Spatial Analysis of Heavy Metals Concentration around the Lagos Lagoon, Nigeria

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Abstract

An analysis of the concentration of 8 heavy metals - Lead (Pb), Arsenic (As), Iron (Fe), Cadmium (Cd), Zinc (Zn), Manganese (Mn), Copper (Cu) and Chromium (Cr) in the bottom sediments of Lagos Lagoon was carried out using an AAS and the result interpreted using Geographical Information System (GIS) tools. The kriging and Inverse Distance Weighed (IDW) technique was used to perform the interpretation of the results with a view to quantify the spatial variability and generate the Metals Risk Maps for each of the metal and all the metals as a whole over the region. The results were compared with the Nigerian Standard for Drinking Water Quality (NSDWQ, 2007) drinking water quality standard. The findings revealed that Mn recorded highest concentrations of 225.9mg/l and 336.5mg/l for dry and rainy seasons respectively around Egbin (A9); Cd recorded highest concentrations of 19.6mg/l for dry season at Tincan creek (A12) and 90.3mg/l for rainy season at Commodore Channel (A10); As recorded highest concentrations of 70.5mg/l and 90.3mg/l for dry and rainy seasons respectively around Tincan creek (A12); Pb had highest concentrations of 28.6mg/l and 41.9mg/l for dry and rainy seasons respectively around Apapa (A11). Cr highest concentrations of 14.0mg/l and 19.7mg/l was recorded around Apapa (A11) for dry and rainy seasons respectively; Cu has concentrations of 22.6mg/l and 24.0mg/l around Okobaba (A4) and Oworoshoki (A7) for dry and rainy seasons respectively; Fe recorded highest concentrations of 3,093mg/l and 2,146mg/l for dry and rainy seasons around Egbin (A9) and Oworoshoki (A7) while Zn recorded highest concentration of 29.7mg/l and 35.2mg/l at Commodore Channel for dry and rainy seasons respectively. It was observed that the concentrations of all the parameters analysed were above the NSDWQ (2007) drinking water standard limit while Cu and Zn are within tolerable limits. The findings also revealed that locations around Tincan Creek, Commodore Channel, Apapa, Five Cowries, Ijora, Iddo towards the south-eastern part of Lagos Lagoon are at higher risks than the Mid-Lagoon and Egbin axis in the north. The factors responsible for the contaminants were identified as sand mining and dredging, urban domestic wastes and sewerages, industrial wastes.

Keywords: *Heavy Metals, Lagos Lagoon, bottom sediments, Spatial Analysis*

1. INTRODUCTION

Large volumeof wastes are continuously discharged into the Lagos lagoon as a result of continuous increase of the human activities and environmental quality degradation (Agenda 21 1992; Osibanjo 2001; Eruola et al., 2011; Amaeze et al., 2015). Most of the environmental pollution emanates from anthropogenic sources through uncontrol human activities (Engelking, 2007). Waste from anthropogenic activities have become the major sources of metals that contaminate surface waters in Lagos particularly Lagos Lagoons and creeks (Ajao*et al*. 1996; Nubi et al., 2008).

Heavy metals are one of the serious pollutants in natural water owingto their toxicity, persistence and bioaccumulation problems (Tam and Wong, 2000; Wuana and Okieimen, 2011; Tangahu *et al.,* 2011; Tchounwou et al., 2012). Consequently, levels of heavy metals contamination in surface water and its surrounding is on the increase (Sharaf and Shehata, 2015; Aladesanmi et al., 2016). The continuous increase has become a concern for research scientists in various water quality fields as a result of the impacts on aquatic lives and human health (Sharaf and Shehata, 2015; Aladesanmi et al., 2016).

The Lagos Lagoon is a depository of last resort for over 70% of the surface runoffs in Lagos Metropolis, drainage channels and some rivers flowing from interior Nigeria to the Atlantic Ocean (Olatunji and Abimbola, 2010). The densely populated and industrialized areas surrounding Lagos Lagoon often generates harmful materials and deposited them into the

Lagos Lagoon (Adewole, 2009; Elenwo and Akankali, 2015). It has been observed in the last two centuries that human activities like industrialization, intensive agriculture and coastal engineering have greatly impacted Lagos Lagoon and seriously threaten its marine life (His et al., 1999; Eruola et al., 2011; Elenwo and Akankali, 2015). These impacts have resulted into environmental pollution.

