Original Research Article

Geochemical and statistical approach to assessing trace metal accumulations in Lagos Lagoon sediments, South Western, Nigeria

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Abstract

The study areas is located in the Northern, central and the southern part of Lagos Lagoon, South western Nigeria, longitude 3° 22' 27.97" to 3° 28' 58.60"East and latitude 6° 27' 41.44" to 6° 35' 42.60" North. Sediment samples were collected from bottom sediments in twelve sampling stations, with the aid of van-veen grab during the wet-season period, from May to July 2014, on a monthly basis. Sediment samples were air dried and disaggregated, 70 grams each of sediment samples were oven dried for 8 hours, and its grain size fractions determined. The result of the grain size analysis range from; coarse to very fine sand, moderate to well sorted, finely skewed to mesokurtic, while the visually described major clay fractions range from; sandy, plastic, whitish brown clay to brownish, shaly, plastic clay with occasional silt. The bi-modal peaks on the particle size plots suggest multiple source of sediment contaminants in; Unilag waterfront, Ijora and Ibeshe, and a unimodal peaks; single source of contaminant to the sediments of; Atlascove, Apapa and Ikorodu. The sieved sediments were further leached with Nitric/Hydrochloric acid (1:3), aqua regia, using APHA method and its trace metal contents analysed with Argillent 200 A model, Atomic Absorption Spectrophotometer (AAS).The analysed concentrations in mg/kg showed; Ni(Nd-17.55), Mn, (12.50-1180.25), Pb(Nd-15.37), Zn(51.68-659.55), Cu(Nd-35.55) and Cr(Nd-53.00).The major element(Fe) used as the normalizer showed a concentration of 832.64-25206.00mg/kg.. Potential contamination benchmarks; contamination factor (CF), enrichment factor (EF), geoaccumulation factor (Lgeo) and pollution load index (PLI), were used to assess whether, the observed concentrations represent background or contaminated levels. The result affirmed the elevation of Zn, Pb and Mn and moderate contamination of zinc metals at; Iddo, Okobaba, Majidun and Ijora stations and the crustal influence in the deposition of; Cu, Cr and Ni. Multivariate statistical analysis employed also affirmed these potential contamination benchmarks. Based on the results it can be concluded that zinc metal represented a contaminated level, but, the overall toxicity level of the Lagos Lagoon sediments to the aquatic ecosystem is low.

Keywords: Lagos Lagoon, bottom sediment samples, grain size fractions, potential contamination benchmarks, multivariate statistical methods.

1 Introduction

The behaviour of metals in aquatic systems in coastal environment requires a serious attention due to the global anthropogenic alteration of trace metal cycles [1-2]. Aquatic animals are exposed to trace and heavy metals;. Most of these metals are toxic environmental pollutants, with well-identified adverse effect on aquatic ecosystems [3].These pollutants could be transferred to humans via ingestions, dermal contact or breathing [4].

The origin of metals that accumulate in sediments is partly from natural sources through the weathering of rocks and partly arising from a variety of human activities including; sand mining, smelting, electroplating, chemical manufacturing plants, as well as domestic discharges, shipping and boating activities, wood logging, saw dust input and marine debris. All these human induced effluents are predominant in Lagos Lagoon [5-8]. It had been established that; several anthropogenic induced activities may cause trace elements contaminations, many researchers have indicated the need for a better understanding of sediment status in coastal environments [9]. Hence, sediment analysis is a good proxy for the assessment of the "geochemical status" and "environmental quality" in such marine environment [10].

This paper presents trace/heavy metals' contaminations on selected stations in Lagos Lagoon sediments. The major objectives of this study are: assessment of the potential contamination and the identification of the different sources that contribute to trace element concentrations in bottom sediments of the selected stations in Lagos Lagoon. To evaluate the extent of trace metal contaminations and the degree to which trace metals are influenced by natural and anthropogenic factors in Lagos Lagoon. Identification of different causes of enrichment and trace metals associations in Lagos Lagoon via the application of multivariate statistics and lastly, to determine the variation in grain size distributions with trace metal concentrations across the selected stations in Lagos Lagoon.

2 Material and methods

2.1 Study area

The study areas are located Lagos, Southwestern Nigeria in between longitude 3° 22' 27.97" to 3° 28' 58.60"East and latitude 6° 27' 41.44" to 6° 35' 42.60" North. It traverses the south Eastern part of the Lagos Lagoon (Atlascove, Apapa stations), to the central part of the Lagoon and Northwestern part of the Lagos Lagoon (Ikorodu and Egbin stations figure1). Geologically, it falls within the eastern part of the Dahomey Basin, bounded to the north by then Precambrian Basement complex of southwestern Nigeria (figure2) [11].

