World Applied Sciences Journal 9 (2): 178-193, 2010
ISSN 1818-4952

Geochemical Evaluation of the Lagos Lagoon Sediments and Water

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Abstract: The Lagos lagoon is a depository of last resort for over 70% of the surface runoffs, drainage channels and important rivers flowing from interior Nigeria to the Atlantic Ocean. The surrounding densely populated and industrialized areas often result in the introduction of potential harmful materials into the Lagoon. This work is aimed at providing reference data for the quality assessment of the Lagoon. One hundred sediment samples obtained from the Lagoon were air dried at room temperature, disaggregated, sieved and digested using aqua-regia and subsequently analyzed with the ICP-OES for elemental composition. 30 water samples were also obtained and analyzed for their metal contents. The geochemical results showed that the order of abundance of the major oxides were Fe_2O_3>SO_4>Na_2O>Al_2O_3>CaO>MgO>K_2O>TiO_2. The concentration of the trace elements in ppm showed the following pattern of distribution: Cd (Bdl-3.7); Cu (3.0-231); Mn (64.0-1737); Mo (Bdl-28); Ni (3-49); Pb (2.0-146); Zn (9-366); As (Bdl-28); B (Bdl-27); Ba (9-167); Be (Bdl-3); Bi (Bdl-8); Co (Bdl-23); Cr (6-87); Ga (Bdl-15); La (7-87); Sb (Bdl-11); Sc (.9-11); Sr (4-192); Te (Bdl-6); Th (Bdl-10); Tl (Bdl-15); V (4-124);W (Bdl-8); Y (2-27) and Zr (1-30). The metal content of the lagoon water also revealed the following metal concentration range in ppm: Fe (4.20-43.67); B (0.08-0.41); Ni (Bdl-0.16); Cu (Bdl-0.016); Zn (0.02-0.118) and Pb (0.01-0.08). The geochemical evaluation of the metals contents of the sediments and water revealed that the metal loads of the media surpass their natural background while Pb, Cd, Bi, Tl, W, Cu and Zn are metals that are of significant environmental implications.

Key words: Lagos Lagoon · Nigeria · Harmful · Geochemical evaluation

INTRODUCTION

The continuous growth in human population and the attendant sophistication in the sort of commodities and materials consumed have led to the generation of substantial wastes of unprecedented quantities. The nature of wastes had moved from mere nuisance to being toxic and hazardous. The African continent continues to witness huge developmental strides in infrastructural and the industrial sector. These had led to the emergence and growth of new cities and mega cities as human population continue to pour into the cities in search of better opportunities in terms of jobs and quality of lives. These cities had emerged and grown without proper planning leading to haphazard development with attendant side effects such as indiscriminate construction of buildings, industries, disposal of households and industrial wastes as well as total lack of reliable data on the nature and quality of the various environmental media. These unwholesome situations had resulted in deplorable quality of water bodies, sediments, soils and vegetation, human and livestock lives. Several workers have undertaken research works into the links between the quality of the environment and the level as well as pattern of development [1-6]. One of the cities in the African continent that had witnessed such tremendous growth is the city of Lagos, the economic and former political capital of Nigeria. The city of Lagos is the most populous in Nigeria and is projected to be the fifth most populous in the world by 2015 [7]. The city also harbors over 75% of the industrial outfits within the country. These industries include textile industries, chemical and paint industries, breweries and bottling companies, metal industries, shipyards, plastic and petrochemical factories, paper mills and sawmills. In addition to these industries are recreational and tourist centers built around the lagoon front at several location in the metropolis. The dense huge population coupled with the industrialized nature of Lagos result in the generation of huge voume of wastes on a daily basis. These industries discharge untreated wastes into the several drainages and canals that litter the metropolis. The dumped wastes eventually find their way

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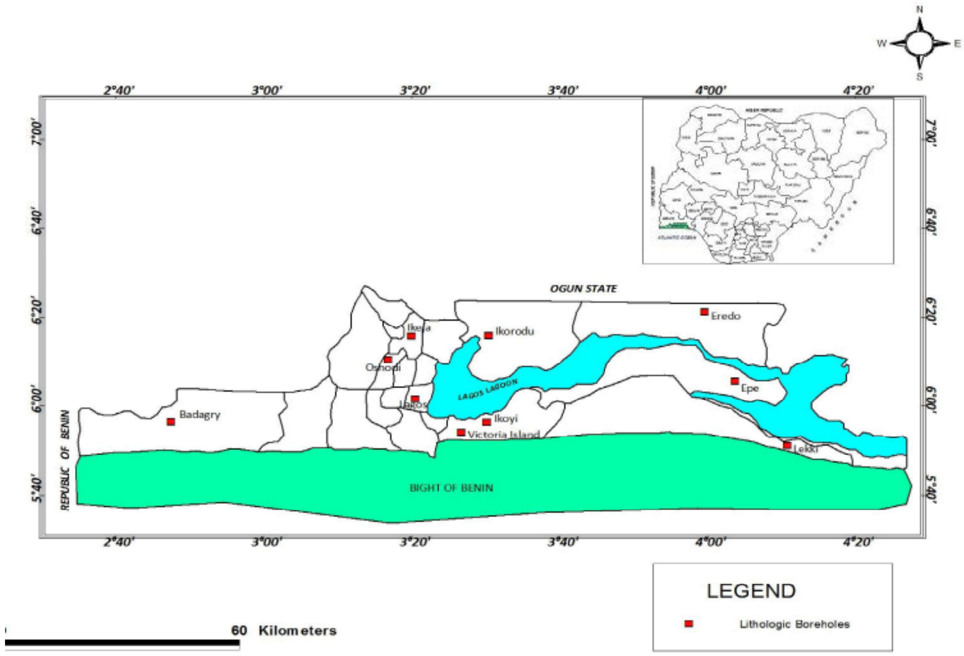

Fig. 1: Map of Lagos State showing the Lagos Lagoon and Borehole Locations

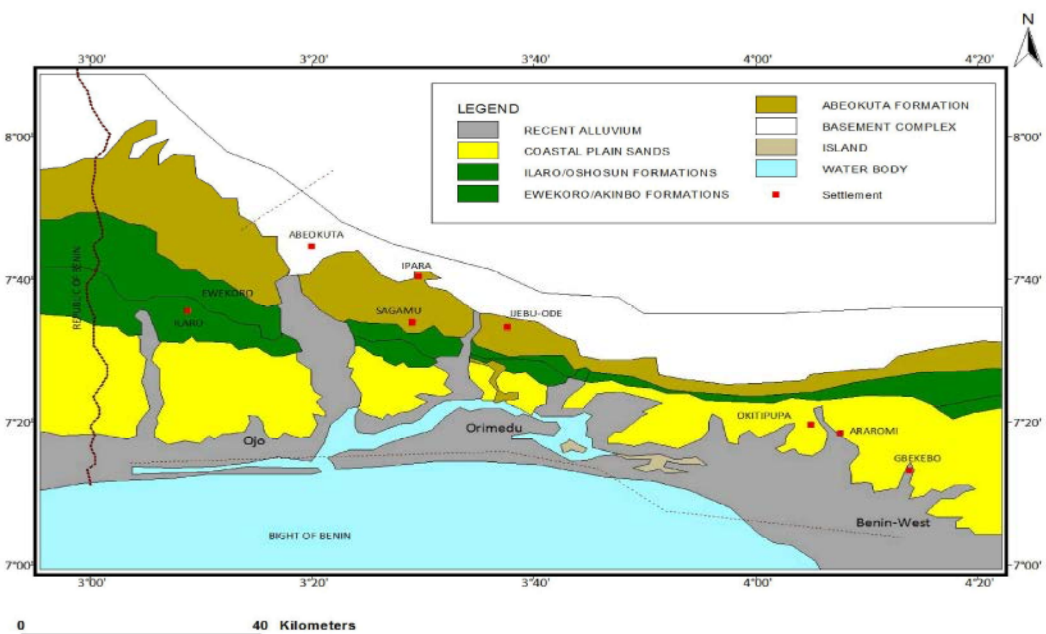

Fig. 2: Geological Map of the eastern Dahomey Basin (modified after Agagu [18])

into the Lagos Lagoon. In addition to these industrial wastes and effluents, active dumping of solid wastes is carried out on the lagoon by the residents that live in areas adjoining the lagoon. The Lagos lagoon can thus be described as a depository of last resort for all the solid and liquid wastes generated in the adjoining land area.

