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Analysis and Seasonal Distribution of Some Heavy Metals in Sediment of Lagos Lagoon Using Environmental Pollution Indices

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Authors' contributions

This study was carried out in collaboration between both authors. Author OAA designed the study, wrote the protocol and the first draft of the manuscript. Both authors POO and OAA managed the analysis and literature searches, read and approved the final manuscript.

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ABSTRACT

Some heavy metals *(*Mn, Pb, Cr, As and Zn) analysis and their seasonal distribution between in the sediment samples of Lagos Lagoon were studied during the dry and wet seasons in November, 2012 to June, 2013 using Atomic Absorption Spectrophotometer (AAS). Contamination Factor (C_f), Degree of Contamination (C_d) and Pollution Load Index (PLI) were the pollution indices employed to ascertain whether the contamination is anthropogenic or natural. Six sampling stations (Iddo, Ijora, Five cowries' creek, Apapa port, Tincan creek, Commodore channel) were identified due to some anthropogenic activities observed in each station. Pb concentrations in all stations were within the permissible limits of 40 mg/kg of USEPA and Department of Petroleum Resources (DPR) of Nigeria except in stations 4 and 6 in wet season. Mn levels in all the analyzed sediments were also exceeded USEPA and DPR values of 46 mg/kg during the two seasons. Cr and Zn are within

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the permissible limits in all the stations during the wet and dry season hence, reflecting their natural background levels in the sediment. The concentration of As in all the analyzed sediments were exceeded the USEPA value of 9.8 mg/kg. Comparison between the results obtained from the sediment analyzed during dry and wet seasons for metal concentration indicates that all the contaminants are significant at $P< 0.05$ level during the dry and wet seasons except for Pb and Cr that are significant at $P< 0.01$ level while As and Mn are not significantly correlated between the two seasons. The metals concentrations decrease in order of Mn > As > Pb> Zn > Cr in the study areas during dry and wet seasons. The mean concentration of metals in sediment for the two seasons is significantly correlated at P=0.05 and 0.01 which implied that the metals increase within the seasons in the sediment. Sediment contamination by heavy metal based on the above indices showed that the study area have very high degree of metal contaminations.

Keywords: Heavy metals; sediment; wet and dry seasons; USEPA; DPR; contamination factor; degree of contamination; pollution load index.

1. INTRODUCTION

The Lagos Lagoon is vastly impacted by numerous wastes that posed a stern threat to the communities that largely depends on it for the source of income especially the masses living along the waters' edge. Wastes of anthropogenic origin often contaminate the Lagoon and creeks in Lagos [1]. Majority of the debris are largely plastics, nylon bags, empty cans of food and drinks, glass bottles, used needles and syringes, and used car tyres etc. Marine sediment is frequently used as indicator for spatial and temporal trends in monitoring of the aquatic ecosystem. The contamination of sediment is one of the main environmental problems that are often require frequent study and monitoring in order to maintain good health and sustenance of aquatic biota since about 70% of Lagos Lagoon is a reservoir for surface runoffs, industrial and domestic discharge as well as input from several rivers [2]. Heavy metals such as cadmium, mercury, lead, copper, arsenic, copper, iron and zinc are considered the most important pollutants of aquatic ecosystems owing to their persistence, toxicity and ability to be integrated into food chains [3]. Globally, metals generally persist and bio-accumulate in the living organisms in the natural ecosystem when they exceed their permissible level [4]. Quantity of wastes discharge to the aquatic environment often lead to bioaccumulation of heavy metal in the aquatic ecosystem, consequently leading to decline of the physical, chemical and biological change of the aquatic environment [5].