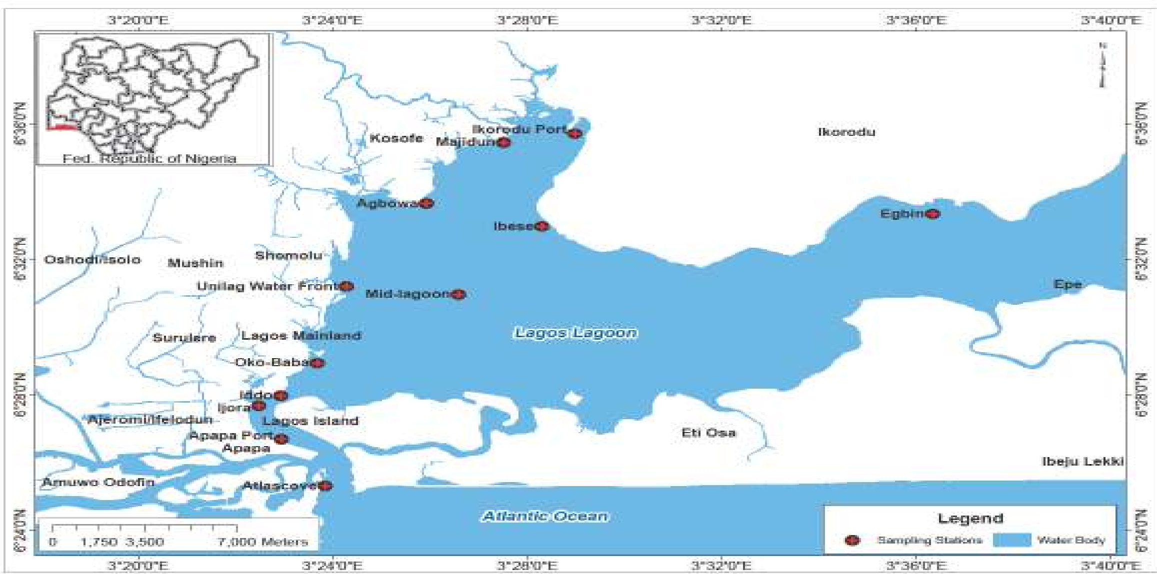

Figure1: Map of the study area showing the 12 stations

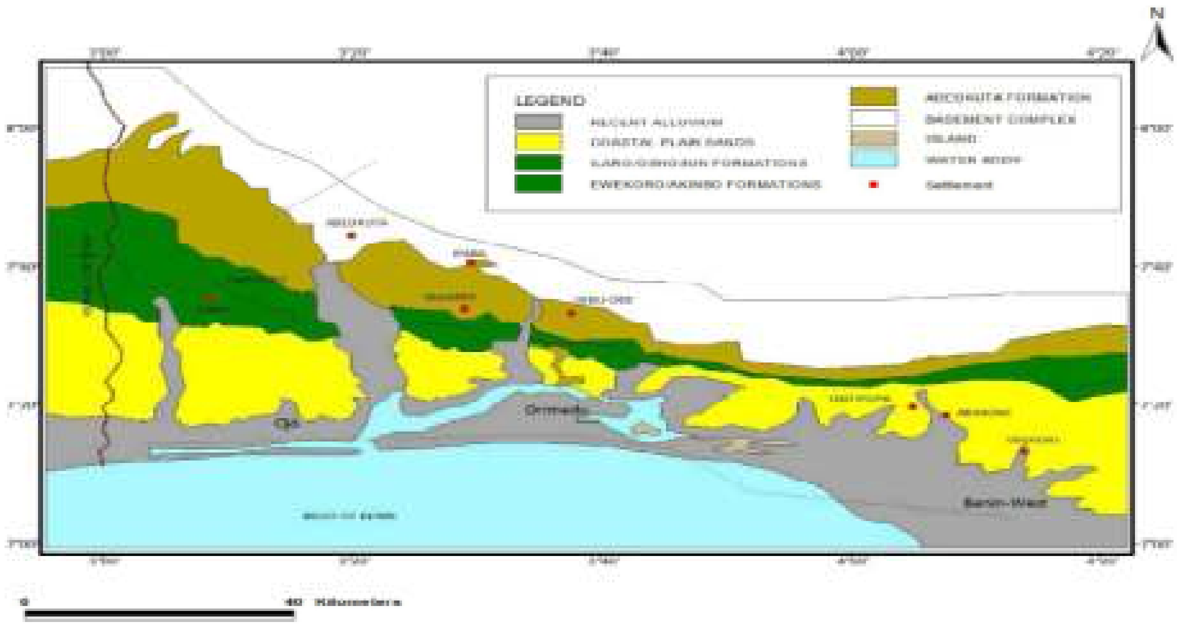

Figure2: Geological Map of the Eastern Dahomey Basin [12]

2.2 Data collection and analysis

All sampling equipments were washed with nitric acid 1N) before sampling. Sample containers were placed in clear plastic bags to minimize sediments cross-contamination. Before each sampling period, sample containers were labeled with the station name, date, time of collection, and the name of the sample collector and/or other information specified by the laboratory [13].Average shale concentration according was used as control [14]. Sediment samples were collected from twelve sampling stations with the aid of van-veen grab, from May to July 2014, on a monthly basis and kept in black polythene bags, air dried, disaggregated to remove large debris and shell fragments, pulverized in agate mortar. 70 grams of each sample was oven dried at 50ºC for 8 hours in order to remove its moisture content. The dried and weighed sediments were transferred carefully to the uppermost (coarsest) of a stacked series of graded sand sieves, sieves were gently brushed of all material from the container. A 62 µm sieve was placed at the bottom of the stack of sieves and care was taken by using a pan below the finest sieve to catch the last of any fine material which may still pass. The stacked column of sieves was now transferred to a Rotap sieve shaker for a period 10-15minutes. When the finality of sieving was checked, the fraction of samples retained on each sieve was emptied on to a sheet of glazed paper and grains lodged in the sieve were removed with a sieve brush. The fractions were then transferred to a pre weighed dish for weighing. The analysis continues sieve by sieve through the series until, finally, the material passing through the last (62 μm) sieve and retained in the pan was also recorded. The sieved sediments were leached with Nitric/Hydrochloric acid (1:3), aqua regia using standard digestion procedure [11]. Trace metal contents were analysed with Argillent 200A model, Atomic Absorption Spectrophotometer (AAS). QA and QC were assessed using duplicates, method blanks and standard reference materials according to EPA standard

3 Results and Discussion

3.1 Sediment transportation patterns

The statistical parameters of grain size distribution have been a major parameter in delineating depositional processes [15]. The mean value is a reflection of the competence of the mechanism of transportation. The result of the granulometric analysis of representative samples from the bottom sediment of Lagos Lagoon is presented in the appendix. The cumulative curve and individual particle size of each sample from which grain size parameters were calculated(figure 8-13). The sediment distributions of ; Unilag water front, Atlas cove, Ijora, Ikorodu port, Apapa port and Ibeshe stations range; from coarse to very fine sand, moderate to well sorted, finely skewed with mesokurtic(appendix). The mean, which is a reflection of the overall size of the sediment, has values ranging from (0.02 to 2.00 mm) which represents coarse grained – very fine sand (see appendix). The bottom sediments of Ibeshe and Ijora are majorly very fine grained-fine grained sand; these attributes attracted incessant sand mining in the area. However, other sediment samples from the central part of the Lagos Lagoon (mid Lagoon), Agboyin, Majidun, Iddo, Egbin and Okobaba range from; sandy, plastic, whitish brown clay to brownish, shaly, plastic clay with occasional silt. A graph of cumulative weight percent against sieve size was plotted on the grain size results. And from the cumulative frequency curve obtained, grain size parameters such as; average size (mean), spread of the sizes about the average (standard deviation) symmetry of preferential spread to one size of the average (skewness) and kurtosis or degree of concentration of the grains to the central size were determined with matlab applications. Pearson correlation analysis (table1-3), Principal Component Analysis (PCA, table4), and Cluster Analysis (CA, fig 15) were carried out using; matlab, Microsoft excel descriptive tools and software statistical 7, to identify the association of metals and geochemical parameters [16-17]