The Lagos lagoon is the largest of the three Lagoon systems occurring in the Lagos area, receiving over 80% of the land-derived run-offs laden with various types of wastes. It lies within longitudes 6°25′ and 6°43′ and latitudes 3°22′ and 3°40′ (Figure 1). The Lagos Lagoon is bounded in the north by extensive land area comprising major population and industrial centers such as Oyingbo,

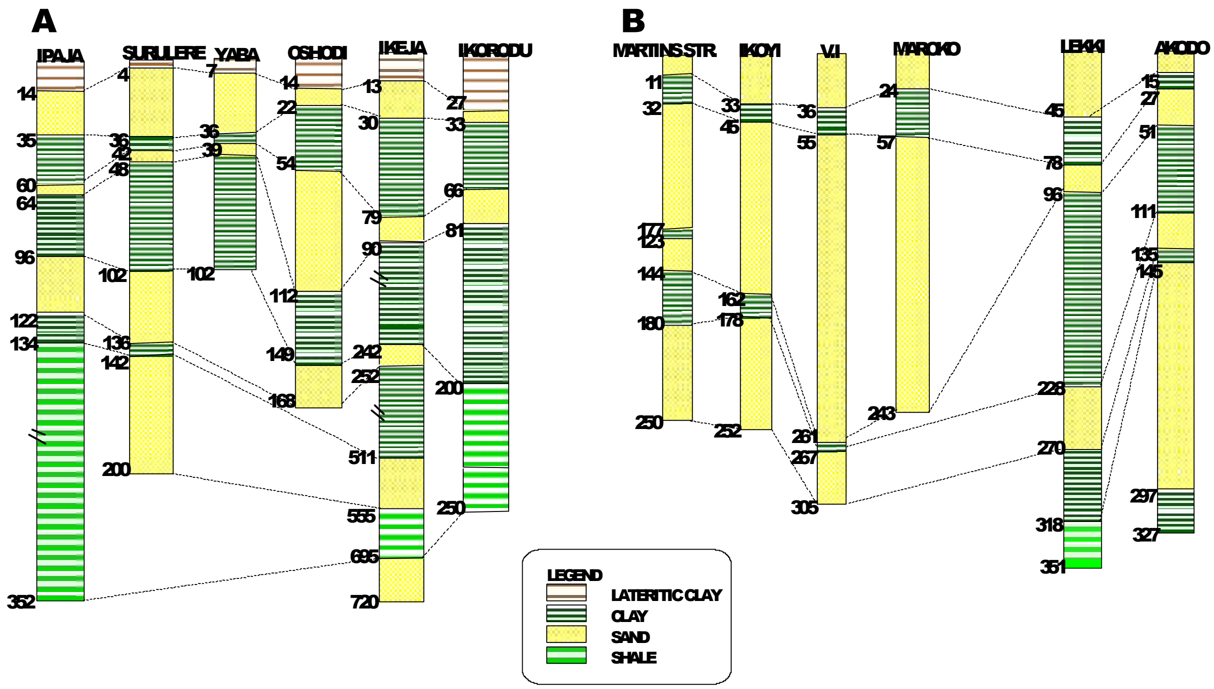

Fig. 3a,b: a: Stratigraphic Sequence of Lithologic Boreholes (East-West)
b: Stratigraphic Sequence of Lithologic Boreholes (East-West)

Ebute-meta, Oworonsoki, Yaba, Oshodi, Ikeja, Mushin, Ikorodu, Ojota, Ketu and Isolo. It is also bounded to the south by the highbrow business and residential areas of Victoria Island, Ikoyi, Marina, Ebute-Ero and Lekki. Accessibility to the Lagos Lagoon can be gained via the several coastline settlements surrounding the Lagoon. The depth of the Lagos Lagoon ranges from 3m in most parts to between 6m and 10m in the deeper portions. The Lagos Lagoon maintains a fairly constant volume of water throughout the year. During the rainy season, the lagoon is fed by the numerous coastal rivers draining into it while during the dry season, the loss of water due to evaporation and the reduced amount of water from the rivers and creeks is compensated for by the underground seepage under the active sandy barrier formation and inflow of the tidal waters from the sea through the Lagos harbor and other lagoon outlets. Metal concentration of sediments from rivers, lakes and lagoons had been studied by various workers as a means of assessing their quality and pollution status [8-14]. In a previous limited work undertaken on the Lagos lagoon sediments, elevated metal content was reported for sediments [15]. The study was carried out on a restricted part of the Lagos lagoon with limited number of samples (twenty in all) and the determination of fewer metals (ten). Due to the relatively limited scope of the previous works, it was difficult to ascertain the quality of the sediments in other parts of the lagoon. This work is aimed bridging such information gap by using more samples (one hundred) from the entire lagoon as well as the lagoon water while analyzing for over thirty elements. This was with a view to evaluate the geochemical distribution of these elements as well as determine those metals that had attained pollution status using various pollution quantification indices.

Geologically, the Lagos area falls within the eastern part of the Dahomey Basin (Figure 2). The eastern Dahomey Basin is bounded to the north by the Precambrian Basement complex of southwestern Nigeria, the Gulf of Guinea to the south and eastward by the Okitipupa ridge [16-18]. The geology of the Lagos area is dominated by a continuous and monotonous repetition of clayey and sandy horizons. These horizons show some lateral continuation in some places but in most parts, these lithology pinches out. Along the coastline (east–west), the topmost unit of the Stratigraphy is made up of sands of various types grading into clay, sandy-clay and coarse, gravely and conglomeratic sand and shale at deeper levels. In the hinterland (northern) section, the Stratigraphy is made up of reddish lateritic clay horizon at the top, grading into sands, clay, sandy clay and shale at deeper levels (Figures 3a and 3b).

MATERIALS AND METHODS

One hundred sediment samples were randomly collected along the banks, drainage channels, shelves and center of the lagoon with all the sampling points appropriately located using the Global positioning System (GPS). The identifiable landmarks in adjoining land areas to the sampling points were also recorded. The sediments were drained of water and subsequently air-dried for three weeks under room temperature. The dried samples were disaggregated and sieved to remove materials such as wastes, animal shells and plant roots. The sieved sediments were subsequently leached with aqua regia. To achieve digestion, 0.5g of the sieved samples was weighed into the digestion flask and digested with aqua regia (0.5m H_2O, 0.6ml concentrated HNO_3 and 1.8ml HCl) for two hours at 95°C. The samples were cooled and then diluted to 10ml with deionized water and homogenized before they were analyzed for their elemental constituents, using the Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES) at the Geochemical Laboratory of the Activation Laboratories Limited Ontario, Canada. A suite of 36 elements (major and trace) were identified in the lagoon sediments

Thirty water samples, made up of twenty-seven lagoon water and three water samples from other sources (rainwater, borehole water and water from Omi River), were collected into sterilized containers and acidified using concentrated hydrochloric acid so as to ensure that the respective ions remain in solution pending analysis. The water samples were subsequently analysed for their metal contents using AAS. The results obtained from the analysis were compared to ascertain the metal enrichment or otherwise in the lagoon water.

RESULTS AND DISCUSSION

Sediment Chemistry

Major Oxides: The concentration of the oxides in the sediments of the Lagos Lagoon showed that SiO_2 ranges from 78.57-98.88% with a mean of 92.285, Al_2O_3 ranges from 0.15-6.32% with a mean of 1.90%, CaO ranges from 0.04-5.50% with a mean of 0.55, Fe_2O_3 ranges from 0.44-11.62%, K_2O ranges from 0.01-0.39% with a mean of 0.12%, MgO ranges from 0.04-0.98% with a mean of 0.37%, Na_2O ranges from 0.10-0.30% with a mean of 0.98%, P_2O_5 ranges from 0.01-0.30% with a mean of 0.07% and TiO_2 ranges from below detection Limit (Bdl)-0.32% with a mean of 0.09% (Table 1). The dominance of SiO_2 over all other oxides is a confirmation of the sandy nature of the sediments. The concentration of Fe_2O_3, Al_2O_3, CaO and Na_2O were found to be elevated in sediments obtained from within creeks and mangroves where there is preponderant fine grained clayey materials in the sediments. Significant correlation exists between SiO_2, Fe_2O_3, Al_2O_3, K_2O, MgO and P_2O_5 with correlation matrix =0.5 (Table 2 and Figure 4(a-c)). This is an indication that these oxides had been primarily contributed from the weathering of aluminosilicate, ferromagnesian and apatite rich minerals in the catchment areas drained by the various sediment laden rivers from the hinterland.