The amount of heavy metals in water are majorly in minute quantities whereas excessive concentration can be identified in the sediment sample thereby, affecting aquatic biota and causing risk to consumers of aquatic seafood [6]. The assessment of sediments developed recently into a foremost issue of significance that can reveal the existing quality of the environment as well as provide vital information on the anthropogenic activities within the aquatic biota. Sediment can be defined as loose sand, clay, silt and other soil particles that settle at the bottom of body of water [7]. Corrosion of bedrock and soils leads to accumulation of sediment of current natural and anthropogenic activities as well as their component [8]. The major contributing factor to metal contamination in the sediment are through numerous pathway such as industrial disposal of liquid effluents, surface runoff, domestic discharge and leachates carrying chemicals originating from numerous urban and agricultural activities as well as atmospheric deposition [9]. Consequently, data from sediment can provide series of information on the impact of anthropogenic activities on the broader environment since sediment is the final sink for metals accumulation. Constituents of sediments progression present the most efficient natural archives of current environmental changes within the aquatic biota. Universally, sediments are significant medium of assessment of anthropogenic inputs in the aquatic ecosystem. Therefore, metal concentration and distribution in sediment can best provide current information about spatial extent as well as magnitude of anthropogenic induced chemical change of the environment thereby leading to useful indicators of contaminant in aquatic ecosystems.

The objectives of this study were to evaluate the spatial and seasonal distributions of heavy metals in the sediment of Lagos Lagoon and compare with sediments quality guidelines. The ecological risk deduction was also made from the results using contamination factor, degree of contamination and pollution load index tools.

These pollution indices are powerful tools to assess heavy metals contamination in sediments, which includes;

1.1 Contamination Factor (Cf)

The extent of contamination of sediment by a metal is often expressed mathematically in terms of a contamination factor calculated by

$$CF = \frac{Metal\ content\ in\ the\ sediment}{Background\ level\ of\ metal} \quad (1)$$

Where CF < 1 refers to low contamination, 1 ≥ CF ≥ 3 means moderate contamination, 3 ≥ CF ≥ 6 indicates considerable contamination, and CF > 6 indicates very high contamination.

1.2 Degree of Contamination (Cd)

This is used to evaluate the extreme values of monitored elements in soil sediment samples. It is express mathematically as given in equation 3. CiF is the contamination factor for the i-th elements.

$$C_{d} = \Sigma\, Ci_{F} \quad (2)$$

Where (Cd)<6 refer to Low degree of contamination, 6≥Cd ≥12 mean moderate degree of contamination, 12≥Cd≥24 refer to high degree of contamination and Cd>24 refer to very high degree of contamination.

1.3 Pollution Load Index (PLI)

This is used to evaluate specific sampling site, according to the method proposed by [11] and it is expressed as:

$$PLI = [CF1xCF2x \ldots \ldots \ldots \ldots \ldots xCFn]1/n \quad (3)$$

Where, n is the number of metals in the present study and CF is the contamination factor.

2. MATERIALS AND METHODS

2.1 Study Area Description

Lagos Lagoon is one of the largest Lagoon systems of the Gulf of Guinea. The Lagos Lagoon receives a number of important large rivers including Osun, Yewa, Ogun and Ona rivers. This Lagoon empties directly into the Atlantic Ocean at Lagos Harbor. It lies between longitude 3°10ʹ and 3°4ʹ E and latitude 6°5ʹ and 6°36ʹ N (Fig. 1).

2.2 Sample Collection

Sediment samples were collected with the aid of Van Veen grab at each station from the months of November, 2012 to June, 2013 and stored immediately in black polythene bags. The samples were stored at 4ºC in an ice-box and transported to the laboratory. The entire samples were separately air-dried in the laboratory. After drying the sediments, it was homogenized and sieved to remove big particulates. Homogenized sediment samples were then digested as follows: 1 g of the powdered sediment samples were weighed into a 100 ml beaker. 25 ml of freshly prepared mixture of aqua regia (HNO_3 /HCl in ratio 1:3) were added to each sample and