3.2 Trace/heavy metals geochemistry

The concentration in mg/kg of some trace metals in the Lagos Lagoon sediments showed Ni concentration from Nd-17.55, Mn from 12.50-1180.25, Pb (Nd-15.37), Zn (51.68-659.55), Cu range(Nd-35.55) and Cr(Nd-53.00). Comparing the observed concentration with the Average Shale Concentration (ASC) as proposed by [14,18], Zn, Pb and Mn, were observed to contain elevated concentration in reference to the average shale concentration(ASC) in the Lagos Lagoon(figure3-4), in stations such as: Iddo, Okobaba, Majidun, Ijora, and Egbin; an indication of human-induced effluents accumulations. These accumulations might not be unconnected with; population increase, commercial centers and industrial activities known for the generation of huge volume of liquid and solid wastes' sink to the adjourning sediments in Lagos Lagoon. This is in agreement with the work of [19] on sediment quality ratios of six industrial sites in Lagos metropolis that eventually drain into the Lagos Lagoon. Metals such as Cu, Cr and Ni were observed to have elevated concentrations relative to their corresponding ASC at stations such as; Ijora, Majidun, Iddo, Agboyin, Okobaba, Egbin and the central part of the lagoon. These might be connected to the binding nature of the dominant clay and colloidal particles in these stations; thereby making the trace metals to be non-bioavailable The average concentration of the trace elements in all the stations is in the descending order of: Mn >Zn >Cr >Cu >Pb > Ni(figure 4).

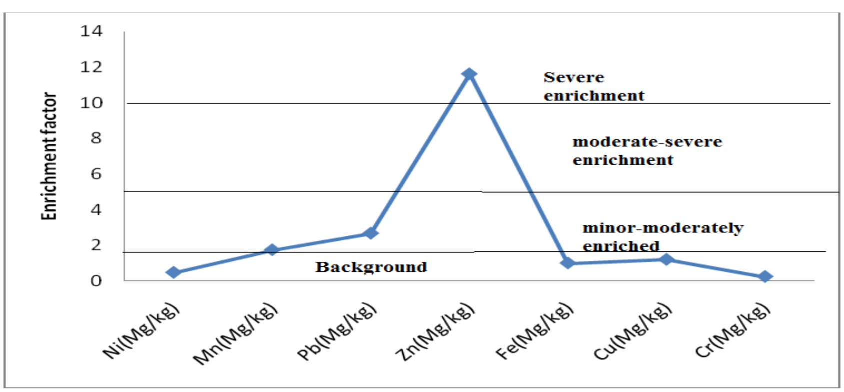

Figure 3: Trace metal enrichment showing zinc, manganese and Pb as enriched metals (anthropogenic source)

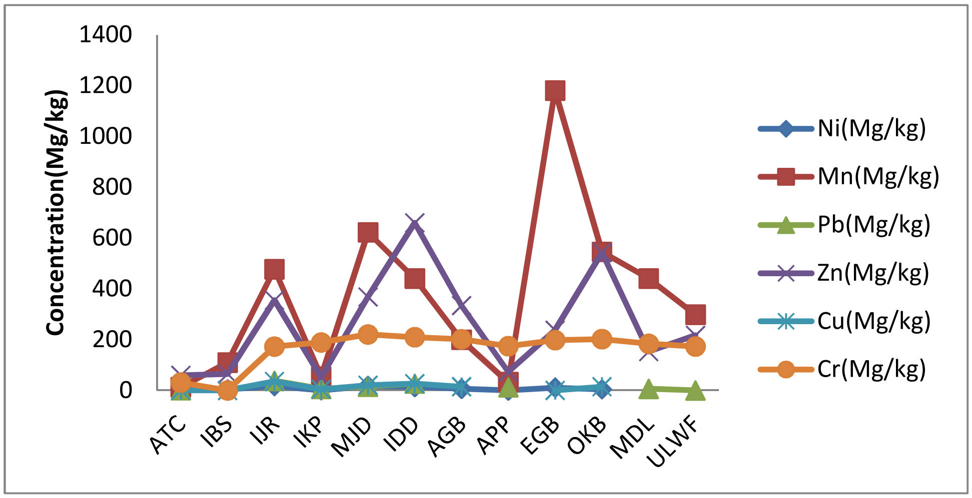

Figure 4: Showing the mean concentration of trace metals in the study area

3.3 Application of proxies in the assessment of Lagos Lagoon Sediments

Sediment analysis is a good proxy for the assessment of the "geochemical status" and "environmental quality" in such marine environment [10]. The quality and potential environmental implication(s) of trace metals were evaluated using contamination indices such as; contamination factor, geo-accumulation indices, pollution load indices and contamination degrees. These methods have been used successfully by various workers to determine the quality of various environmental media [9, 20-21].

3.3.1 Contamination Factor (CF) is calculated as the ratio between the sediment metal content at a given station and the normal concentration levels. Concentration factor, $CF = C / Cn$ (1) CF = contamination factor; C = mean concentration of each metal in the sediments; Cn=background value. The contamination factor modified by [20] showed the following classes: CF<1, low contamination, 1<CF<3, moderate contamination and 3<CF<6, considerable contamination. Zinc metal falls within the moderate contamination ratio (figure5).

