Trend of Heavy Metal Concentrations in Lagos Lagoon Ecosystem, Nigeria

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Abstract

The distribution and occurrence of heavy metals in the sediment, water and benthic animals of the Lagos lagoon during the dry and rainy seasons were investigated over a 7-year period. In the ecological surveys, the main body of the lagoon was divided into five zones, with a built-in bias to separate areas of the lagoon close to entry points of industrial effluents from the areas that were far away from the entry points. Types of heavy metals found to be prominent in industrial effluents were also the types prominent in the significant lagoon media and seasonal variation. The concentrations of the metals detected in the lagoon sediment and water increased by about 2–200 fold over the period of observation. For example, the mean concentration of sediment lead (Pb) increased over 130-fold from 2.38 µg/g in February 1991 to 400.33 µg/g in February 1995. Similarly, the concentration of metals bioaccumulated in the body tissues of benthic animals (*Tympanotonus fuscatus* and *Clibanarius africanus*) increased about 2–4 fold over a time interval of 5-7 years. Furthermore, sediment, water and animal samples collected from zones 1–3 of the lagoon that received most of the industrial effluents generally had higher concentrations than the samples collected from zones 4 and 5, which received fewer or no industrial effluents. The significance of the observed upward trend in the concentration of heavy metals, particularly the need to include benthic animals such as *T. fuscatus* in biomonitoring programmes aimed at controlling lagoon pollution and the potential risk to public health was discussed.

Introduction

Heavy metals are high priority pollutants because of their relative high toxicity and persistent nature in the environment. Therefore, a knowledge of the changing concentrations and distribution of heavy metals and their compounds in various compartments of the environment is a priority for good environmental management programmes all over the world.

In Nigeria, most investigations of heavy metals pollution have focused on occasional determination of the types and concentrations of such metals in industrial effluents (Akintola *et al.*, 1981; Bhalerao & Adeeko, 1981; Oyewo, 1998) and some segment of the ecosystem, particularly sediment and water column (Fodeke, 1979; Okoye, 1989; Chukwu, 1991; Ogunsua *et al.*, 1991). There is, however, a significant paucity of records on sustained and co-ordinated measurement of levels of heavy metals at identifiable sampling points of principal media in the recipient ecosystems. As long as human-induced generation of heavy metals continues in industrial and domestic activities, such sustained measurements will be needed to assess the effectiveness of set limitation standards and facilitate the identification and quantification of the state of environmental degradation attributable to the discharged heavy metals.

By virtue of its position the Lagos lagoon is surrounded by the densely populated and industrialised Lagos metropolis, making it a convenient dumping site for numerous industrial and domestic wastes. According to Singh *et al.* (1995), an estimated 10,000 m^3 of industrial effluents are discharged into the Lagos lagoon per day. Oyewo (1998) also established a mathematical relationship between the following (i) actual measurement of rate of flow of effluents from major types of industries in Lagos State, (ii) days of effluent production and emission, and (iii) the concentrations of heavy metals in such effluents over a period of one year. From these various factors, Oyewo (1998) estimated levels of heavy metals discharged into drains/canals/streams and, subsequently, into the Lagos lagoon as follows: Fe – 161,718 kg, Mn – 205,989 kg, CO – 15,683 kg, Zn – 7026 kg, Cr – 5285 kg, Pb – 2259 kg, Ni – 6124 kg, Cd – 538 kg and Hg – 278 kg per annum. These estimates also confirmed that the industries were a major source of metal contaminants in the drains, streams and the lagoon, since the graded prominence of metal types was similar in the sampled effluents and aquatic systems.

The paper reports on the 5 yearly monitoring of heavy metal levels in the sediment, water and selected benthic animals, *Tympanotonus fuscatus* var. *radula* and *Clibanarius africanus* of the Lagos lagoon. The first measurements were carried out between 1989–1991 and the second, five years later between 1994–1995. The main objective of the monitoring programmes is to establish the trend of heavy metal concentrations in the Lagos lagoon ecosystem.