1.1 The study area

Lagos State is a coastal environment characterized with wetlands, sandy barrier islands, beaches, low-lying tidal flats and estuaries (Aina 1994, Peil 1991). The Lagos Lagoon is a water body in the heart of the metropolis, and cuts across the southern part of the metropolis, linking the Atlantic Ocean (in the west and south) and Lekki Lagoon (to the east). It is about 6354.788sq km in area and 285km in perimeter and it lies between latitudes 3°22 to 3°40Nand longitudes 6°25 to 6°43E, (Fig. 1). The Lagos lagoon is a means of livelihood and transport as well as places of abode and recreation. In addition, it is a recipient of wastes from residential areas and industries. Virtually, all industries in Lagos State discharge their effluents which are mainly untreated into the Lagos lagoon.

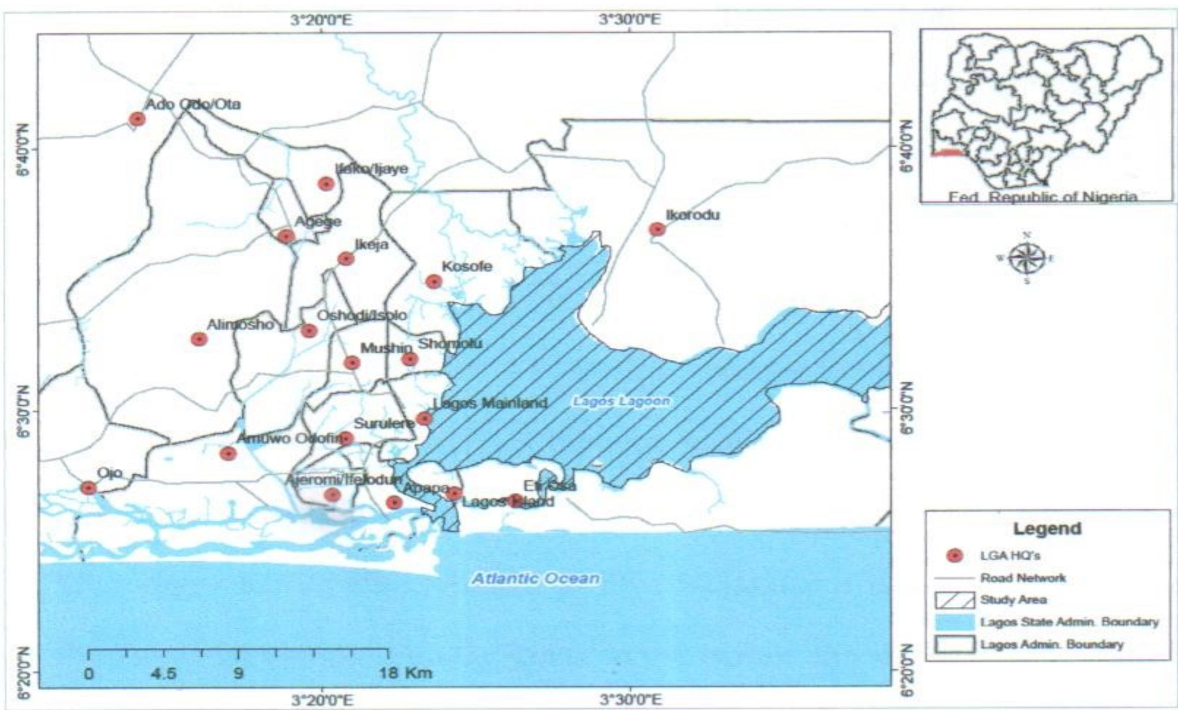

Fig. 1: Lagos Lagoon and adjourning Local Government Areas (LGAs) in Lagos State, Nigeria

The study area includes: Ibeshe, Egbin, Oworoshoki, Makoko, Okobaba, Unilag front, Iddo, Ijora, Apapa, Five Cowries Creek, Commodore Channel, Tincan Creek and Epe.

2. MATERIALS AND METHODS

2.1 Data Acquisition

Spatial and non-spatial data were used for this study and were derived from direct and indirect sources. The spatial data includes the geospatial location of all the sampling location and existing base map of the sampling site. On the other hand, the non-spatial data includes the nature, description and characteristics of the all sampling locations.