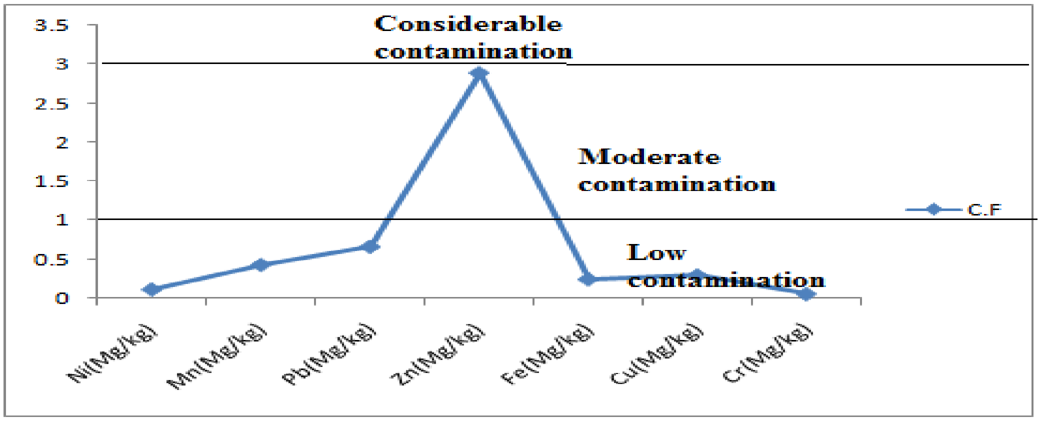

Figure 5: The contamination factor plot of the Lagos Lagoon sediments

3.3.2 Geoaccumulation Index (lgeo). The lgeo is used to understand the current environmental status and trace metal pollution extent with respect to natural environment. It is distinct from Enrichment factor(EF) because the factor 1.5 is introduced to include possible variations of the background values that are due to lithogenic variations [21]. The lgeo (equation2) classes are:

$$I_{geo} = \log_2\left(\frac{C_{HM}}{1.5 \times B_{HM}}\right) \qquad (2)$$

C_{HM} = concentration of metals, B_{HM} =background level of metals.

0 ≤lgeo≤1, unpolluted to moderately polluted, 1≤lgeo≤3, moderately to strongly polluted and 3≤lgeo≤5, strongly to very strongly polluted. The six metals examined all fall within the geochemical benchmarks for unpolluted to moderately polluted ratio, this affirmed that the pollution arising from trace metals/heavy metals have not undergone a progressive pollution state in all the stations (figure6).

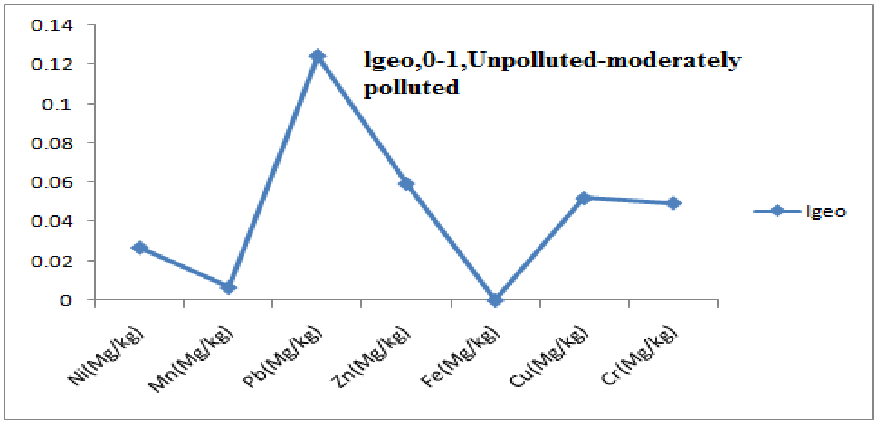

Figure 6: showing the geoaccumulation factor of the study area

3.3.3 Integrated Pollution indices. Degree of contamination (DC) and average pollution index (PLI) were utilized as the integrated pollution indices in the selected stations. According to [9, 20, 22], DC is calculated as; (equation3)

$$DC = \Sigma\, Cf \,. \qquad (3)$$

Cf= Contamination factor, Σ=summation

Summation of the contamination factors of the trace metals

DC values of ≤ 8, represent a low degree contamination, while, 8≤DC≤16, represent a moderate contamination (figure7).

3.3.4 Pollution Load Index(PLI). PLI assesses the overall sediments toxicity. A PLI ≤1, represent close to background concentration, while, PLI.>1, represent a progressive pollution. The degree of contamination values for the study area is lower than 8; while the pollution load index values is less than 1(figure7).This fall within a low degree of contamination and close to background value (non-bioavailable state).

$$PLI \qquad \sqrt[6]{cfNi * cfCr * cfMn * cfCu * cfZn * cfPb} \qquad (4)$$

CF = Contamination factor of each metals

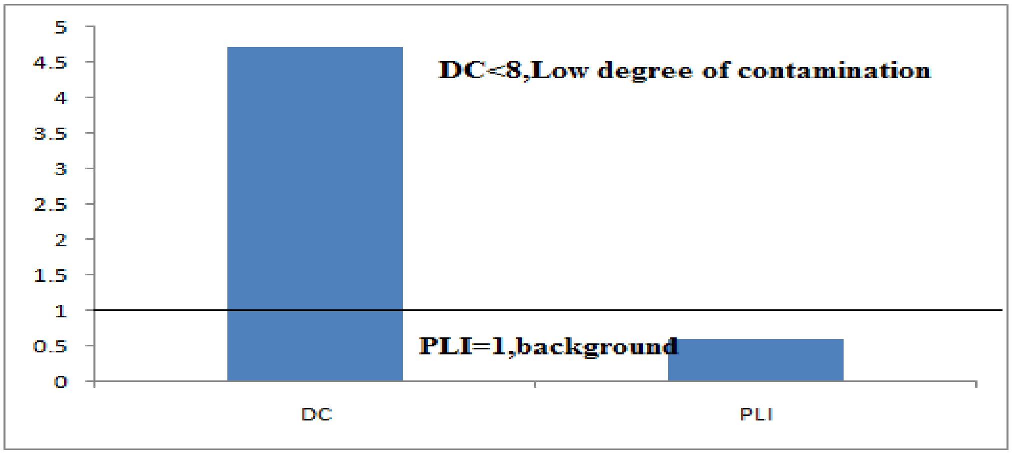

Fig7: Showing the pollution load index and degree of contamination

3.4 Multivariate statistical methods

A correlation matrix was used to understand the relationship among the metals. Principal component analysis was applied to transform the correlation matrix, with an aim of explaining the relationships between the different factors. The resulting factors were then rotated using varimax method, for deriving more significant information on the distribution of the weights of the variables on the factors [23]. The factors are presented as factor 1 (F1) and factor 2 (F2) for 12 sediment samples (figure14, table4). Hierarchical Cluster Analysis (HCA) was performed to create the data into groups, based on pattern and closeness.