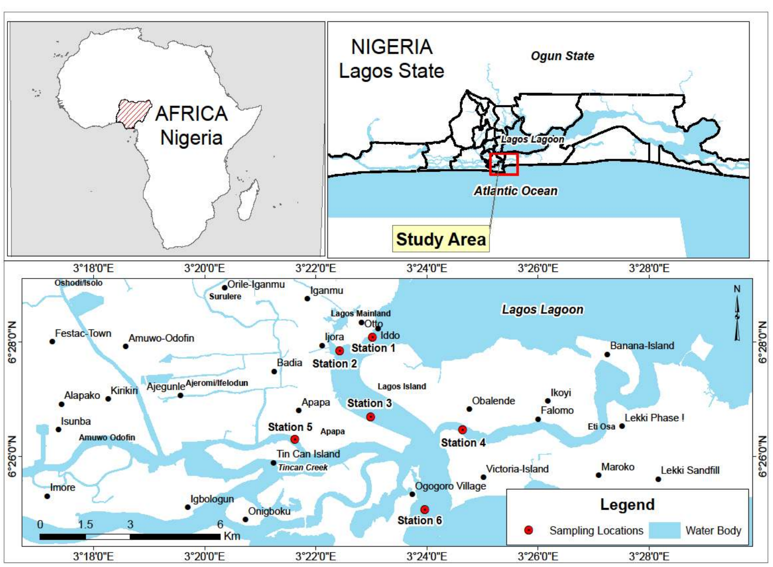

Fig. 1. Map of the study area showing the sampling locations

Table 1. Description of sampling stations and local activities

Station	Longitude	Latitude	Sampling area description	Location	Waste type
1	3°23' 5.602"	6°28' 02.7"	Based on the visitatio n of itinerant tankers to the jetty to discharge raw faeces.	Iddo	Sewage
2	3°22' 37.8"	6°27' 54.7"	Wastes are majorly from seafood, cement bag washing, as well as influx of sewage discharged from Iddo all find their way into Ijora.	Ijora	Industrial
3	3°23' 48.6"	6°26' 17.9"	Receives wastes from Ik oyi, Lagos Island and Victoria Island.	Five cowries	Domestic and industrial
4	3°22' 42.4"	6°26' 48.5"	Seaport activities with various effluents from the sea well as ship discharge from the passing vessel.	Apapa port	Industrial
5	3°21' 37.44"	6°25' 46.8"	It houses most of the oil port and tank farms in the Lagos Lagoon as well as effluents from the Port novo creek, Badagry Creek and the commodore channel.	Tin can creek	Industrial and domestic
6	3°24' 26.0"	6°25'14.1"	Characterized by differe nt types of wastes from ship discharged as well influx of others domestic wastes from Victoria Island.	Commodore channel	Industrial and domestic

covered with a watch glass. It was allowed to stand for 30 minutes during which initial reaction subsided [10].

Digestion was carried out on hot plate whose temperature was allowed to rise gradually until it reached a maximum temperature of 160ºC in a fume cupboard. Heating was continued for about 2 hours, reducing the volume in the beaker to about 2 – 5 ml. The beaker and its contents were allowed to cool and the content was transferred through whatman's filter paper into a 50 ml volumetric flask and made up to mark with distilled water. The digested samples were then analyzed for Pb, Zn, Mn and Cr using a Flame Atomic Absorption Spectrophotometer model Varian SpectAA 400. While As was detected with the aid of Varian AA240 hydride generated Atomic Absorption Spectrophotometer (AAS).

2.3 Statistical Analysis

The metals were evaluated using the One-way Analysis of Variance (ANOVA) and means were compared using Duncan multiple range test. P values < 0.05 were considered significant.

3. RESULTS AND DISCUSSION

The mean concentration of each metal examined in the sediment from each sampling station is shown in Table 2 and Figs. 2-6. Mean metal concentrations ranged within the following intervals during the dry season: Mn: 124.42 -60.3 mg/kg, As: 70.46-11.3 mg/kg, Pb: 28.6-9.73 mg/kg, Cr: 14.19-2.43 mg/kg and Zn:29.8-6.4 mg/kg while their mean concentrations during the wet season were Mn: 219.13-139.07 mg/kg, As:90.26-22.5 mg/kg, Pb: 41.89-21.17 mg/kg, Cr: 19.7-4.92 mg/kg and Zn: 35.21-6.5 mg/kg. The metals concentrations are arranged in order of their distributions in the sampling stations during the dry season as follows: Mn>As>Zn>Pb>Cr while the mean metal concentrations arrangement for wet season as follows: Mn>As>Pb>Zn>Cr. The high levels of heavy metals obtained in the sediments of the Lagos Lagoon could probably be associated with the following activities such as sewage, cement bags washing, domestic and industrial wastes that took place within and around the Lagoon. The highest mean metal concentration values for Mn and Zn were recorded at station 6 while station 4 and 5 recorded the highest mean metal concentrations for Pb, As and Cr in the dry season. These were expected due to large number of fishing vessel and fuel dispensing points that are heavy at these sampling stations. In the wet season the highest mean metal concentrations value for Mn and As were detected in the station 5 while the highest mean metal concentrations were recorded for Pb, Zn and Cr in station 4 and 6. The results generally signified that mean concentrations of all heavy metals in the sediment samples analyzed during wet season were higher than concentrations of all heavy metals during dry season.