2.2 Field Mapping/ Reconnaissance Survey

A reconnaissance survey was carried out for visual observation of contaminants d areas along the Lagos Lagoon. The areas observed include industrial, residential and areas where sewage waste discharged into the Lagoon. The major points in these areas comprises of Five Cowries creek, Ijora, Iddo, Okobaba, Makoko, University of Lagos lagoon front, Oworoshoki, Commodore channel, Ibeshe, Egbin, Tincan creek, Apapa and Mid Lagoon of Lagos lagoon within Lagos metropolis of Lagos State, Nigeria.

2.3 Justification for locations' selection

The selection of the sampled sites are based on the nature of the various waste discharged into each of the areas and their relevance to this study (Table 1 and Plate 1).

Table 1: Justification for locations' selection

S/N	Sampling locations	Type of waste	Nature
A1	Five cowries	Waste discharged (generally floating garbage/debris and oil base discharges especially from commercial boat operators) from the Lagos Island, Ikoyi and Victoria island find their way unabated into the Lagos Lagoon via five cowries.	Domestics and industrial.
A2	Ijora	Majorly sea food, cement bags, and household waste are discharged from to Lagos lagoon via Ijora entry.	Industrial
A3	Iddo	The frequent discharges of human wastes (mainly raw faece) by itinerant tankers at the Iddo jetty.	Sewage
A4	Okobaba	Okobaba waste are characterized by massive amount of sawdust generated from the sawmill activities (sawdust) as well as garbage from the workers.	Industrial and domestic
A5	Makoko	The waste generated in this area includes sawdust dust, dyes, paints, faece, nylon as well as domestic waste and sewage, and are regularly transported and discharged to Lagos Lagoon via Makoko.	Industrial and domestic
A6	Unilag Lagoon Front	The University of Lagos shoreline on the Lagos lagoon is used for recreational activities which eventually constitute debris at the water front.	Domestic
A7	Oworoshoki	It is characterized mainly by domestic waste with various types of wastes deposited by Ogun River into Lagos Lagoon via Oworoshoki point. Also, domestic waste, sand mining and fishing activities are also common in this area.	Domestic and industrial
A8	Ibeshe	Ibeshe water front received effluent from industries such as textile mills, Foods industries and others situated at the Ibeshe community area in Ikorodu area of Lagos State.	Industrial
A9	Egbin	The associated waste is the hydropower generation and experiences both tidal and salinity regimes.	Industrial
A10	Commodore channel	The commodore channel is characterized with different type of waste from wrecked ships and the influx of domestics' waste from both Victoria Island and the Bar beach.	Industrial and domestic
A11	Apapa	Apapa is characterized by seaport activities with various effluents from sea port and wrecked ships.	Industrial
A12	Tincan Creek	The Tincan Creek characterized with effluents from the Port NoVo Creek, Badagry Creek and the Commodore Channel.	Industrial and domestic
A13	Mid Lagoon	The activity within the Mid lagoon is quite low and as a result used as the control point for this study.	Control point