3.4.1 Particle size plots

The plot of individual particle size against phi size for the various samples shows bi-modal peaks in bottom sediments of Unilag water front, Ijora and Ibeshe .This suggests multiple source of sediment contamination, however, the bottom sediments of Atlascove, Apapa and Ikorodu exhibited a uni-modal peaks an evidence of a single pollution source. The low trace metal concentration in the coarse sand texture of Apapa and Ikorodu Port, coupled with the medium sand texture at the Unilag water front and Atlascove sediments affirmed low affinity of coarse fractions with trace metals. However, the high concentration of Mn in Ibeshe station confirmed the great affinity of trace metals to fine sand fractions [24-25].

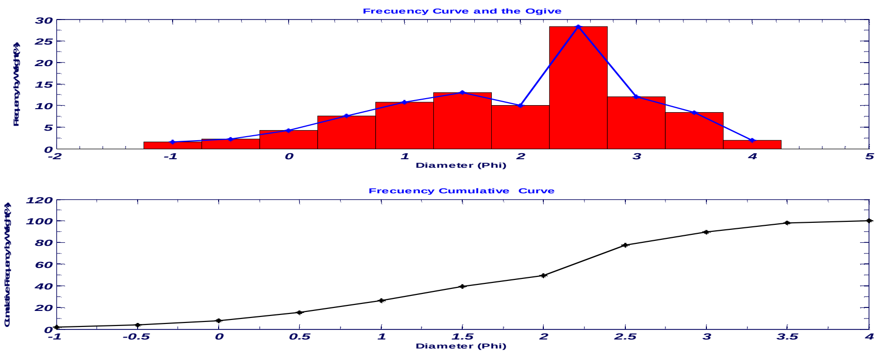

Fig8 : The plot of sediments particle size at UWF station against phi

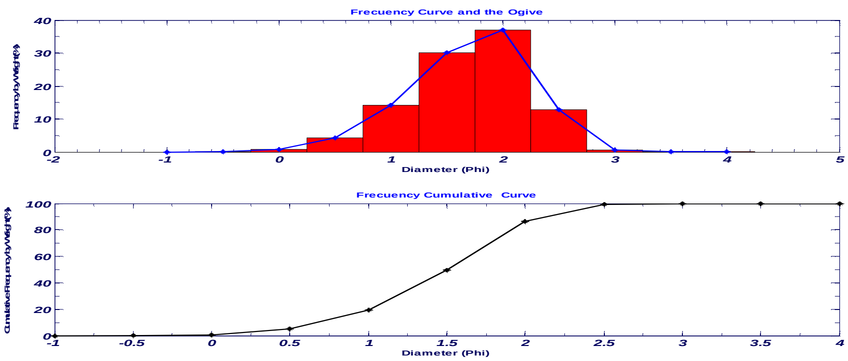

Fig9 : The plot of sediments particle size at ATC station against phi

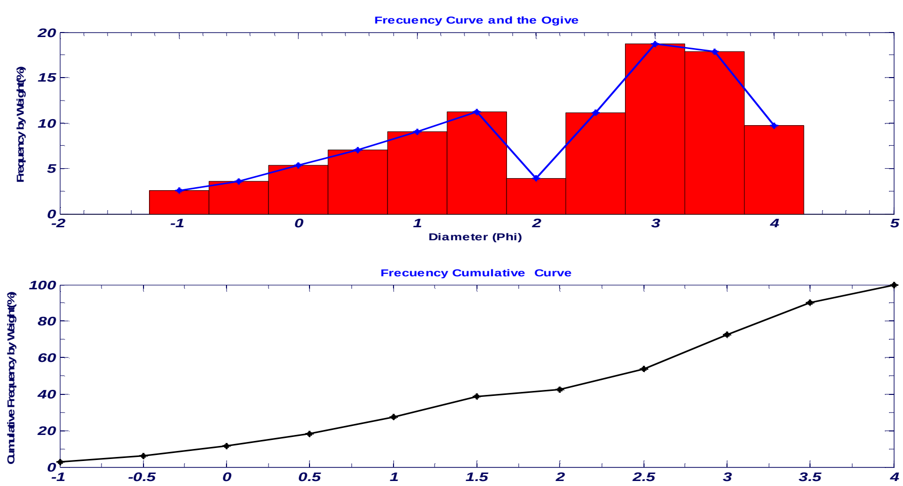

Fig10 : The plot of sediments particle size at IJR stations against phi

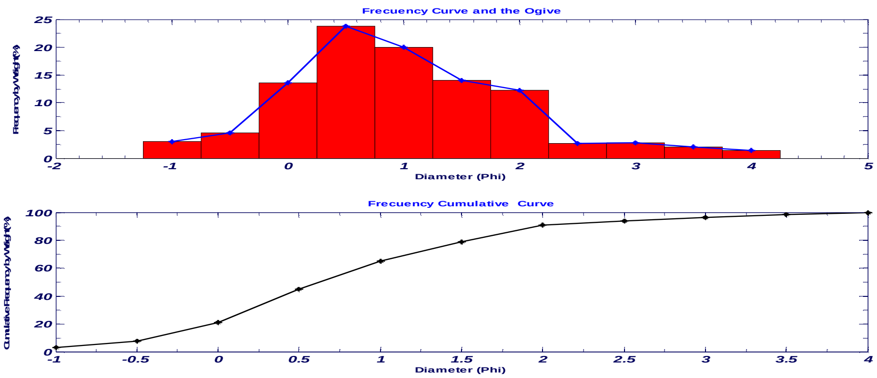

Fig11 : The plot of sediments particle size at IKP stations against phi

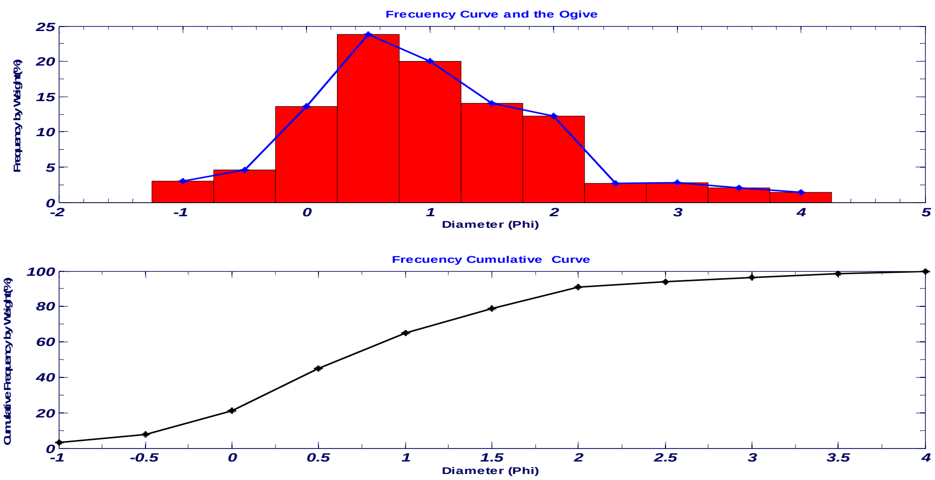

Fig12 : A: The plot of sediments particle size at APP stations against phi

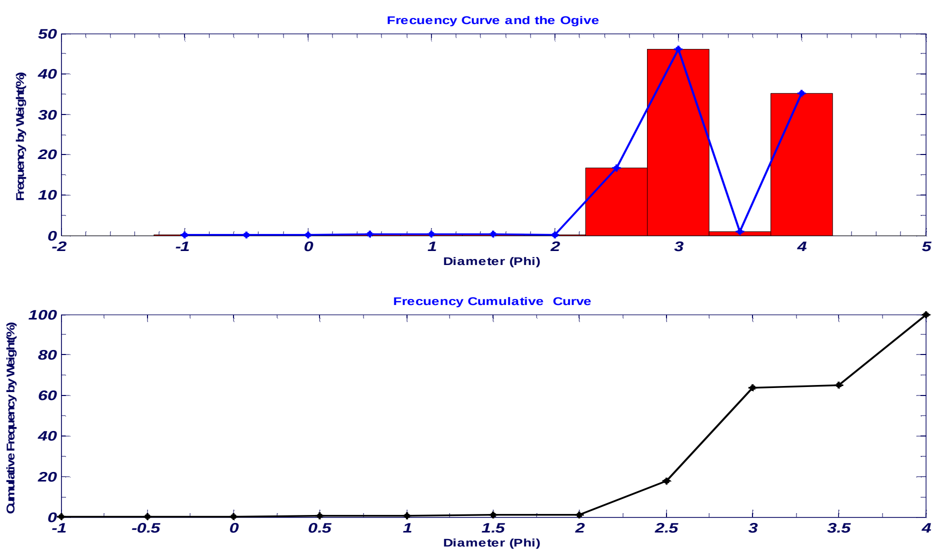

Fig 13:The plot of sediments particle size at IBS stations against phi

3.4.2 Pearson correlation analysis