Table 2. Mean concentration of heavy metals ± SD (mg/kg) and their standard geochemical background value

Station	Dry season					Wet season				
	Mn	As	Pb	Cr	Zn	Mn	As	Pb	Cr	Zn
Ijora	82.19±0.92	61.52±0.28	13.5±1.56	2.43±0.08	13± 1.47	176.73±1.37	55.46±1.37	21.17±1.46	5.18±1.56	10 .47±1.88
Iddo	104.05±1.24	11.39±1.98	17.09±1.19	2.93±1.63	14 .19±1.23	139.07±2.58	62.48±1.49	24.18±1.97	4.92±0.9 0	18.81±1.83
Five cowries creek	109.66±0.93	25.78±1.67	9.73±1.22	2.48±1.05	3.57±1.73	159.35±0.91	25.99±1.60	25.9±2. 36	6.1±0.91	13.78±1.74
Apapa port	60.3±1.73	15.49±1.63	28.61±1.78	13.96±0. 69	17.39±1.49	108.26±3.42	22.5±1.59	40.64±2.01	19.7 1±0.71	23.04±1.80
Tincan creek	114.01±1.77	15.49±1.84	22.96±1.67	14.7 4±1.07	6.4±1.82	219.13±2.21	90.26±1.54	31.7±2.34	17 .04±1.24	6.5±1.02
Commodore channel	124.42±3.52	15.49±1.65	25.34±1.58	11.8±1.05	29.8±1.29	179.37±3.76	29.74±1.46	41.89±1 .47	17.6±1.32	35.21±1.63
World surface rock value	720	13	20	97	129	720	13	20	97	129

SD = Standard deviation

Table 3. The mean of heavy metal and Duncan's multiple range tests using one way-ANOVA

	Dry season					Wet season				
Station	Mn	As	Pb	Cr	Zn	Mn	As	Pb	Cr	Zn
Ijora	82.19^{1}	61.52^{2*}	$13.50^{1\ 2*}$	2.43^{1*}	$13.00^{2\&3*}$	$176.73^{2\ \&\ 3}$	$55.46^{1\&2*}$	21.17^{1*}	5.18^{1*}	10.47^{1*}
Iddo	104.05^{1}	11.39^{1*}	$17.09^{1,\ 2\ \&3*}$	2.93^{1*}	14.19^{3*}	$139.07^{1\&2}$	$62.48^{1\&2*}$	$24.18^{1\&2*}$	4.92^{1*}	$18.81^{2\&3v}$
Five cowries creek	109.66^{1}	25.78^{1*}	9.73^{1*}	2.48^{1*}	3.57^{1*}	$159.35^{1,\ 2\ \&3}$	25.99^{1*}	$25.90^{1\&2*}$	$6.10^{1\ *}$	$13.78^{1\&2*}$
Apapa port	60.30^{1}	15.49^{2*}	28.61^{4*}	13.96^{2*}	17.39^{3*}	108.26^{1}	22.50^{1*}	40.64^{2*}	19.71^{3*}	23.04^{3*}
Tincan creek	114.01^{1}	70.46^{2*}	$22.96^{2,\ 3\ \&\ 4*}$	$14.74^{1\ \&2*}$	$6.40^{1\&2*}$	219.13^{3}	90.26^{2*}	31.70^{3*}	17.04^{2*}	6.50^{1*}
Commodore channel	124.42^{1}	16.34^{1}	$25.34^{3\ \&\ 4*}$	11.80^{2*}	29.80^{4*}	$179.37^{2\&\ 3}$	29.74^{1*}	41.89^{3*}	17.60^{2*}	35.21^{4v}

Values are the means of metals per station. Means in a row with the same superscript are not significantly different from each other.
$^{1\text{-}4}$Means in a row with different superscript are significant ($P < 0.05$)

Table 4. Pearson correlation matrix for heavy metal concentration during the dry and wet seasons