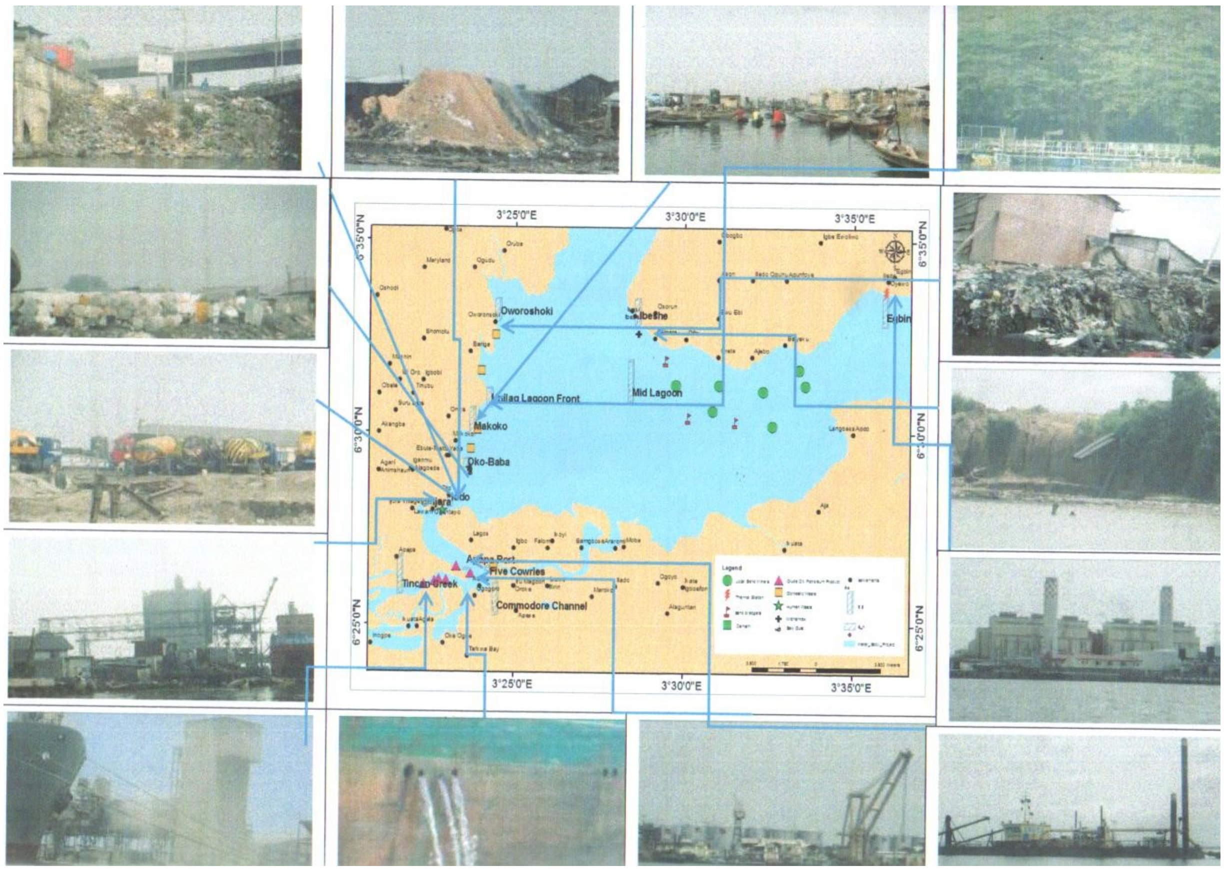

Plate 1: Activities around Lagos Lagoon

December 2012 and February 2013. These periods correspond to low water levels (the dry season) and peak flooding (Rainy season) in the Lagos. The raining season sampling was conducted between April to June 2013. One sample was collected from the control station making a total of 13 samples. The sediment samples were kept in labeled polythene bags and taken to the laboratory for analysis. The concentrations of the 8 heavy metals viz Lead (Pb), Arsenic (As), Iron (Fe), Cadmium (Cd), Zinc (Zn), Manganese (Mn), Copper (Cu) and Chromium (Cr) were examined based on standard methods of APHA 2006 for Heavy metals assessment spectrophotometrically using atomic absorptions spectrophotometer (AAS).

2.4 GIS and Database Development

Indicator parameters (Mn, Cd, As, Pb, Cr, Cu, Fe, and Zn) and sampled data were grouped into different classes of metals. GIS Database system tools were used to develop a visual display pattern to aid in the study. From the attribute geo-data base table, series of Query analysis were used to produce a risk assessment map along the Lagos Lagoon. Each of the result was then interpreted and displayed in table and maps for better understanding and visualization.

3. RESULTS AND DISCUSSION

The results obtained for the various sediment samples for both the dry season (December, January and February) and rainy season (April, May and June) are shown in table 2. It was observed that the level of pollution varies from one location to the other depending on the activities around each location.