Materials and methods

Study site and sampling design

The Lagos lagoon complex stretches from Cotonou in the Republic of Benin and extends to the fringes of the Niger Delta in Nigeria along its 257 km course (Hill & Webb, 1958). The main body of the lagoon complex which served as the study site lies between longitude 3° 22' and 3° 40' E and latitudes 6° 17' and 6° 28' N (Fig. 1).

The main body of the Lagos lagoon was divided into five zones with a built-in bias to separate areas of the lagoon close to entry points of industrial effluents (I - III) from areas which are further away from entry points of effluent laden discharges and taken as control zones (IV - V). Within each zone, three sampling stations were randomly selected and taken as replicates thereby giving a total of 15 sampling stations within the lagoon (Fig. 2). Sampling was carried out in February and July representing the dry and wet seasons, in two sets: 1989-1991 and 1994-1995.

Collection of samples for analysis

At each of the sampling stations, water samples were collected using a hydrobios water sampler, while sediment and benthic animals were collected with the aid of a Van Veen grab.

Measurement of some physico-chemical parameters

Salinity and temperature were determined using a Beckman electrodeless salinometer

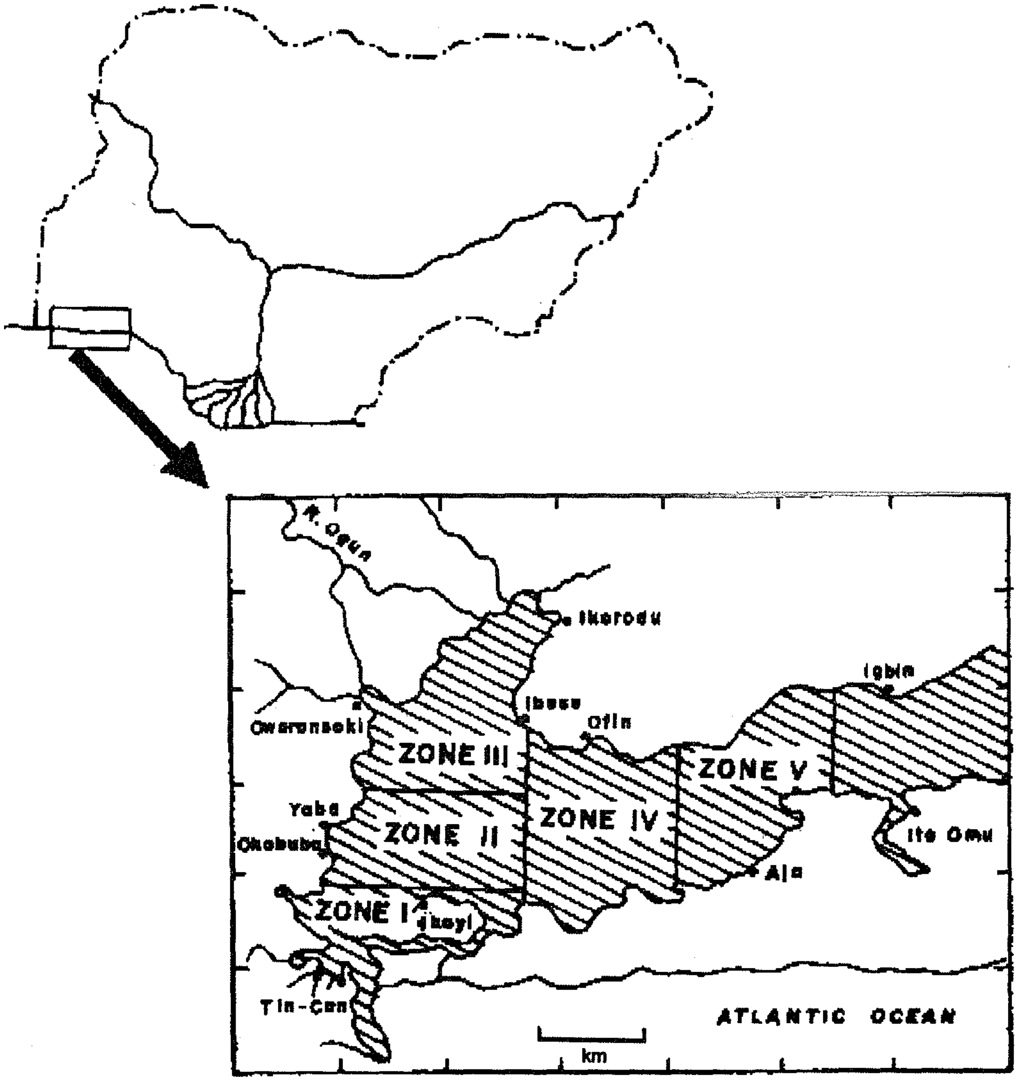

Fig. 1. Map showing location of Lagos lagoon (study area) in Nigeria and the designated sampling zones