		Mn.Dry	As.Dry	Pb.Dry	Cr.Dry	Zn.Dry	Mn.Wet	As.Wet	Pb..Wet	Cr.Wet	Zn. .Wet
	1										
Mn.Dry	0.245	1									
As.Dry	-0.113	0.291	1								
Pb.Dry	$.565^{*}$	0.316	0.027	1							
Cr.Dry	$.747^{**}$	0.199	0.133	$.841^{**}$	1						
Zn.Dry	0.399	0.233	-0.321	$.631^{**}$	0.388	1					
Mn.Wet	0.225	$.699^{**}$	$.673^{**}$	0.12	0.226	-0.094	1				
As.Wet	-0.079	0.234	$.622^{**}$	-0.059	0.071	-0.25	0.408	1			
Pb.Wet	$.786^{**}$	0.215	-0.219	$.854^{**}$	$.805^{**}$	$.665^{**}$	-0.043	-0.307	1		
Cr.Wet	$.843^{**}$	-0.024	-0.044	$.764^{**}$	$.891^{**}$	0.431	0.031	-0.143	$.845^{**}$	1	
Zn Wet	$.469^{*}$	0.062	$-.605^{**}$	0.44	0.216	$.829^{**}$	-0.379	-0.44	$.683^{**}$	0.367	1

**. Correlation is significant at the 0.05 level (2-tailed), **. Correlation is significant at the 0.01 level (2-tailed)*