All the metal pairs in the sediments exhibit positive relations and some of them were significant at the 95% confidence levels. The Pearson correlation coefficient shows the existence of similar geochemical association for these metals; Fe–Mn, Fe–Cr-Zn, Fe–Ni-Pb-Zn and Pb–Zn-Cu pairs. Pb and Zn are significantly positively correlated with each other, which may suggest a common pollution sources or a similar geochemical behaviour [26], this is also in agreement with the enrichment factor geochemical benchmarks of the Lagos Lagoon sediments [27]. Fe-Cr and Fe-Mn are significantly correlated(r=0.63, 0.88, P=0.06, 0.0001) table1-3; this may suggest a similar terrigenous source or a result of similar mechanisms of transport and accumulation within the sediments. They are Ferro-allied metals and are associated with mafic-ultramafic rock provenance [28]. However, Cr-Zn and Fe-Ni-Pb-Zn are none significantly correlated. Positive correlation between all metal studied with Fe confirmed that Fe has a higher affinity with most elements.

Table1 :Pearson Correlation coefficient result Table							
R	Ni	Mn	Pb	Zn	Fe	Cu	Cr
Ni	1						
Mn	0.4804	1					
Pb	0.6107	0.0891	1				
Zn	0.5484	0.4539	0.4266	1			
Fe	0.5489	0.884	0.2974	0.5229	1		
Cu	0.7651	0.2175	0.8038	0.755	0.4363	1	
Cr	0.1302	0.5021	0.2536	0.5603	0.6364	0.3878	1
Table 2 : Statistical Test at 5% significant figure (P-value)							
P-VAL	Ni	Mn	Pb	Zn	Fe	Cu	Cr
Ni	1						
Mn	0.1139	1					
Pb	0.0349	0.783	1				
Zn	0.0649	0.1383	0.1666	1			
Fe	0.0645	0.0001	0.3479	0.0811	1		
Cu	0.0037	0.497	0.0016	0.0045	0.1562	1	
Cr	0.6868	0.0962	0.4265	0.0581	0.0261	0.2129	1
Table3: Percentage of data utilized (R^2) IN PERCENTAGE							

R^2	Ni	Mn	Pb	Zn	Fe	Cu	Cr
Ni	1						
Mn	0.2308	1					
Pb	0.3729	0.0079	1				
Zn	0.3007	0.206	0.182	1			
Fe	0.3013	0.7815	0.0884	0.2734	1		
Cu	0.5855	0.0473	0.6461	0.5701	0.1904	1	
Cr	0.0169	0.2521	0.0643	0.3139	0.405	0.1504	1

