni for Ilado, Ajindo and Gbelejo.

while the order of copper level across the study areas follow Ilado > Ajindo > Ajah > gbelejo > Ojo > Imore.

The level of Cu observed in this study was below the limits of TEL and PEL of Canadian Council of Ministers of the Environment Guidelines for the Protection of Aquatic Life. Copper is essential for metabolic processes in living system. Lead, Nickel and Cadmium are toxic metals, even at low concentration. These toxic elements occur naturally in the environment and can be an end product of anthropogenic activities.

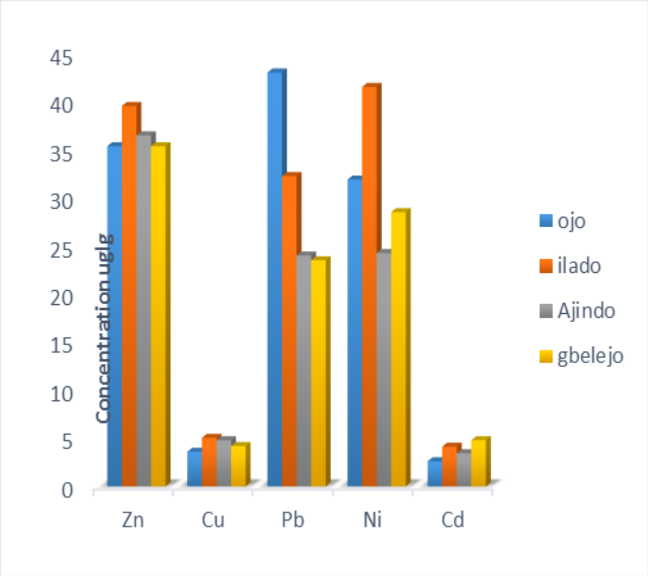

Fig. 3. Bar chart representation of locally dredge sediment from Ojo, Ilado, Ajindo and Gbelejo areas

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This suggests the need for regular monitoring because of the effect of bioaccumulation and magnification of metals in the environment.The pollution index, pollution classification and geo accumulation index in the sediments analysed are shown in Table 4.0.The trend of variation of pollution index across the study areas are as follow; Cu < Zn < Pb < Cd < Ni for Ajah; Cu < Zn < Cd < Pb < Ni for Imore; Zn < Cu < Cd < Pb < Ni for Ojo and Zn < Cu < Pb < Cd < Ni for Ilado, Ajindo and Gbelejo.

The entire study sites can be classified polluted in respect of Pd and Ni while in respect of other metals, the study areas can be classified as contaminated.

Table 4. Pollution Index and Pollution Classification and Geo Accumulation Index in sediment in coastal communities in Lagos

Site	Zn			Cu			Pb			Ni			Cd		
	P_i	P_c	I_{geo}	P_i	P_c	I_{geo}	P_i	P_c	I_{geo}	P_i	P_c	I_{geo}	P_i	P_c	I_{geo}
Ajah	0.53	-156	-1.5	0.34	-19.9	-1.9	2.36	6.70	0.68	6.51	3.98	2.11	2.39	0.70	0.67
Imore	0.62	-106	-1.2	0.23	-36.5	-2.4	2.05	5.95	0.49	3.30	3.27	1.14	1.58	0.43	0.07
Ojo	0.20	-635	-2.9	0.23	-32.1	-2.1	3.71	8.46	1.32	6.78	4.1	2.81	2.18	0.65	0.54
Ilado	0.22	-617	-2.7	0.32	-18.6	-1.7	2.78	7.45	0.89	8.83	4.17	2.59	3.41	0.86	1.19
Ajindo	0.21	-660	-2.9	0.43	-14.4	-1.7	2.07	6.00	0.49	5.17	3.79	1.79	2.88	0.78	0.93
Gbelejo	0.20	-699	-2.7	0.38	-17.9	-2.0	2.00	5.85	0.41	6.06	3.93	2.01	4.00	0.9	1.42

This reflects a very high level of Pb and Nickel in the areas investigated. Sources of nickel and lead in aquatic environment include urban run - off, industrial discharges and run off from agricultural fields as well as geological formation of an area. Leaching of metals from the surface coat of the ship and boat is another source of metals just as the oil waste and oil spill can also contribute greatly to the amount of Pb in the water body and sediments. These two metals (Pb and Ni) have been implicated in a number of diseases conditions, hence the need to continuously monitor the water environment.

The geo accumulation index (Igeo) reveal variations of pollution status in the study area with regards to the metals determined. The study areas varied from moderately polluted to strongly polluted in respect of nickel but only moderately polluted in respect of Pb. Ilado and Gbelejo areas showed moderate pollution in respect of Cd while others coastal areas investigated showed unpolluted status. The ecological potential risks of heavy metals in the sediment from the six study areas are presented in Table 5.0.

Table 5. Heavy Metal Ecological Potential Risk Indices in sediment in coastal communities, Lagos

Site	Monomial Ecological Risk For Metals					
	Zn	Cu	Pb	Ni	Cd	RI
Ajah	0.53	1.70	11.2	32.6	71.7	117.7
Imore	0.62	1.15	10.3	16.5	47.4	76.0
Ojo	0.20	1.15	18.6	33.9	65.4	119.3
Ilado	0.22	1.60	13.9	44.2	102.2	162.1
Ajindo	0.21	2.15	10.4	25.9	86.4	125.1
Gbelejo	0.20	1.90	10.0	30.3	42.6	85.0

The average monomial ecological potential risk for zinc, copper, lead and nickel in all the study areas posed low potential risk (<40) except nickel in Ilado which reveal a moderate ecological potential risk. However, the trend observed in the cadmium showed a potential ranging from moderate to considerable ecological potential risk.

The overall ecological risk for the six study areas revealed moderate potential risk, except Imore and Gbelejo which showed low potential risk (< 110).

4. CONCLUSION

The level of heavy metals in the dredge sediments from six coastal communities in Lagos and their associated ecological risk was investigated. The level of lead, nickel and cadmium observed in this study was higher than their respective background values indicating that the magnitude of these toxic elements in the study area is a cause of health concern. The entire study sites can be classified polluted in respect of Pd and Ni (Igeo >1) while in respect of other metals, the study areas can be classified as contaminated. The overall ecological risk for the six study areas revealed moderate potential risk (110 ≤ RI < 200), except Imore and Gbelejo which showed low potential risk (RI < 110). Measures must be set up the stakeholders in environmental management to prevent cross contamination of environment in the course of transferring the sediment to the initial transits stations, thereby ensuring sustainability.

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