Table 2: Heavy metals' mean concentration: Dry (Dec, Jan, Feb) and Rainy (Apr, May, Jun) seasons

		A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	NSD WQ
Mn (mg/l)	Dry	109.7	82.2	104.0	99.6	53.8	84.2	176.8	90.4	225.9	124.4	60.3	114.0	72.2	0.2
	Rainy	193.8	138.6	142.8	143.7	98.0	107.2	286.6	135.1	336.5	179.4	108.3	219.1	137.2	
Cd (mg/l)	Dry	5.9	3.7	4.0	8.2	6.8	12.8	14.0	12.3	9.5	16.5	13.1	19.6	5.7	0.003
	Rainy	9.1	6.1	6.0	13.2	14.7	25.9	19.7	21.7	14.7	21.8	13.1	28.7	9.3	
As (mg/l)	Dry	25.8	61.5	11.4	54.1	36.1	22.2	33.3	13.5	10.0	16.3	15.5	70.5	7.1	0.01
	Rainy	40.7	87.3	16.0	78.2	49.4	29.4	33.3	22.2	19.2	29.7	22.5	90.3	24.9	
Pb (mg/l)	Dry	9.7	13.5	17.1	30.5	20.1	16.0	17.1	16.1	13.4	25.3	28.6	23.0	3.2	0.01
	Rainy	20.2	23.3	27.8	51.1	30.7	22.3	23.9	22.8	20.5	41.9	40.6	31.7	3.9	
Cr (mg/l)	Dry	2.5	2.4	2.9	12.7	7.2	4.7	10.9	10.8	4.9	11.8	14.0	14.7	2.2	0.05
	Rainy	6.0	4.0	6.2	17.2	11.0	7.2	14.4	15.3	8.6	17.6	19.7	17.0	3.5	
Cu (mg/l)	Dry	11.7	12.7	9.8	22.6	9.3	9.9	18.4	15.5	13.7	11.9	10.7	17.4	8.2	1
	Rainy	16.3	12.6	15.2	37.2	19.0	17.8	24.0	21.4	19.8	16.4	10.7	16.2	8.2	
Fe (mg/l)	Dry	1047	1231	1090	1680	1801	1090	2146	1334	1823	1320	1030	1138	852	0.3
	Rainy	1597	1712	1957	2554	2608	1586	2962	1618	3093	1718	1030	1708	1399	
Zn (mg/l)	Dry	3.6	13.0	14.2	15.2	10.3	8.5	12.4	14.6	15.2	29.8	17.4	6.4	4.7	3
	Rainy	6.1	19.0	18.0	20.5	15.7	12.3	15.9	19.5	18.7	35.2	23.0	6.5	11.0	

The mean concentrations of the 8 heavy metals analyzed from the Lagos Lagoon sediment during dry and rainy seasons are discussed and compared with Nigerian Standard for Drinking Water Quality (NSDWQ, 2007)?

Manganese (Mn): The concentrations of Mn during the dry season are in the range of*225.9 to 53.8*in decreasing order of A9>A7>A10>A12>A1>A3>A4>A8>A6>A2>A13>A11>A5while the rainy season are in the range of 336.5 to 98.0indecreasing order of A9>A7>A12> A1>A10>A4>A3>A2>A13>A8>A11>A6>A5 (Table 2; Fig. 2a). The mean concentration of all the thirteen-sampled station exceeds the permissible standard limit of 0.2mg/l for Mn as recommended by the NSDWQ (2007). The highest concentration for the two seasons was detected in Egbin lagoon; this is largely attributed to the materials used in building the hydropower station in the area within the Lagos Lagoon while it is understandable that the lowest value is detected in Makoko as the inhabitants of the area used wood and plank in building their houses and their boats. The Adverse effects of Mn can result from both deficiency and overexposure.

Cadmium (Cd): The concentration of *Cd during dry season* are in the range of *19.6mg/l to 3.7mg/l and* in decreasing order *of A12>A10>A7>A11>A6>A8>A9>A4>A5>A1>A13>A3>A2* while the rainy season are range of 28.74mg/l to 6.0mg/l and in decreasing order of *A3>A2>A1>A13>A11>A4>A5>A9>A7>A8>A10>A6>A12* (Table2; Fig. 2b). High concentration of cadmium detected could be attributed to shipping company coming into Nigerian territorial water and local air pollutant.