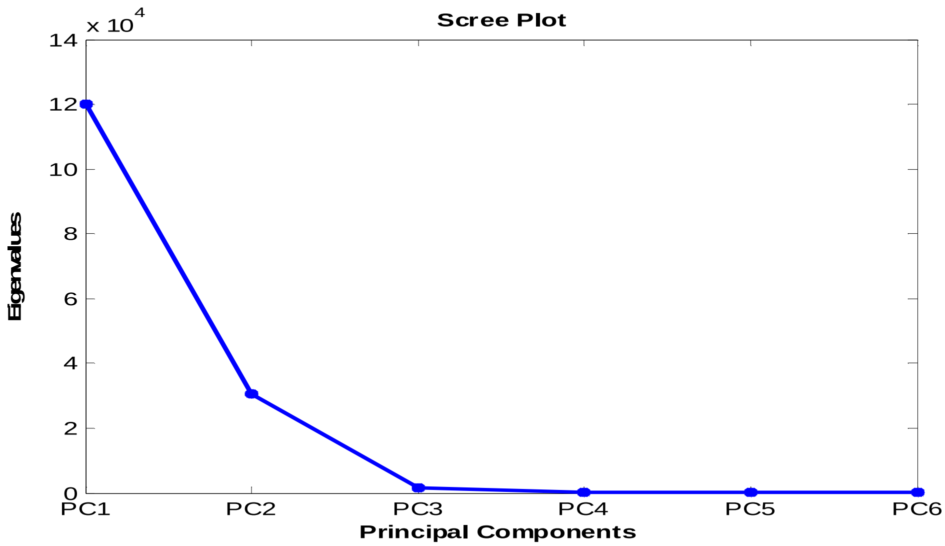

Figure 14: Scree plot for the principal component1 and 2 loading

Table4: Summary of Principal component analysis of some trace metals in Lagos Lagoon sediments

	PC1	PC2
Ni	0.009	0.01
Mn	**0.94**	-0.33
Pb	0.005	0.031
Zn	0.33	**0.937**
Cu	0.003	0.043
Cr	0.08	0.093
Eigen value	12.01	3.063
% variance	78.71	20.07
Cumulative %	78.71	98.77

Bold values: loadings > 0.5

3.4.3 Principal component analysis

The statistical analysis revealed that the trace metals can be grouped into two identities PC1 and PC2 (figure 14, table4). All the % variance that are less than 20% were eliminated (see appendix). The first group identity is Zn and this account for 79% of the total variance of the variables with Eigen value of 12.05. This metal is believed to be majorly contributed from anthropogenic source (industrial effluents from electroplating, paints, fertilizers, vehicular emissions and others); the enrichment factor, contamination factor and Pearson correlation relationship corroborate this (figure 3-6).The second identity Mn account for approximately 21% of the total variance with an Eigen value of 3.06. Mn is believed to have been contributed to the sediments of the Lagos Lagoon from washed down automobile aerosols, worn-out vulcanized products such as tyres, brake linings as well as expended paints and paint products. It is used as additives and alloys in chemical and metallurgical industries and is believed to have been contributed to the sediments from the leaching of industrial, chemical and domestic wastes. This is also in agreement with the enrichment factor, contamination factor and Pearson correlation relationship.

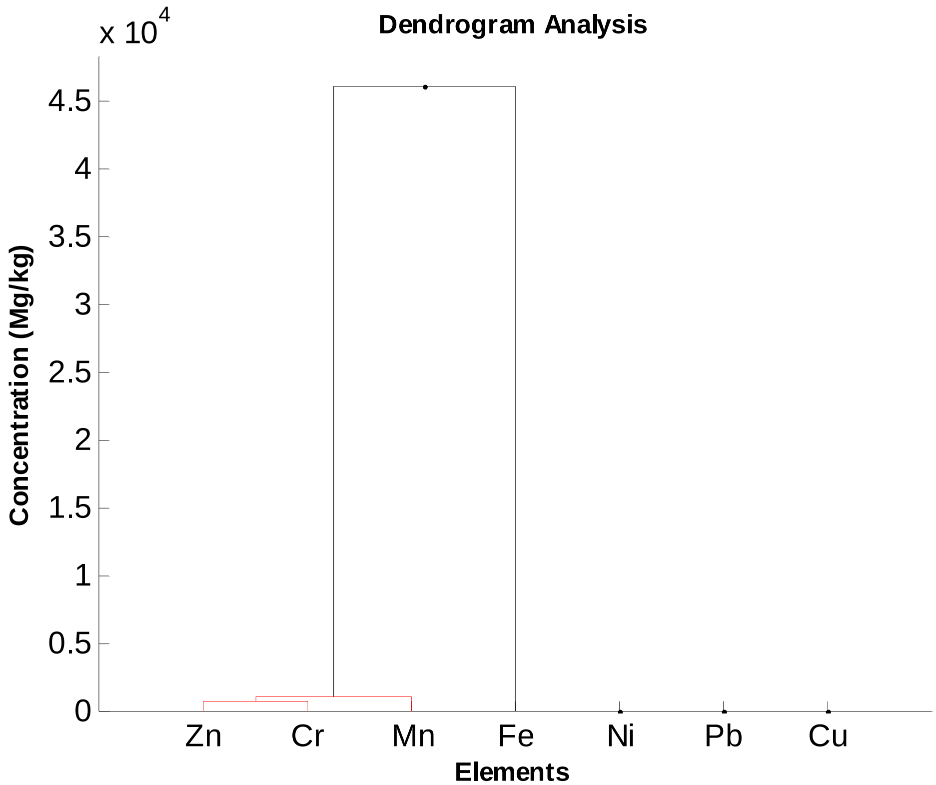

Figure 15: Cluster Relationship of the Metals

3.4.4 Hierarchical Cluster Analysis (HCA)

This is the most important cluster analysis method most commonly used for environmental analysis. It identifies groups of samples according to their similarities. The results obtained were presented in a two-dimensional plot called dendrogram using Matlab R2009b software. The dendrogram based on the linear pair coefficient of correlation between the variables indicate different clusters for the bottom sediments of Lagos Lagoon (Fig.15). Three groups were distinguished in the dendrogram, performed using the Ward method, which used the squared Euclidean distance as a similarity measure. The domination of Zn, Cr, Mn with Fe indicates their association with the Fe oxides. These corroborate the significant geochemical relationship as described in the Pearson correlation analysis (table 1-3).