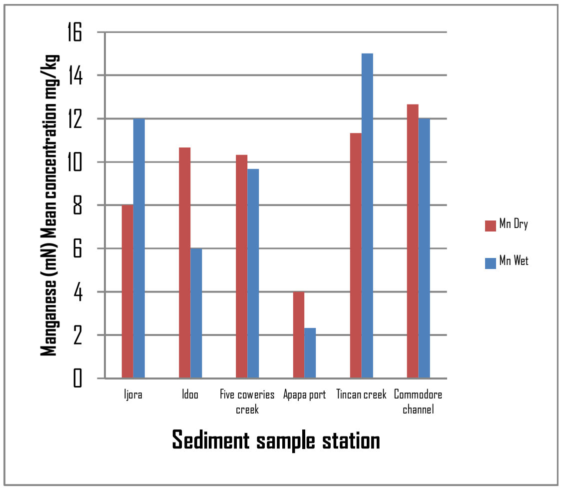

Fig. 2. Manganese concentration in the sediment

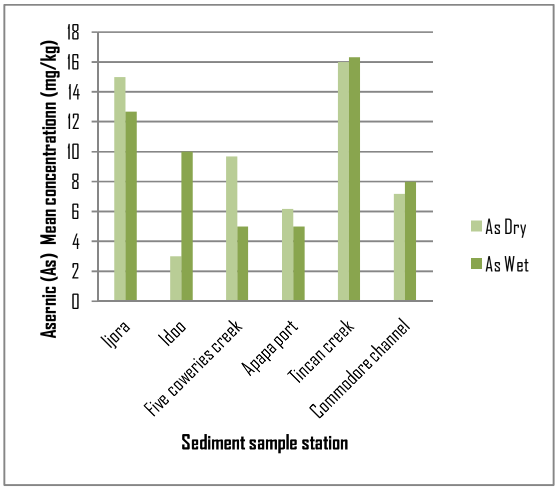

Fig. 3. Arsenic concentration in the sediment

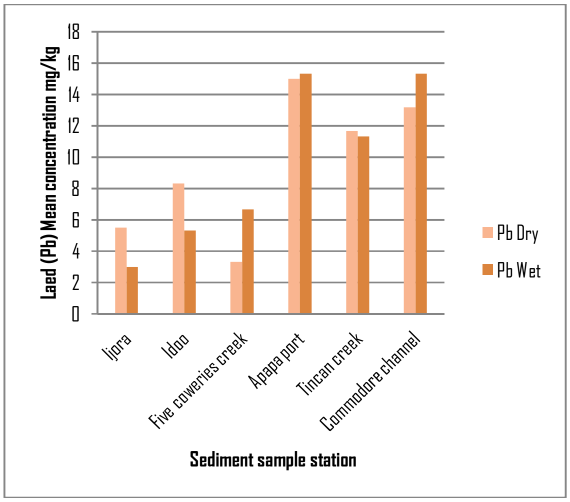

Fig. 4. Lead concentration in the sediment

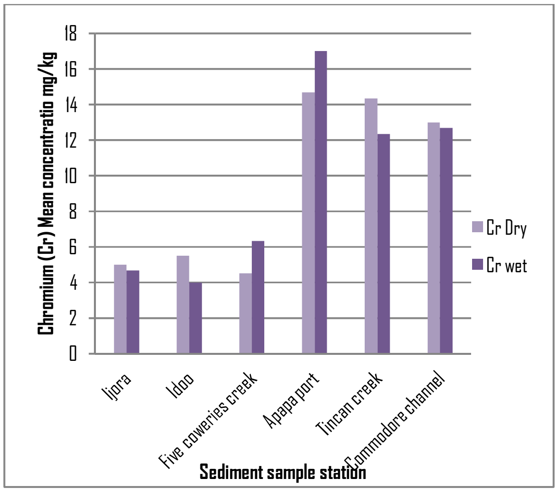

Fig. 5. Chromium concentration in the sediment

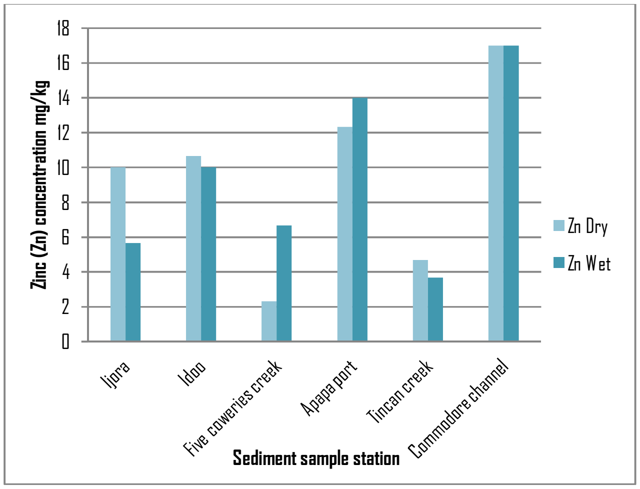

Fig. 6. Zinc concentration in the sediment

ANOVA was used to establish whether cluster of variables have the same means on data that are continuous distributed and with homogeneous variance using Duncan multiple range. Furthermore, it was used to evaluate the relationship between heavy metal concentrations and their elemental interaction between sections of the stream. There was significant difference (P<0.05) between the level of heavy metals during the two seasons except for Mn (Table 3).

3.1 Pearson's Correlation Coefficient

Pearson's correlation coefficient matrix among the selected heavy metals is presented in Table 4. Significant correlations between the contaminants during the dry season was between Pb and Cr (r=0.865), Pb and Zn (r=0.692), Cr and Pb (r=0.865), which probably indicate the related source input during the dry season while for wet season, the significant correlation between the metal concentration is between Mn and Pb (r=0.731), Pb and Mn (r=0.731), Pb and Cr (r=0.809), Pb and Zn(r=0.802), Cr and Pb (r=0.809), Zn and Pb (r=0.802) may possibly signify the similar source. Lagos Lagoon is surrounded by very old buildings with galvanized (zinc coated) roofing sheets and with the walls painted with lead-containing paints. So the high correlation between Zn and Pb in sediment could be attributed to roofing sheets and paints from the homes located along the shore of the Lagos Lagoon. The availability of As at a location has been attributed to the unsuitable disposal of electronic waste, industrial effluents, fertilizers in agricultural surface runoff and atmospheric depositions [12]. By comparing the result obtain from metal concentrations during the dry and wet season respectively, it could be shown that all the metals are significant at P>0.05 level during the dry and wet seasons except for Pb and Cr that are significant at 0.01 level while As is not significantly correlated between the two seasons.

Evaluations of the metal contaminations in the sediment were estimated by comparison with the sediment quality guideline proposed by [13] and [14]. These criteria are shown in Table 5. The Mean concentration of metals in the present study shows that all the sites according to the USEPA scale indicated a heavy pollution level for Mn and As while for Pb in station 4 is moderately polluted during the wet season. For Cr and Zn are within the permissible limits for the two seasons in all the stations, hence, not polluted.