Table 1: Summary of Major Oxides Composition of the Lagos Sediments

Oxides	Range(%)	Mean N=100
SiO_2	78.57-98.88	92.28±0.10
Al_2O_3	0.15-6.32	1.90±1.33
CaO	0.04-5.50	0.55±0.64
Fe_2O_3	0.44-11.62	3.26±1.75
K_2O	0.01-0.39	0.12±0.08
MgO	0.04-0.98	0.37±0.23
Na_2O	0.10-9.60	0.98±1.13
P_2O_5	0.01-0.30	0.07±0.06
TiO_2	Bdl-0.32	0.09±0.06

Bdl=Below Detection Limit

Table 2: Correlation coefficients of major oxides in the Lagos Lagoon sediments

Oxides	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	Na_2O	P_2O_5	TiO_2	SiO_2
Al_2O_3	1								
CaO	.46	1							
Fe_2O_3	.81	.47	1						
K_2O	.87	.62	.77	1					
MgO	.67	.56	.63	.86	1				
Na_2O	.24	.31	.09	.42	.50	1			
P_2O_5	.69	.53	.63	.82	.80	.36	1		
TiO_2	-.01	.08	-.03	-.09	.02	-.07	-.07	1	
SiO_2	.47	.44	.62	.58	.49	.18	.28	.29	1

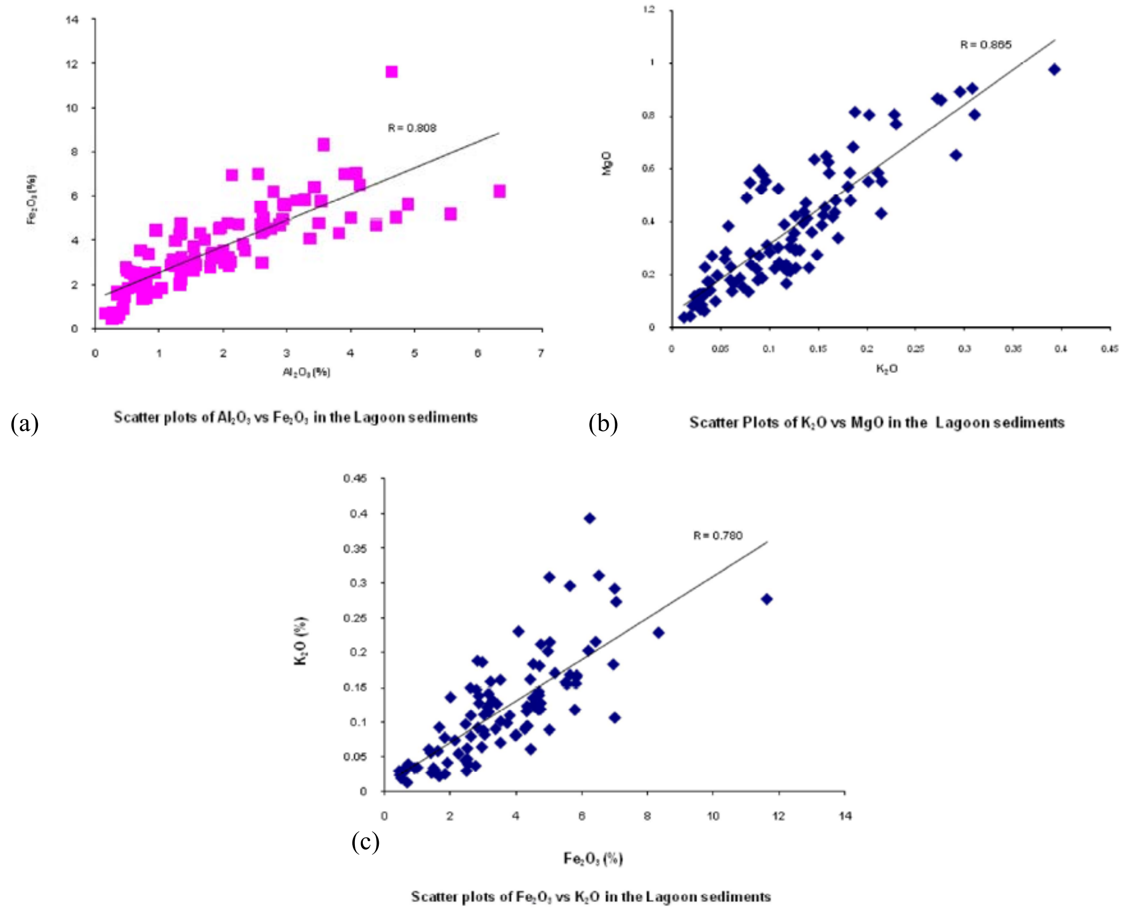

Fig. 4(a-c): Relationship between some of the oxides in the Lagoon sediments

Table 3: Summary of trace element concentration in Lagos lagoon sediments

Element	Range (ppm)	Median	Mean	ASC*
Cd	Bdl-3.70	Bdl	0.27±0.66	0.3
Cu	3.00-231.00	25.00	36.04±37.83	50
Mn	64.00-1737.00	437.00	494.98±309.64	850
Mo	Bdl-28.00	Bdl	Bdl	2
Ni	3.00-49.00	11.00	12.66±7.466	80
Pb	2.00-146.00	15.00	20.27±23.20	20
Zn	9.0.-366.00	54.00	72.33±69.76	90
As	Bdl-28.00	4.00	2.99±5.768	10
B	Bdl-27.00	10.0	9.87±7.24	100
Ba	9.00-167.00	35.0	37.81±	600
Be	Bdl-3.00	Bdl	Bdl	3
Bi	Bdl-8.00	Bdl	Bdl	0.2
Co	Bdl-23.00	9.00	9.52±5.52	20
Cr	6.00-87.00	31.00	31.52±15.98	100
Ga	Bdl-15.00	6.00	6.80±3.94	25
La	7.00-67.00	26.00	26.97±12.89	40
Sb	Bdl-11.00	Bdl	Bdl	1.5
Sc	0.90-11.00	4.60	4.70±2.31	15
Sr	4.00-192.00	24.00	31.43±25.58	400
Te	Bdl-6.00	Bdl	Bdl	**
Th	Bdl-10.00	3.00	3.29±2.35	12
Tl	Bdl-15.00	Bdl	0.64±4.51	1
V	4.00-124.00	31.00	33.64±22.30	130
W	Bdl-8.00	2.00	1.73±2.65	1.8
Y	2.00-27.00	11.00	10.91±5.28	35
Zr	1.00-30.00	8.00	8.36±4.92	180

** ASC values not available. Bdl=below detection Limit
*Average Shale Concentration after Turekian and Wedepohl [7]

Trace Elements: The concentration in ppm of the trace elements in the Lagos Lagoon sediments showed Cd to range from Bdl-3.70, Cu ranges from 3.00-241.00, Mn ranges from 64.00-1737.00, Mo ranges from Bdl-28.00, Ni ranges from 3.00-49.00, Pb ranges from 2.00-146.00, Zn ranges from 9.0-366.00, As ranges from Bdl-28.00, B ranges from Bdl- 27.00, Ba ranges from 9.00-167.00, Be ranges from Bdl-3.00, Bi ranges from Bdl-8.00, Co ranges from Bdl-23.00, Cr ranges from 6.00-87.00, Ga ranges from Bdl-15.00, La ranges from 7.00-67.00, Sb ranges from Bdl-11.00, Sc ranges from 0.9-11.00, Sr ranges from4.00-192.00, Te ranges from Bdl-6.00, Th ranges from Bdl-10.00, Tl ranges from Bdl-15.00, v ranges from 4.00-124.00, W ranges from Bdl-8.00, Y ranges from 2.00-27.00 and Zr ranges from 1.00-30.00 (Table 3). Comparing the observed concentration with the Average Shale Concentration (ASC) as proposed by [19], Cd, Cu, Mn, Mo, Pb, Zn, As, Co, La, Sb, Tl and W were observed to contain elevated concentration in reference to the ASC at most of the sampling points (Table 3).