4 CONCLUSION

The study highlights the; importance of environmental quality evaluation and trace metals' contamination in sediments, spatial variations in elemental distributions, iron utilization in trace metals' nominalizations, vis-à-vis background levels and human-induced metal enrichment. Trace metal distributions in Lagos Lagoon sediments have been affected by various factors, such as; marine debris, industrial and domestic effluents discharges, human-induced/anthropogenic effluents. These are in agreement with past researchers in the selected stations (appendix).Moreover, it was observed that; Zn, Mn and Pb distributions are significantly enriched from anthropogenic source, mostly prevalent at; Ijora, Iddo, Okobaba, Majidun and Egbin sediments. These enrichments might not be unconnected to the prevalent, domestic and industrial effluents from the adjourning communities around the stations. On the basis of the calculated contamination risk assessment; it was adduced that the analysed sediments of the Lagos Lagoon stations are; unpolluted to moderately polluted by trace metals (Pb, ,Zn, Cu Cr, Ni, Mn and Fe),moderately contaminated by Zn (especially at Ijora, Iddo, Okobaba, Majidun and Egbin stations). Nonetheless, the integrated toxicity assessment of the study area (PLI and DC) falls within background geochemical benchmarks, therefore exhibited a synthetic low toxic effect on the aquatic ecosystem.

The pearson correlation coefficient exhibit positive relations in all the metals, the trace metals geochemical associations suggest a similar; terrigenous source or mechanisms of transport and accumulations within the sediments. Hierarchical Cluster Analysis (HCA), Pearson correlation analysis and the Principal component analysis all corroborate; zinc and manganese as an anthropogenically enriched metals and, Ni, Fe and Cu background status in the Lagos Lagoon sediments.Cr however,exhibit a mix source of deposition in the Lagos Lagoon sediments.

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Sampling stations and its associated anthropogenic activities [5}

Station Number /Name	Latitude	Longitude	Anthropogenic activities	Full name
1 ATC	6° 25' 19.063"	3° 23' 51.93"	Accidental petroleum discharge, dredging Oil and Grease, lead combustion	Atlascove
2 APP	6° 26' 43.03"	3° 22' 57.18"	Dredging(oil and Grease, spillages, ship garbage.	Apapa Port
3 IJR	6° 27' 41.44"	3° 22' 27.97"	Residential, sewage and industrial effluents, oil and grease.	Ijora
4 IDD	6° 27' 58.96"	3° 22' 56.45"	Domestic sewage discharges,(Bio degradable organic matter.	Iddo
5 OKB	6° 28' 57.37"	3° 23' 40.98"	Wood logging, saw dust input (Biodegradable organic matter.	Okobaba
6 UWF	6° 31' 11.72"	3° 24' 16.76"	Marine debris.	University of Lagos waterfront
7 MDL	6° 30' 57.12	3° 26' 34.03"	Recent residential effluents accumulation.	Middle/central Lagoon
8 AGB	6° 33'	3° 25'	Local dredging	Agboyin

	39.211"	55.333"		
9 MJD	6° 35' 26.54"	3° 27' 29.52"	Local dredging, dumpsite/residential discharges.	Majidun
10 IKP	6° 35' 42.60"	3° 28' 58.60"	Industrial effluents	Ikorodu Port
11 IBS	6° 32' 58.32"	3° 28' 17.71"	Dredging	Ibeshe
12 EGB	6° 33' 20.96"	3° 36' 19.60"	Thermal pollution, Elevated water temperature.	Egbin

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Station		Description
UNILAG	Medium sand(0,02-2.0)	Medium sand Poorly sorted Strongly fine skewed Mesokurtic
ATLASCOVE	Medium sand(0,02-2.0)	Medium sand Moderately well sorted Fine skewed Mesokurtic
IJORA	Fine sand(0,02-0.2mm)	Fine sand Poorly sorted Strongly skewed Platykurtic
IKORODU PORT	Intertidal environment Coarse sand(0.2-2.0mm)	Coarse sand Moderately sorted Coarse skewed Mesokurtic

APAPA PORT	Coarse sand(0.2-2.0mm)	Coarse sand Moderately sorted Near symmetrical Mesokurtic
IBESHE	Intertidal environment Silt(0.002-0.02mm (diameter)	Very fine sand Moderately well sorted Strongly coarse skewed Very platykurtic

Table1: Result of Granulometric analysis of Lagos Lagoon sediments

Station	Mean	Standard Dev	Skewness	Kurtosis	Description
UNILAG	1.76	1.11	0.33	0.98	Medium sand Poorly sorted Strongly fine skewed Mesokurtic
ATLASCOVE	1.46	0.51	0.17	1.02	Medium sand Moderately well sorted Fine skewed Mesokurtic
IJORA	2.01	1.39	0.38	0.81	Fine sand Poorly sorted Strongly fine skewed Platykurtic
IKORODU PORT	0.71	0.96	-0.19	1.09	Coarse sand Moderately sorted Coarse skewed Mesokurtic

APAPA PORT	0.58	0.93	0.008	0.93	Coarse sand Moderately sorted Near symmetrical Mesokurtic
IBESHE	3.05	0.63	-0.55	0.59	Very fine sand Moderately well sorted Strongly coarse skewed Very platykurtic

Principal Component Analysis of the sampling stations from which PC1 and PC2 was chosen

	PC1	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**
Ni	0.0099	0.0114	-0.0533	0.2509	0.0617	0.9645
Mn	0.9418	-0.3327	-0.0451	0.0133	-0.0065	-0.0113
Pb	0.0049	0.0306	0.0221	0.6591	0.7191	-0.2167
Zn	0.3258	0.9369	-0.1186	-0.0442	-0.0007	-0.0094
Cu	0.0034	0.0426	0.0983	0.7033	-0.6899	-0.1339
Cr	0.0824	0.0932	0.9854	-0.0761	0.0556	0.0687

Principal Component	Eigenvalue (Variance)	Percentage Variance Explained (%)	Cumulative Percentage Variance (%)
PC1	120115	78.7061	78.7061
PC2	30631	20.0712	98.7773
PC3	1586	1.0392	99.8165
PC4	213	0.1396	99.9561
PC5	57	0.0373	99.9934
PC6	10	0.0066	100