3.2 Contamination Factor (C_F) and Degree of Contamination (C_d)

The values of the studied metals from all six sampling stations are shown in Table 6. This present study, the highest C_F value was obtained for As and therefore give a very high contamination factor while low contamination factors are being registered for Cr and Zn. Based on the mean C_F values, the sediments sampled analyzed in during the two season may probably be considered to be enriched by the examined metals in the following order: As > Mn > Pb > Cr > Zn. CF values for metals analyzed in the sediment shows higher (>1) values due to the influence of anthropogenic inputs except for Zn during the dry season. The cumulative effect of each mean metals presents in the sediment sample at each of the stations signify that station 5 has the highest degree of contamination while station 2 record the lowest contamination during the dry season and station 4 has the lowest degree of contamination during the wet season.

3.3 Pollution Load Index (PLI)

The values of Pollution Load Index (Fig. 7) were found to be generally higher (<1) in all the studied stations except in Zn which is 0.93 during the dry season. The variation in index results obtained was probably due to the disparity in sensitivity of this index towards the sediment contamination [15]. This confirmed that Lagos Lagoon is currently undergoing possible environmental contamination especially with hazardous metals Pb and As.

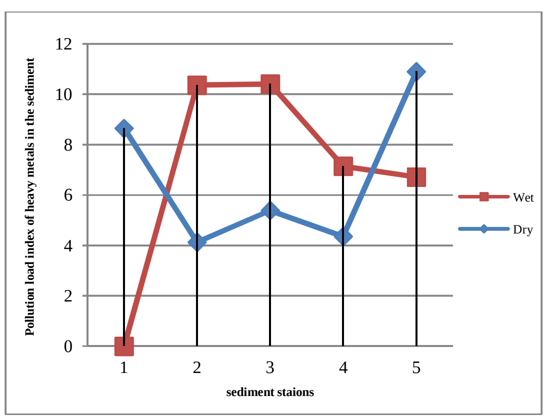

Fig. 7. Pollution load index of heavy metals in the sediment of Lagos Lagoon

Table 5. Comparison with USEPA guidelines for sediment

Metal	USEPA pollution level (mg/kg)			Present study (mg/kg)	
	Not polluted	**Moderately polluted**	**Heavily polluted**	**Dry season**	**Wet season**
Mn	<46		>46	55.17 – 137.56	105.25 - 194.76
Pb	<40	40-60	>60	9.62 - 27.59	15.65 - 89.65
Cr	<25	25-75	>75	2.09 - 12.07	3.89 - 19.65
As	<9.8		>9.8	10.94 - 72.86	44.18 - 18.98
Zn	<90	90-200	>200	3.88 - 29.06	6.05- 34.56

Table 6. Contamination factor (C_F) and degree of contamination (Cd) values for sediments of Lagos Lagoon

Station	Contamination factor (C_F) during dry season					Degree of contamination (C_d)	Contamination factor (C_F) during wet season					Degree of contamination (C_d)
	Mn	**As**	**Pb**	**Cr**	**Zn**		**Mn**	**As**	**Pb**	**Cr**	**Zn**	
1	1.79	6.3	0.3	0.1	0.14	8.65(2nd)	3.84	5.66	0.53	0.21	0.12	10.36(3rd)
2	2.26	1.2	0.4	0.12	0.16	4.13(6th)	3.02	6.38	0.6	0.2	0.21	10.41(2nd)
3	2.38	2.6	0.2	0.1	0.04	5.39(4th)	3.46	2.65	0.65	0.24	0.15	7.15(5th)
4	1.31	1.6	0.7	0.56	0.19	4.36(5th)	2.35	2.3	1.02	0.79	0.26	6.72(6th)
5	2.48	7.2	0.6	0.59	0.07	10.9(1st)	4.76	9.21	0.79	0.68	0.07	15.51(1st)
6	2.7	1.7	0.6	0.47	0.33	5.8(3rd)	3.9	3.03	1.05	0.7	0.39	9.07(4th)
Total per metal C_F	12.92	20.51	2.93	1.94	0.93	39.23	21.33	29.23	4.64	2.82	1.2	59.22