The results obtained from the elemental analysis were used to plot geochemical maps for some selected metals (Figures 6-13). The maps showed the distribution pattern of selected metals in the Lagos lagoon sediments to be influenced by adjoining land based activities such as industrialization, dense urban settlements as well as areas of commercial activities. The results revealed that metals such as Cd, Cu, Pb and Zn were found to be elevated at locations within the lagoon bounded by the land areas such as Oworonsoki, Ogudu, Oyingbo, University of Lagos, Ido, Marina Ebute-Meta, Oreta and Ofin, areas associated with dense human population, commercial centers and industrial activities known for the generation of huge volume of liquid and solid wastes. However metals such as Bi, W and Tl were observed to have elevated concentration relative to their corresponding ASC at additional locations of Victoria Island, Ikoyi and Lekki as well as with the central part of the lagoon. The results were further analysed statistically to ascertain the relationship between the various metal concentrations

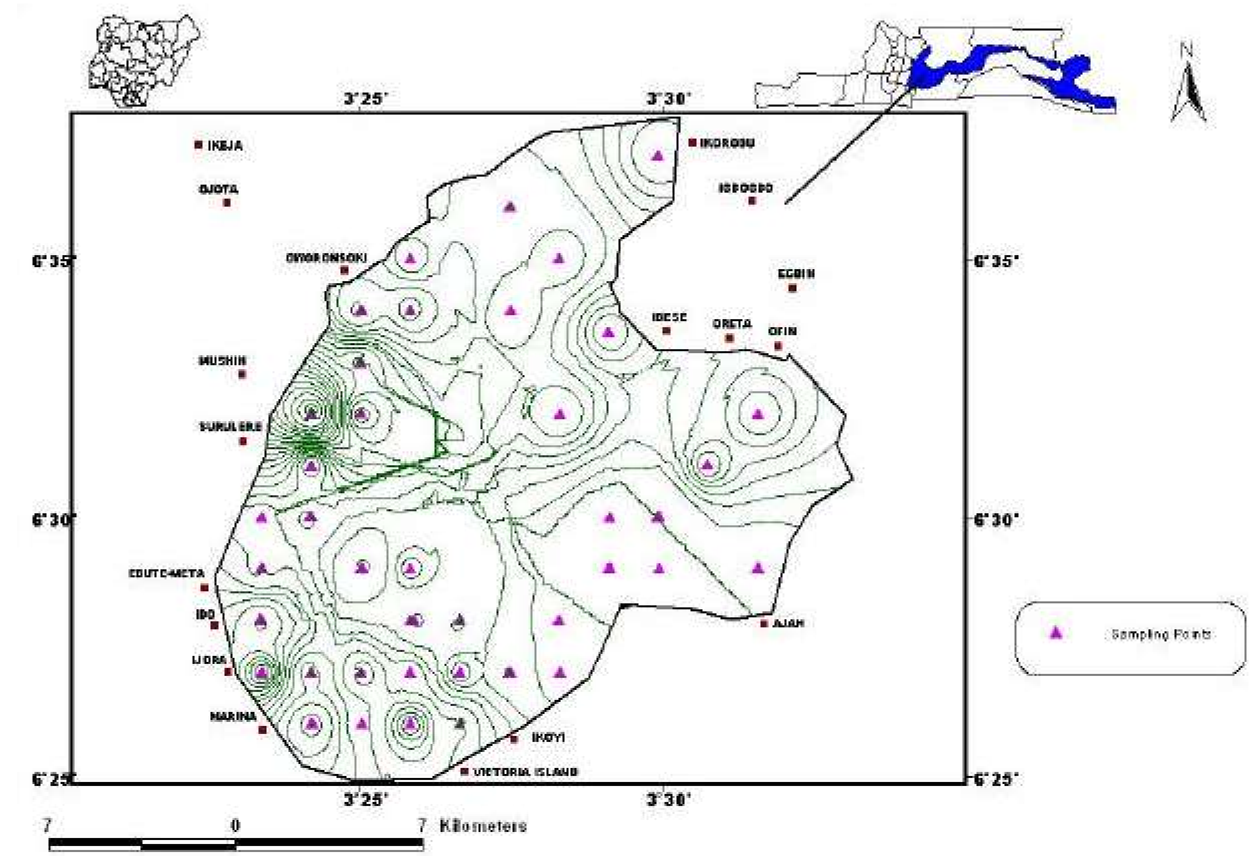

Fig. 5: Geochemical map of Cd distribution in the Lagoon sediments

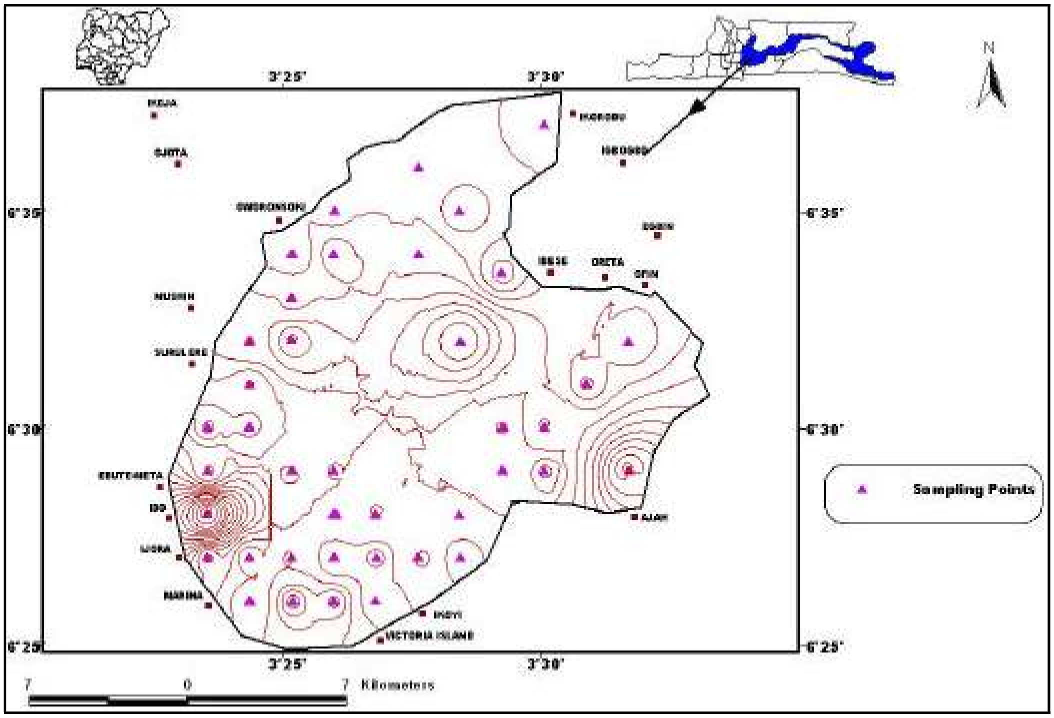

Fig. 6: Geochemical map of Cu distribution in the Lagoon sediments

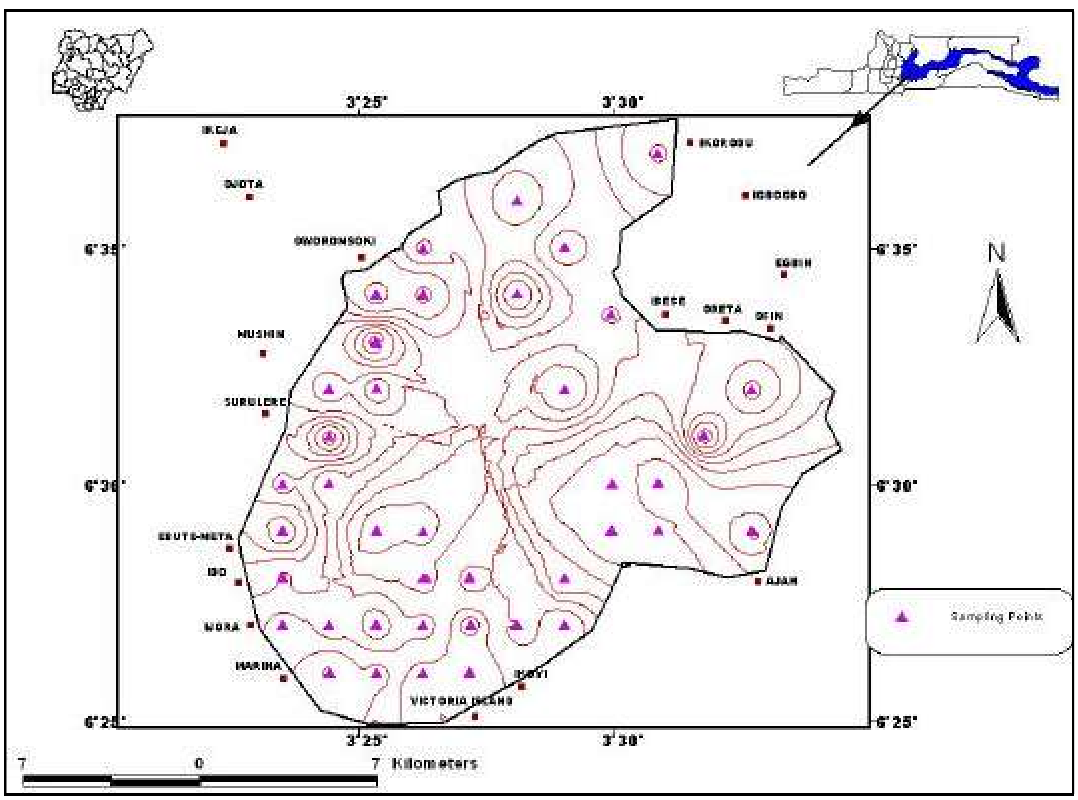

Fig. 7: Geochemical map of Mn distribution in the Lagoon sediments