(model RS 5-3). Dissolved oxygen (DO) and *p*H were also determined *in situ* using a Jenway DO and *p*H meter.

Chemical analyses for heavy metal content

Digestion of samples. Water samples collected from the experimental stations were filtered and digested using standard digestion procedure (APHA/AWWA/WPCF, 1995). Sediment samples were dried, sieved through a 200–µm sieve to normalize for particle size, and digested using the method provided by Agemian & Chau (1976).

The wholebody tissues of *T. fuscatus* or *C. africanus* were extracted from their shells and cleaned with distilled water to remove debris, plankton and other external adherents before they were homogenised.

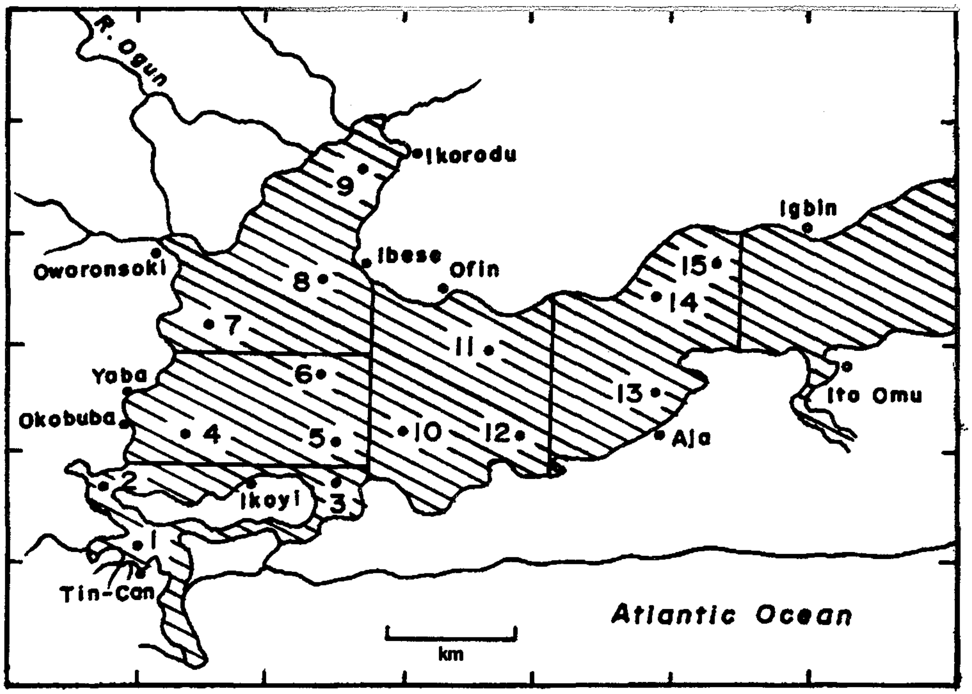

Fig. 2. Map of Lagos lagoon showing the designated sampling stations

A portion (10 g wet weight basis) from the homogenate of each animal species was digested using the method described by FAO/SIDA (1986).

Atomic absorption spectrophotometry (AAS). The heavy metal concentration in each digested sample was determined by comparing their absorbances with those of standards (solutions of known metal concentration) using an Alpha-4 cathodeon AAS. For data quality, particular attention was paid to the cleanliness of all wares. In addition, factory prepared AAS standard solutions were run as samples for accuracy check after every five measurements.