Heavy metals contamination in sediment is of major concern particularly in many modern countries due to their toxicity, persistence and bioaccumulative nature [16]. It has been reported that the high level of metal concentration observed in all the stations during the wet season may be due to influx of waste which influences their concentration and metals mobility which depends directly on the environment and some metals properties such as pH, organic matter concentration, silt and clay concentration, salinity, dissolved oxygen concentration [17]. However, it has been reported that mobility of heavy metals depends not only on the total concentration in the soil and sediment but also on the sediment properties, metal properties and environmental factors. Occurrence and spatial distribution patterns of Mn, As, Cr, Zn and Pb in Lagos Lagoon sediments were illustrated in Figs. 2-6. The mean concentrations of Pb in the sediments are within 40 mg/kg in USEPA Sediment Quality Guidelines except in station 4 and 6 that exceed the maximum permissible level. The results indicate that urbanization has contributed to the elevation of Pb content in the sediment. Domestic and industrial effluents, municipal runoffs and atmospheric deposition may be the major sources. The contribution of Pb from the use of leaded petrol in ship and speed boat operator is possibly significant. [18] reported that low concentrations of Pb still might pose a threat to life in a marine environment in comparison with other heavy metals. As mean concentration exceeds the permissible level of 9.8 mg/kg in all the sampling stations during the dry and wet season according to USEPA and DPR sediment quality guideline and have potential damage to the ecological communities according to the environmental protection agency of USA .The relatively low concentration detected in chromium and zinc in the sediment reflects their natural background levels in the sediment. [19] reported that Zn is a micronutrient for aquatic life in all natural water and sediments, even at low concentration Zn can become toxic to aquatic organisms at higher concentration level than the threshold required contents.

Mn in sediment during the wet season was higher than that of the dry season. This agrees with the finding of [20]. Mn has been found to occur at high concentrations in Lagos Lagoon [21]. Previous studies also have indicated elevated levels of heavy metals in aquatic systems receiving effluents from urban areas and the disposal of untreated sewage has been reported to contribute significantly to the level of heavy metals in the aquatic environment [22]. The finding in this study shows that metals concentration is higher in the wet season than in the dry season in all the stations which are probably due to urban surface run-off or influx of heavy metals containing waste substances and other anthropogenic activities within the sampling stations in the Lagoon. The chromium and zinc at sampling stations are within the permissible limit of USEPA for sediment quality guideline of 25 mg/kg and 40 mg/kg respectively while for Mn and As exceeded their permissible level in all the sediment sampled analyzed expect for Pb that exceed the permissible level in station 4. Generally, the pollution load index value significant increased as anthropogenic activities increased as well as dispersion of metal content with increasing distance from point of discharged. The relative low value of pollution load index in Zn indicates no significant input from anthropogenic sources. Table 6 shows the contamination factor of each element and the degree of contamination in each of the sampling stations. According to [23], the contamination factor for all the sampling stations fall within the high contamination factor and the values of contamination degree indicates high degree of contamination. The degree of contamination for the individual metal are within the range of 4.13-10.9 during the dry season while degree of contamination during the wet season are within the range of 6.72-15.51 which are more than 1.5, indicating very high C_d. The degree of contamination data signifies anthropogenic impact in all the sampling stations. Pollution load index were found to increase in sediments upstream along Lagos Lagoon (Fig. 7). This may be attributed to domestic and industrial effluents such as sewage discharges, cement bags washing and influx from the nearby rivers loaded with various wastes that are subsequently deposited into the Lagos Lagoon sediments.

4. CONCLUSION

The results obtained in this study indicate high levels of Mn, As and Pb at the sampling stations which was linked with the deleterious effect of anthropogenic activities on the Lagos Lagoon. The pollution indices are also very useful tools for identification of sediment contamination. Contaminations in the sediments were further evaluated by applying contamination factor, degree of contamination and pollution load index. The results of contamination factor, degree of contamination illustrated that the sampling station falls within high to very high contamination. Calculation of Pollution load Index the study area is regarded as polluted. Based on this study, the framework for mandatory action should be initiated for regular assessment of Lagos Lagoon to ensure conservation of Lagos lagoon coastal resources. There should be strict regulations to control the dumping of chemical contaminants into the lagoon with enforcement of penalties imposed on defaulters. Enlightenment programs for the public on the dangers of Lagos lagoon pollution are very necessary.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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