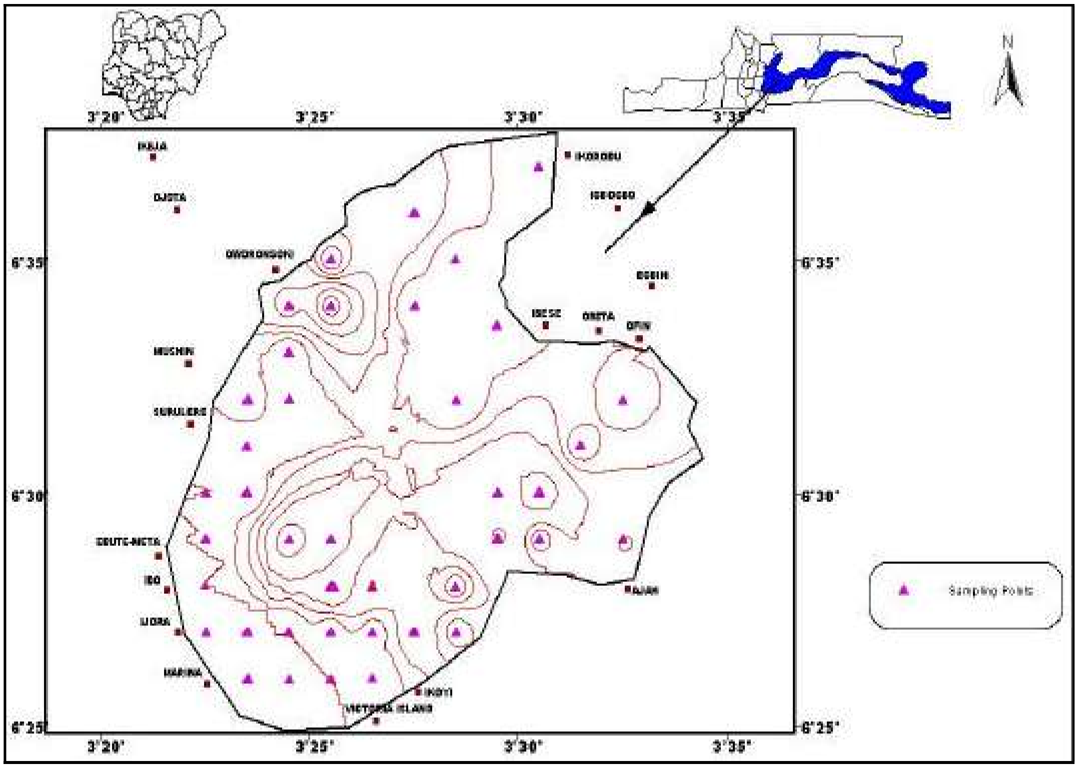

Fig. 8: Geochemical map of Bi distribution in the Lagoon sediments

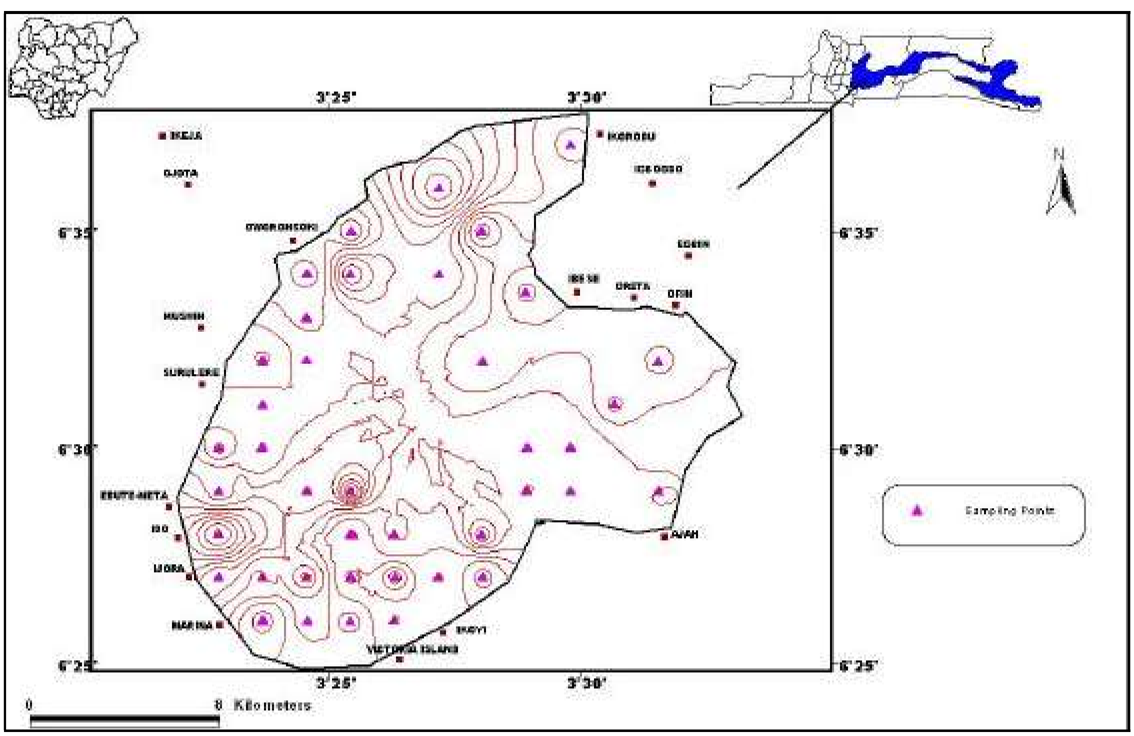

Fig. 9: Geochemical map of Cr dis tribution in the Lagoon sediments

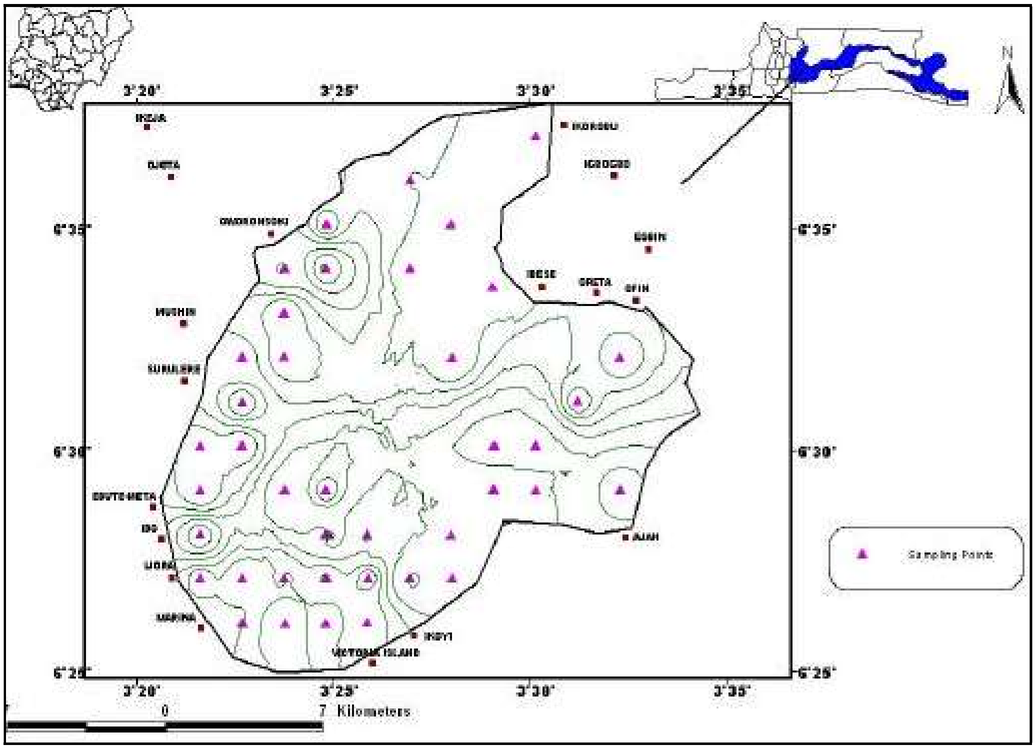

Fig. 10: Geochemical map of W distribution in the Lagoon sediments

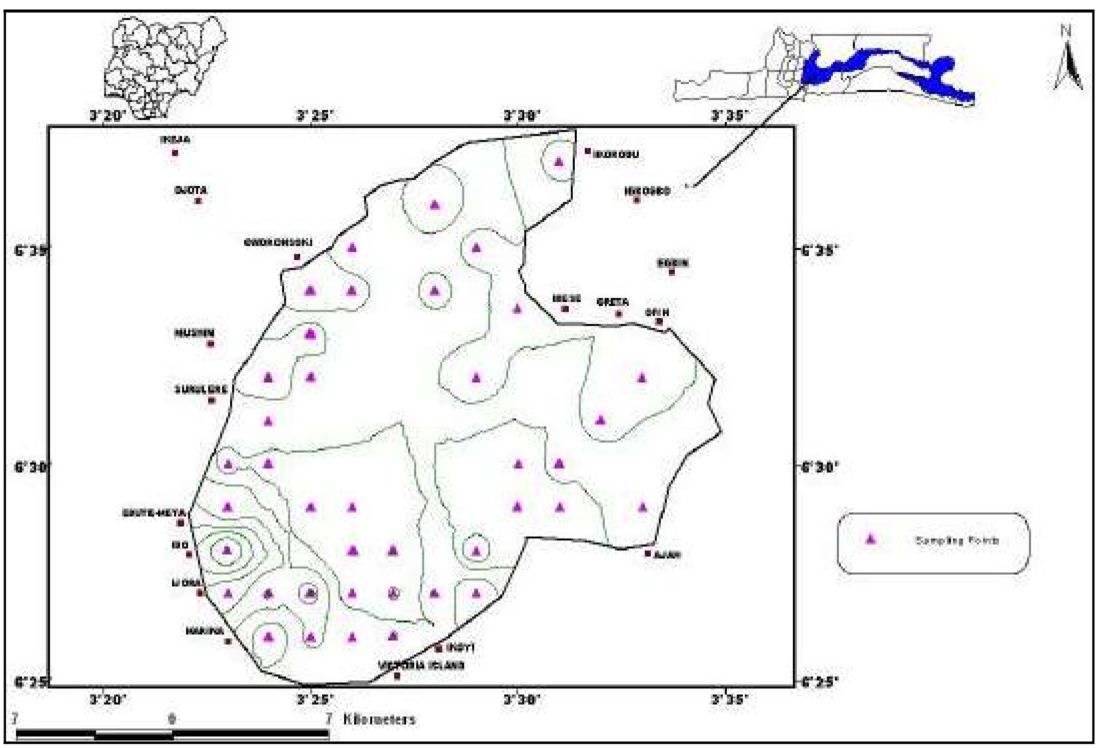

Fig. 11: Geochemical map of Ni distribution in the Lagoon sediments

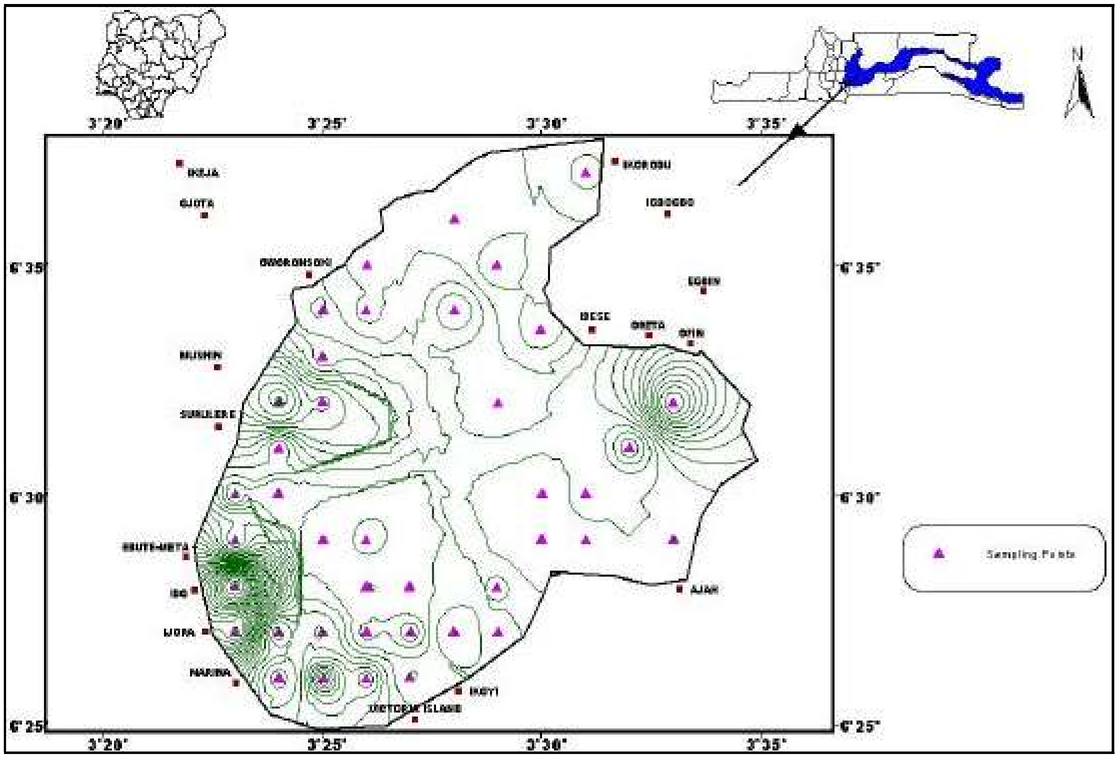

Fig. 12: Geochemical map of Zn distribution in the Lagoon sediments

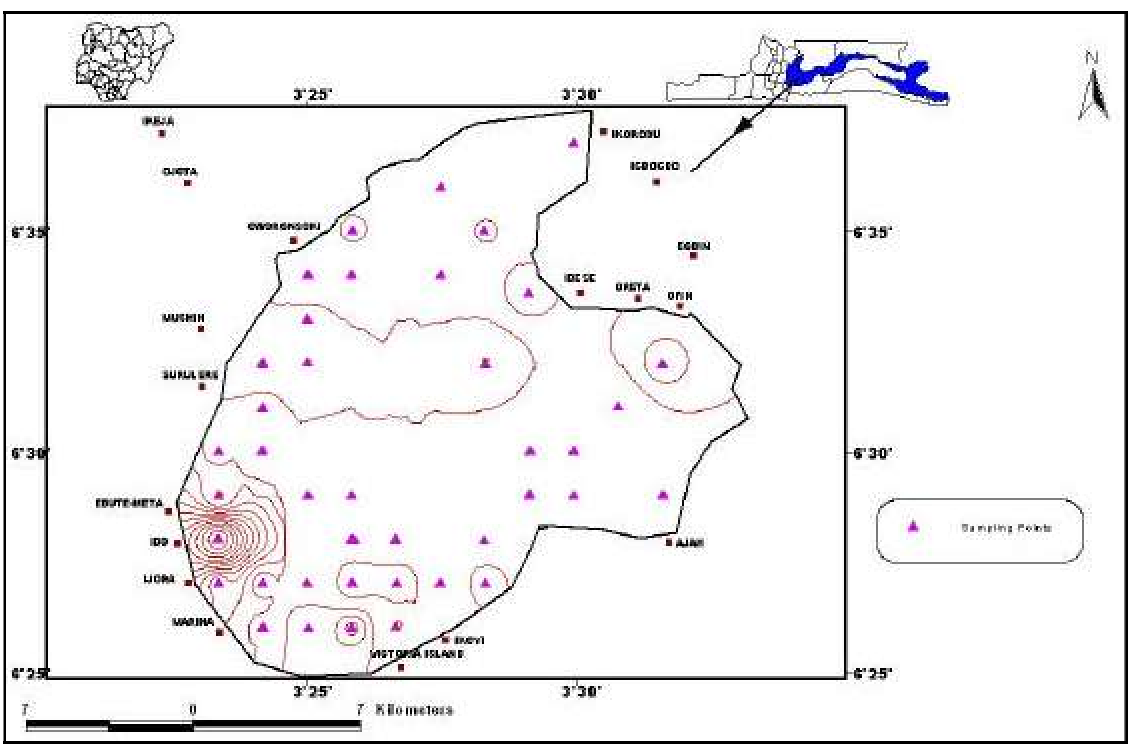

Fig. 13: Geochemical map of Pb distribution in the Lagoon sediments

Table 4: Summary of factor Analysis of the trace elements in the Lagoon sediments