Statistical analysis

Analysis of variance (ANOVA) was used to compare means of metal concentrations in the media (animal, water and sediment) of the lagoon ecosystem. Further analysis was carried out only where there was a significant difference at the 5% ($P < 0.05$) level of significance (taken as minimum requirement). Further analyses were conducted where necessary by comparing pairs of mean (i.e. individual treatment means with controls or themselves based on least significant differences (LSD) at 0.05 and 0.001 levels of significance).

Results

Sediment

Comparisons of levels of metal content in media samples from specific zones of the Lagos lagoon within each set of 2 consecutive years (1990/91 and 1994/95) revealed no significant ($P > 0.05$) differences. Instead, there were fluctuations in levels with no consistent upward or downward trend (Table 1).

The concentration of heavy metals

TABLE I

Comparison between the mean concentrations (µg/g ± SD} of heavy metals in sediment samples collected from different zones of the Lagos lagoon in February {1991 & 1995} and July 1990 & 1995}*

Zones	Zn				Pb			
	P>0.05		P<0.05		P<0.05		P<0.05	
	Feb 91	Feb 95	Jul 90	Jul 95	Feb 91	Feb 95	Jul 90	Jul 95
1	133.3 ± 26.5	141.61±22	126.9±12.6a	165.00±27b	3.37±2.76a	370.33±6c	22.64±12.96a	363.70±20c
2	128.9±17.2	136.67±7	154.3±18.3b	148.33±10a	22.03±7.76b	384.33±8c	20.04±5.49a	390.33±7c
3	147.3±4.08	165.0±6	139.7±5.98a	162.00±8b	2.38±1.95a	400.30±11c	ND	443.67±8c
4	-	151.67±22	-	186.67±13	-	234.33±8	-	367.67±6
5	22.99±9.08	24.80±1	12.85±3.42c	27.10±1d	ND a	143.00±7e	0.33±0.27b	127.7±16d
6	12.97±3.35	6.73±3	12.01±2.0c	10±5c	13.49±11.04b	107.67±7e	1.32±0.20b	117.67±3d

Zones	Cu				Mn			
	P>0.05		P<0.05		P<0.05		P<0.05	
	Feb 91	Feb 95	Jul L 90	Jul 95	Feb 91	Feb 95	Jul 90	Jul 95
1	2.90±0.75a	14.33±3c	1.43±0.15a	19.33±3b	163.83±71.8	143.67±8	153.4±69.9a	266.67±5b
2	2.20±0.75a	8.87±2c	2.28±0.65a	13.73±2b	300.60±21.3	369.67±2	300.6±21.3b	728.33±9c
3	2.82±0.69a	22.60±2d	2.98±0.97a	14.70±1b	380.45±18.5	1405.0±214	380.5±18.5b	1657±51d
5	1.29±0.34a	10.50±1c	2.67±0.83a	14.40±1b	595.60±152	264.33±12	595.6±152.3c	206.3±13b
6	0.50±0.17b	3.57±1a	1.75±0.58a	2.23±1a	70.03±4.14	138.67±3	70.03±4.14a	74.00±8a

Zones	Cr				Fe			
	P>0.05		P<0.05		P<0.05		P<0.05	
	Feb 91	Feb 95	Jul 90	Jul 95	Feb 91	Feb 95	Jul 90	Jul 95
1	7.85±1.47a	18.83±7c	6.38±1.71a	12.67±2d	13287±2733	11474±1575	5712.6±2134	13146±1804
2	7.90±1.0a	12.87±0d	6.76±1.09a	14.33±4d	7.366±2664	14286.7±945	11600±1090	39876±1451
3	5.01±1.34a	24.70±4c	5.63±0.5a	19.73±1d	2770.7±1343	37149.3±953	2264±1653	17538±3554
4	3.38±0.09b	6.77±0a	13.89±4.25b	13.00±3d	2675.4±674	6613±612	4488±1423	3423±1155
5	1.94±0.16b	3.37±0b	1.71±0.29c	2.60±0c	4963.4±9.5	4394±603	6242±1994	5269±571