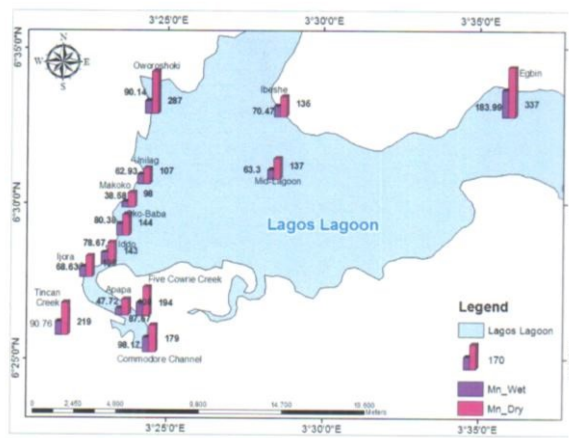

Fig. 2a: Manganese concentration

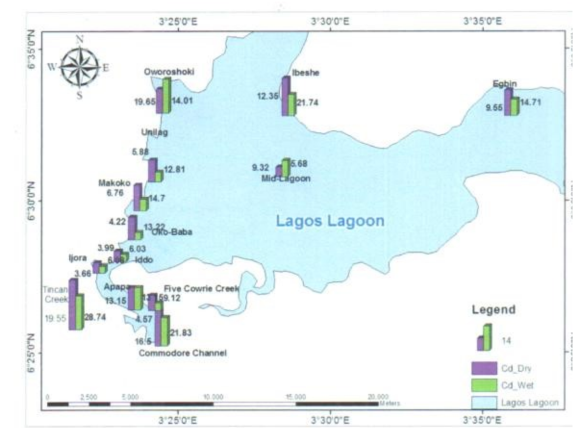

Fig. 2b: Cadmium concentration

Arsenic (As): The concentration of *As* for dry season ranges between 70.5and7.1*mg/l,* and in decreasing order of *A12>A2>A4>A5>A7>A1>A6>A10>A11>A8>A3>A9>A13* while the rainy season mean concentration is between 90.3 *and* 16.0*mg/l,* and in decreasing order *A12>A2>A4>A5>A1>A7>A10>A6>A13>A11>A8>A9>A3* (Table 2 & 3; Fig. 2c). The high concentration of Arsenic detected in dry season is within Apapa Port while commodore channel has the lowest mean concentration. During the wet season, Tincan Creek experienced the highest mean concentration. These could be attributed to human an thropogenic activities of sand mining either through industrial mining or bottom sand miners within the Lagos Lagoon.

Lead (Pb): The concentration of *Pb* for dry season are in the range of*30.5 mg/l to 3.2 mg/l, and in decreasing order A4>A11>A10>A12> A5>A3>A7> A8>A6>A2> A9>A1>A13*while the rainy season are between 51.1*and3.9 mg/l,* and in decreasing order of *A4>A10>A11>A12>A5>A3>A7>A2>A8>A6>A9>A1>A13* (Table 2; Fig. 2d). The high concentrations of Lead can be attributed to human activities within the Lagos Lagoon especially from commercial speed boat and freight load carrier using petrol (PMS-Premium Motor Spirit) and other industrial activities within the Lagos Lagoon where fossil fuels are burned. The concentration of Lead (Pb) detected in the sediment sampled analyzed within the Lagos Lagoon is far above the NSDWQ (2007) limit.