Element	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Communality
Cd	-	-	-	-	.180	.576
Cu	.606	-	-	-	-	.685
Mn	-	-	.597	-	-	.850
Mo	.607	-	-	-	-	.607
Ni	.876	-	-	-	-	.900
Pb	-	-	.577	-	-	.846
Zn	.552	-	-	-	-	.799
As	.571	-	-	-	-	.618
B	.597	-	-	-	-	.728
Ba	-	-	-	-	.622	.629
Be	.785	-	-	-	-	.729
Bi	-	.845	-	-	-	.816
Co	.674	-	-	-	-	.705
Cr	.852	-	-	-	-	.878
Ga	.933	-	-	-	-	.937
La	.691	-	-	-	-	.911
Sc	.908	-	-	-	-	.947
Sr	.643	-	-	-	-	.711
Th	-	.548	-	.483	-	.674
Tl	-	-	.454	-	-	.380
V	.641	-	-	-	-	.917
W	-	.654	-	-	-	.728
Y	.855	-	-	-	-	.916
Zr	.660	-	-	-	-	.745
Eigen values	9.430	3.353	2.636	1.563	1.250	
Percentage of variance	39.292	13.971	10.981	6.512	5.208	
Cumulative percentage	39.292	53.263	64.245	70.756	75.964	

of the sediment samples using the R-mode factor analysis. The summary of the results of the factor analysis is presented in Table 4

The statistical analysis revealed that the trace metals can be grouped into five. The first group consists of Cu, Mo, Ni, Zn, As, B, Be, Co, Cr, Ga, La, Sc, V, Y and Zr and this account for 39% of the total variance of the variables with Eigen value of 9.43. These elements are believed to be held as hydrated oxides and hydroxides in the sediments and are more likely to have been contributed mainly from liquid wastes and effluents. These groups of elements exhibit very high correlation within the group, a few of these are illustrated in Figure 14(a-c). The second group consist Bi, Th and W accounting for approximately 14% of the total variance with an Eigen value of 3.35. These elements are used as additives and alloys in chemical and metallurgical industries and are believed to have been contributed to the sediments from the leaching of industrial, chemical and domestic wastes. The third group consist Mn, Pb and Tl which account for about 11% of the total variance with an Eigen value of 2.64. These are 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 pain products. Th alone makes up group four with account ting for 6.51% of the total variance.

Th is widely used as additive in many chemical products and its preponderant around the Ikorodu axis of the Lagoon is an indication that it had been introduced into the sediments via discharged effluents and dye products. The fifth group comprises Cd and Ba which account for about 5% of the total variance of the data set. These two metals have been contributed to the sediments through the discharge of domestic and industrial wastes.

Quality of Lagoon Sediment: The quality and potential environmental implication(s) of the metals were evaluated using contamination indices such as metal ratio and geo-accumulation indices. These methods have been used successfully by various workers to determine the quality of various environmental media [20-24].

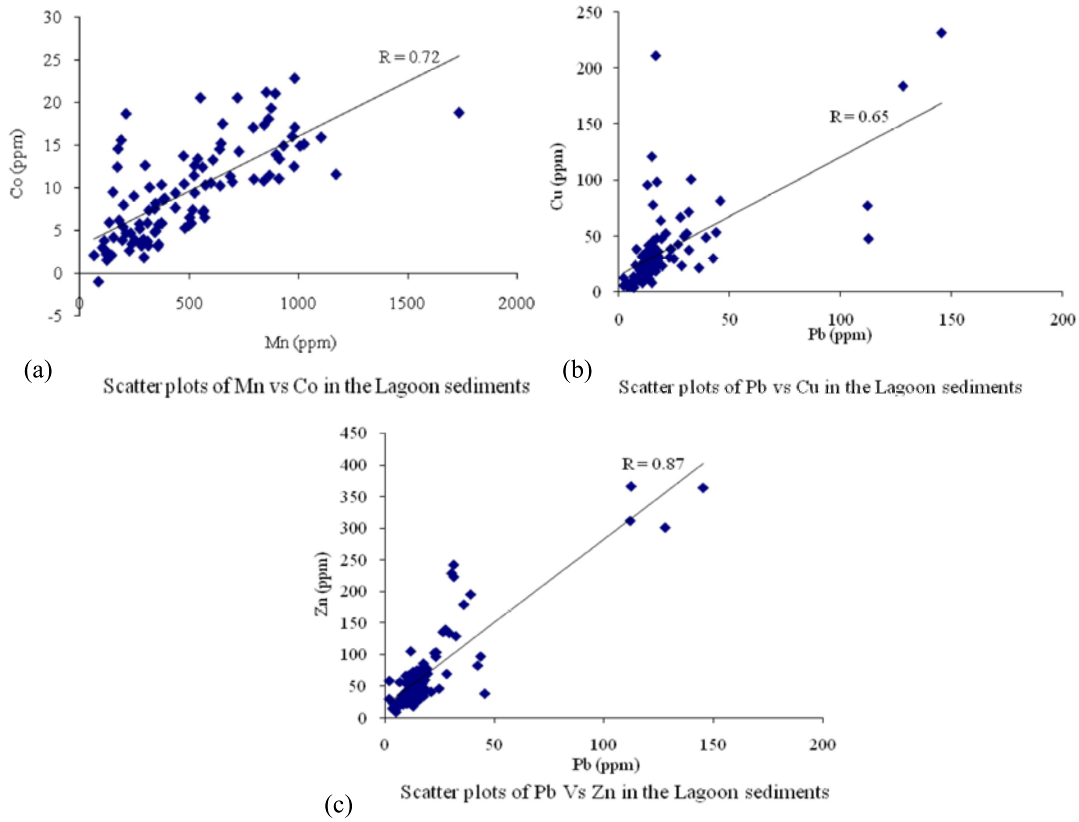

Fig. 14(a-c): Relationship between some of the oxides in the Lagoon sediments

Table 5: Summary of calculated metal ratio for selected metals in the sediments

Metal	Range of Metal Ratio
Cd	0-13
Cu	0-5
Pb	0-7
Zn	0-4
As	0-3
Bi	0-42
Co	0-1
Cr	0-1
Ga	0-1
La	0-2
Th	0-1
Tl	0-15
V	0-1
W	0-5
Y	0-1

Metal Ratios: The metal ratio as a pollution quantification index is achieved by comparing the observed metal concentration in the sediments with its Average Shale Concentration [19, 20]. The calculated metal ratios (Table 5) for all the metals range showed that certain parts of the lagoon still have metal concentration lower than the ASC (locations with zero values) while other locations showed elevated metal ratios. The locations where the metal ratio are <1.0 are areas where the metal concentrations have not attained levels that can pose environmental problem individually. Locations with values of 1.0 are considered as areas with optimal concentrations of the metals as their concentrations are about the same with the ASC while locations with calculated metal ratios >1.0 are considered as places with enhanced metal concentration and could be of environmental significance. Locations with localized elevation of metal concentration can be described as "hotspots" where under favourable physico-chemical conditions, there is possibility of the metals getting into the food chain via metal recycling and flushing resulting from wave action. Metals with considerable metal ratio elevation in overwhelming number of sediments sampled are Bi, Tl, Cd, Pb, Cu, Zn and W while a few samples showed elevated metal ratio for As and La. The samples with elevated metal ratios were obtained from locations surrounded by identified industrial estates,

Table 6: Summary of Geo-accumulation Index Calculated for Selected Elements in the Lagos Lagoon Sediments

Metal	I_{geo} Range	Interpretation
Cd	0-3	Unpolluted –highly polluted
Mo	0-1	Unpolluted to moderately polluted
Pb	0-2	Unpolluted to moderately polluted
Zn	0-1	Unpolluted to moderately polluted
Bi	0-4	Unpolluted to very highly polluted
Tl	0-3	Unpolluted to very highly polluted
W	0-1	Unpolluted to moderately polluted

Table 7: Summary of Lagos Lagoon Water Chemistry

Parameters	Lagoon Water n=27	River Omi n=1	Borehole water n=1	Rain Water n=1
EC (µS/cm)	538-6820	251	35	51
pH	3.2-5.8	6.8	6.7	7.0
Na (mg/l)	645.00-6383.00	30.20	2.50	1.35
Mg (mg/l)	50.10-765.00	8.45	0.48	0.19
K (mg/l)	16.10-238.20	6.23	0.31	0.35
Ca (mg/l)	24.20-246.80	18.83	1.07	7.33
Fe (mg/l)	4.20-43.67	0.50	0.03	Bdl
B (mg/l)	0.08-0.41	0.10	Bdl	Bdl
Ni (mg/l)	Bdl -0.04	0.03	Bdl	Bdl
Cu (mg/l)	Bdl -.016	Bdl	0.01	Bdl
Zn (mg/l)	0.02-0.118	0.001	0.05	Bdl
Pb (mg/l)	0.01-0.08	0.02	Bdl	Bdl

Bdl= below detection limit of analytical technique
N= Number of samples

Table 8: Correlation coefficients of the Lagoon water chemistry.

	Na	Mg	K	Ca	Fe	B	Ni	Cu	Zn	Pb
Na	1.00									
Mg	0.99	1.00								
K	0.99	0.99	1.00							
Ca	0.99	0.99	0.99	1.00						
Fe	0.99	0.99	0.99	0.99	1.00					
B	0.62	0.60	0.60	0.60	0.61	1.00				
Ni	-0.73	-.69	-.70	-.67	-.68	-.50	1.00			
Cu	-0.71	-.73	-.72	-.73	-.73	-.54	0.45	1.00		
Zn	0.04	0.06	0.06	0.07	0.06	-.09	0.19	-.04	1.00	
Pb	-0.64	-.69	-.67	-.69	-.69	-.40	0.21	0.80	-0.11	1.00

commercial centers and densely populated centers. This result is in consonance with results obtained in other part of the world [22, 23,25].

Geo-accumulation Index: The geo-accumulation index proposed by [20] for quantification of metal accumulation in sediments was also used for the evaluation of the pollution status of the sediments. The formula for the geo-accumulation index is expressed as:

$$I_{geo}=Log_2 Cn/1.5B_n$$

where I_{geo} represents the geo-accumulation index, C_n represent measured concentration of the metal in the sediment, B_n represent the background value (in this case the average shale value) and 1.5 is the background matrix correction. The geo-accumulation index consists of seven classes ranging from unpolluted to very highly polluted [20, 24]. The geo-accumulation index calculated for the metals from all the samples revealed that most of the samples can be described as being unpolluted with most of the metals. However, a few of the metals are significant in terms of the calculated geo-accumulation index. These metals are Bi, Tl, Pb, Cd, W, Zn and Mo (Table 6). The calculated I_{geo} revealed that the sediments of the Lagos lagoon vary from unpolluted to highly polluted with Bi; unpolluted through moderately-polluted to highly polluted with Tl and Cd; unpolluted to moderately polluted with Pb and unpolluted to moderately polluted with Zn, Mo and W. All the sediments that are moderately to very highly polluted are those samples obtained from locations surrounded by areas with industrial estates and high human activities as a result of population and commerce. The elevated geo-accumulation index recorded for areas with influx of industrial wastes and effluents is in consonance with similar studies undertaken by various workers [24, 26,27].

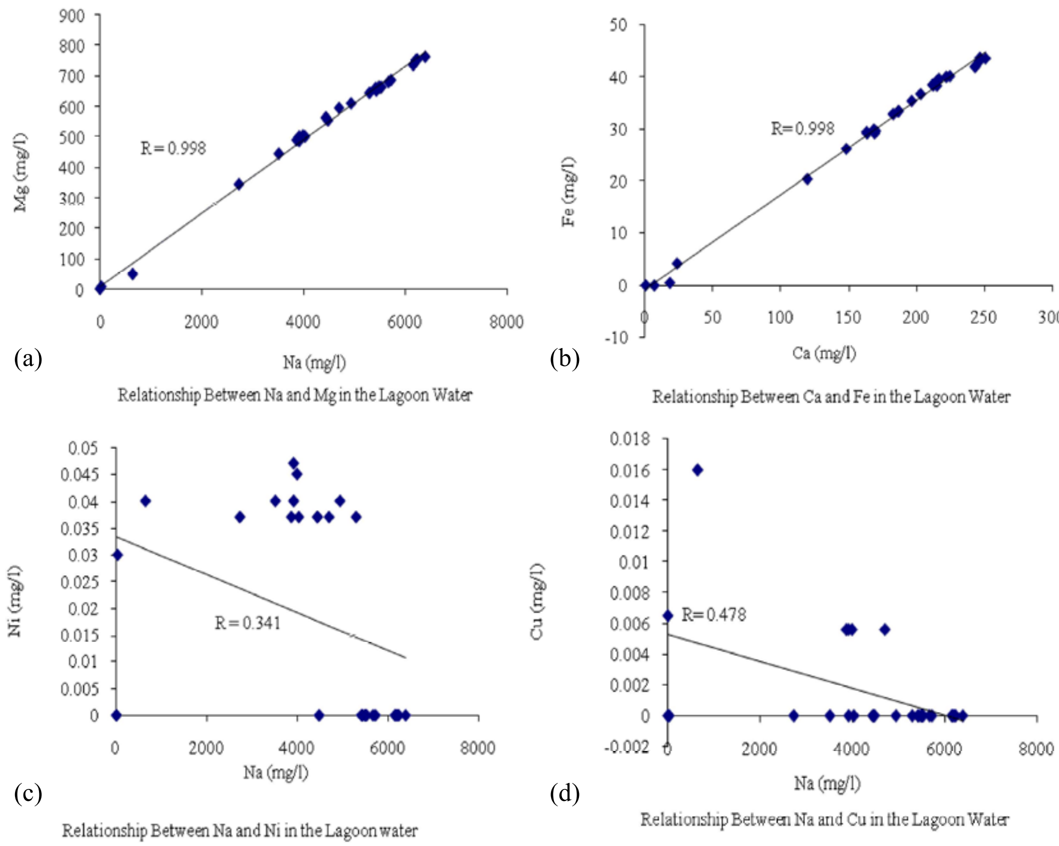

Fig. 15(a-d): Elemental relationship in the Lagoon Water.

Water Chemistry: The pH of the Lagoon water sample ranges from 3.2-5.8 while the electrical conductivity (EC) ranges from 538-6820µS/cm The chemical results of the Lagos Lagoon water showed that Na ranges from 645-6383 mg/l, Mg ranges from 50.1-765 mg/l, K ranges from 16.1-238.2 mg/l, Ca ranges from 24.2-246.8 mg/l, Fe ranges from 4.2-43.66mg/l, B ranges from 0.08-0.41mg/l, Ni ranges from Bdl-0.04mg/l, Cu ranges from Bdl-0.016mg/l, Zn ranges from 0.02-0.118mg/l and Pb ranges from 0.01-0.08mg/l. The results for the Lagos Lagoon water was observed to contain elevated elemental concentrations when compared with the results obtained from the analysis of water from other sources than the Lagoon (Omi River water, Rainwater and Groundwater) (Table 7). The Pearson correlation analysis of the results for the water samples from the Lagos Lagoon revealed strong positive correlation among Na, Mg, K, Ca,Fe and B with correlation coefficients = 0.60 while the heavy metals of Ni, Cu, Zn and Pb showed negative correlation with the major metals (Table 8 and Figure 15a-15d). This indicate that the major metals of Na, Mg, K, Ca, Fe and B had been contributed to the Lagoon water naturally from the influx of the seawater as well as the fresh water that had interacted with the geologic materials on their way towards the Lagoon.

Summary and Conclusions: The Lagos Lagoon water and sediments have been studied and the various metal contents determined. The chemistry of the Lagoon water indicated that the major metals in the water were sourced from similar geogenic sources while the heavy metal contents have been sourced from anthropogenic sources. The chemistry of the Lagoon water was also found to be markedly different from water samples obtained from other sources. Geochemical evaluation of the sediment metal concentration showed that the major oxide was dominated by SiO_2 a confirmation of the predominantly sandy nature of the sediments of the Lagoon. The heavy metals analysis and subsequent evaluation revealed elevated metal contents for the sediment samples from locations with identifiable active industrial, commercial and human waste discharge into the Lagoon. Further pollution level quantification of the heavy metals revealed that Pb, Cd, Bi, Tl, W and Zn have attained significant pollutant stature in the sediments of the lagoon as they have exceeded their background levels in most of the sediment population recording a metal ratio ranging from 2-fold to as high as 42-folds. In terms of the geo-accumulation index values, the sediments of the Lagos lagoon could be described as slightly polluted with Mo, Zn and W and moderately to highly polluted with Cd, Pb and Bi.

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