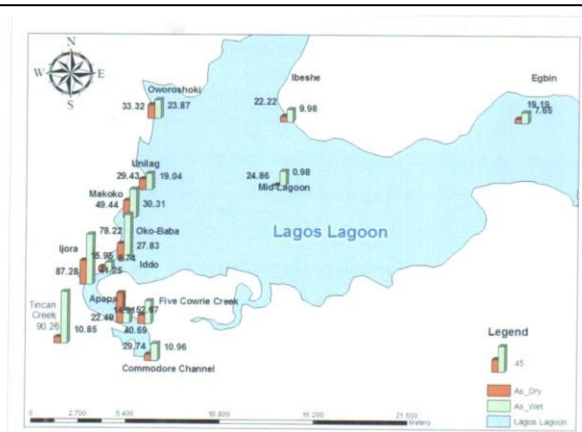

Fig. 2c: Arsenic concentration

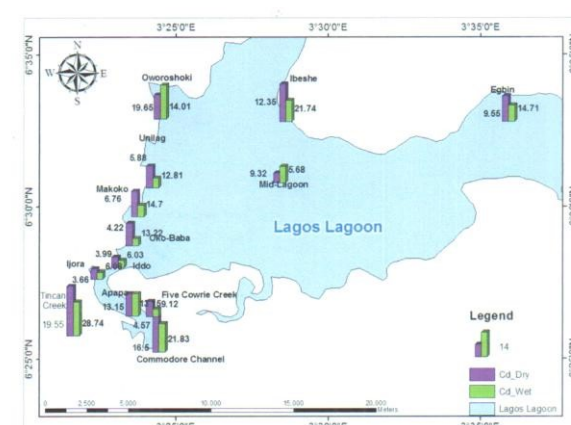

Fig. 2d: Lead concentration

Chromium (Cr): The concentration of Cr for dry season was in the range of *14.7mg/l to 2.2 mg/l,* and in decreasing order*A12>A11>A4>A10>A7>A8>A5>A9>A6> A3>A1>A2>A13,* while the rainy season mean concentration ranges between *19.7and 3.5mg/l,* and are in the decreasing of*A11>A10>A4>A12>A8>A7>A5>A9>A6>A3> A1>A2>A13*(Table 2; Fig. 2e). The concentrations of Chromium detected in all the 13 locations sampled are far above the NSDWQ (2007). The high concentrations can be attributed to human anthropogenic activities (e.g. metal alloys, paints, cement bag, paper, rubber etc are discharged into the Lagos Lagoon.

Copper (Cu): The concentration of *Cu* in the analyzed sediments during the dry season is in the range of *18.4 mg/l* and *8.2 mg/l,* with decreasing order of*A4>A7>A12>A8>A9>A2>A10>A1>A11>A6> A3>A5>A13*. On the other hand, the rainy season ranges between *37.2*and *8.2mg/l* with decreasing order of*A4>A7>A8>A9>A5>A6>A10>A1>A12>A3> A2>A11>A13* (Table 2; Fig. 2f). The high concentration of Copper for dry season is detected in Oworoshoki location while for wet season Okobaba has the highest concentration. These may be due to influx and high tide of Atlantic Ocean experienced during this season. All of the activities introduced by human knowingly or unknowingly can lead to high increase of Copper detected within the sampling locations. The concentrations are noted to have exceeded standard permissible limit of NSDWQ (2007). Therefore, all levels can be considered to pose a great threat to the local environment.

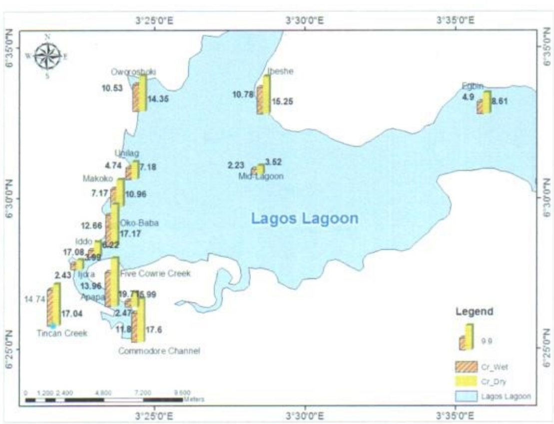

Fig. 2e: Chromium concentration

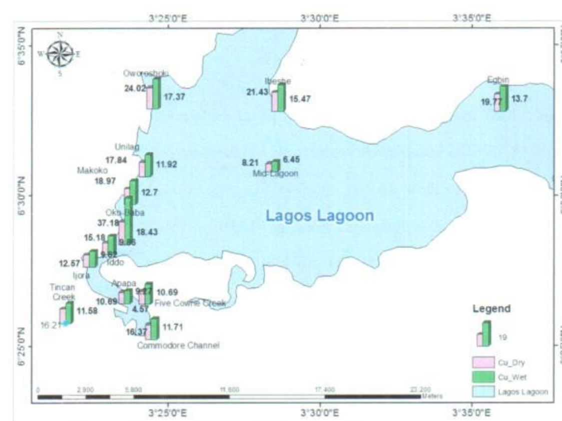

Fig. 2f: Copper concentration

Iron (Fe): The concentration of *Fe* in the sediment collected along the Lagos Lagoon during the dry season ranges between *2147*and*852mg/ with* decreasing order of *A7> A9>A5>A4>A8>A10>A2>A12>A6>A3 >A1>A11>A13*. On the other hand, the rainy season ranges between *3093 and 1030mg/l* with decreasing order *A9>A7>A5>A4>A3>A10>A2>A12>A8>A1>A6 >A13>A11* (Table 2; Fig. 2g). The concentration of iron detected is far above the NSDWQ (2007) limit. High concentration of Fe found in all the sampling location for the two seasons could be attributed to the influx of waste and indiscriminate discharged of domestic waste as well as other anthropogenic wastes which are washed and drained into the Lagos Lagoon.

Zinc (Zn): The concentration of *Zn* in the Lagos Lagoon sediment for dry season ranges between *29.8*and*3.6mg/l,* and are arranged in decreasing order of *A10>A11>A4>A9>A8>A3>A2>A7>A5>A6>A1 2>A13>A1* while the rainy season, the concentration ranges between *35.2and 6.1mg/l,* and are arranged in decreasing order of *A10>A11>A4>A8>A2>A9>A3>A7>A5>A6>A1 3>A12>A1* (Table 2; Fig. 2h). There was variation in Zinc level in the Lagos Lagoon. The high Zinc concentration detected could be largely attributed to large quantities of Zn present in the wastewater of industrial plants discharged directly or indirectly into the Lagoon.

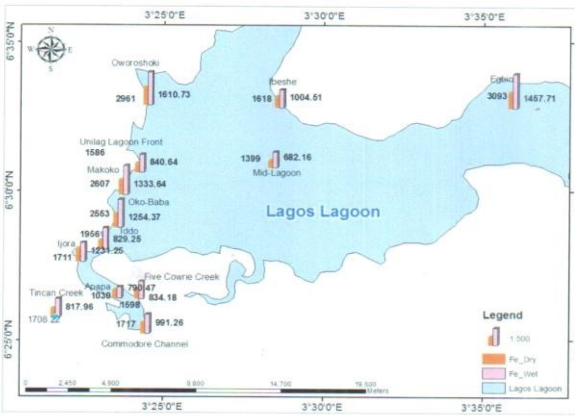

Fig. 2g: Iron construction

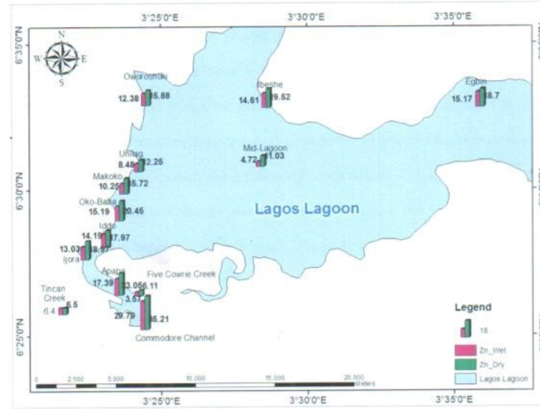

Fig. 2h: Zinc construction

4. CONCLUSION

Thirteen areas were identified to have high concentration of heavy metals and as well the possible factors responsible for their concentration. These areas are Five cowry's creek, Ijora, Iddo, Ibeshe, Commodore channel, Okobaba, Makoko, Oworoshoki, Egbin, Unilag Lagoon front, Tincan Creek, Apapa port and Mid Lagoon. The factors responsible for their concertation in the lagoon bottom sediment are mainly domestic/urban waste, industrial waste both solid and effluent, sewages, etc. The concentrations of all the heavy metals vary from one location to the others. The variations in the concentrations of the sampled heavy metals in both dry and rainy seasons particularly the high concentrations of Mn around Egbin (A9), Cd around Tincan (A12) and Commodore Channel (A10), As at Tincan creek (A12), Pb at Apapa (A11), Cr around Apapa (A11), Cu at Okobaba (A4) and Oworoshoki (A7&), Fe around Egbin (A9) and Oworoshoki (A7), and Zn at Commodore Channel could be resulted from industrial waste and effluent, urban waste, oil from ship and speedy boat as well as atmospheric deposition which are discharge into Lagos Lagoon may contribute to the variation of parameters concentration. Also, the low value of Mn, As, Cr, Pb, Cd and Zn in Mid Lagoon (control point) in both season could be attributed to pollution free activities in the area. It was observed that various activities surrounding Lagos Lagoon are responsible for the heavy metals detected.

This study therefore, concluded that Lagos lagoon is contaminated, though, some of the metals are not above safe or permissible levels and may not present any deleterious effects in the present levels, further discharges from respective sources suggest possible detrimental effects on the local environment.

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