Zones	Cd				Ni			
	P>0.05		P<0.05		P<0.05		P<0.05	
	Feb 91	Feb 95	Jul 90	Jul 95	Feb 91	Feb 95	Jul 90	Jul 95
1	0.31±0.13	0.30±0	ND	0.60±0b	6.27±4.84	1.45±0	0.14±0.06a	1.96±0d
2	0.20±0.1	0.23±0	0.24±0.1a	0.83±0b	9.52±4.34	1.74±0	0.49±0.17a	1.96±0d
3	0.20±0.09	0.33±0	0.14±0.09a	0.48±0b	0.19±0.08	1.50±0	16.78±7.96b	3.47±0e
4	0.22±0.09	0.20±0	0.25±0.07a	0.32±0b	0.14±0.08	0.68±0	32.50±2.85c	1.74±0d
5	ND	0.20±0	0.13±0.02a	0.20±0c	0.03±0.003	1.57±0	14.61±0.57b	1.58±0d

ND – Not detected

Means without identical letters in vertical column are significantly {$P < 0.01$} different from themselves based on LSD following ANOVA.

detected in sediment samples collected from the same zones of the Lagos lagoon during the 1994/95 sampling year was found to be significantly ($P < 0.05$) higher than the levels of each respective metal (Zn, Pb, Cu, Mn, Cr, Fe, Cd and Ni) in equivalent zones sampled during 1989/91 sampling regime. These results show a consistent upward trend in values from 2-200 fold between the two sets of samples over the 5-year period. For example, the mean concentration of lead detected in the sediment samples from zones II and III (high effluent reception zones) in 1991 were 22.03 µg/g and 2.38 µg/g, respectively. However, by 1995, the concentration of the same metal in the same zones had increased about 19 and 200 times to 384.33 µg/g and 400.33 µg/g, respectively. Similarly, the concentrations of Cu and Cr in the same zones (II and III) increased from 2.2 µg/g (zone II) in 1991 to 22.6 µg/g (zone II) by 11 times for Cu; with Cr, the mean concentration increased from between 5.01 µg/g in 1991 to 24.7 µg/g (about 5 times increase) in 1995.

Water

The concentrations of heavy metals in water samples collected during the 1995 ecosurvey were found to be 2–25 fold higher than the concentrations in equivalent samples collected earlier in 1991 (Table 2). For example, the mean concentration of lead detected in water samples collected from the zones II and III (high effluent reception zones) in 1991 were 15.0 µg/l and 13.4 µg/l, respectively, whereas by 1995, the concentration of the metal (Pb) detected in the same zones had increased by 18–160 times to 240.33 µg/l and 236 µg/l, respectively (Table 2). With other metal ions such as Cu (February & July), Mn (July), Fe (July), Cd (February & July) and Ni (February), there were no significant ($P > 0.05$) differences between the concentrations of metals detected in the samples collected during the 1991 and 1995 ecosurveys.

Benthic animals

Tympanotonus fuscatus. Analysis of variance (ANOVA) showed that there were significant ($P < 0.05$) differences between the metal concentrations (Zn, Pb) detected in the whole body of edible *Tympanotonus fuscatus* collected from the same zones during the 1991 and 1995 ecosurvey (Table 3). The mean concentration of metals detected in *T. fuscatus* collected during the 1995 ecosurvey were found to be about 2-4 fold higher than the levels in respect of metals in the whole body homogenates of *T. fuscatus* collected from the equivalent zones during the 1991 survey. However, with other metal ions such as Cu, Mn, Cr, Fe, Cd and Ni, there were no significant ($P > 0.05$) differences between the concentrations of metals detected in the samples collected during the 1991 and 1995 ecosurveys.

Clibanarius africanus. With regards to *Clibanarius africanus*, the concentrations of heavy metals detected in the animal samples collected during the 1995 survey were found to be about 1.2-3 fold higher than the levels of each respective metal detected in the animal samples collected during the 1991 survey from equivalent zones. It is, however, noteworthy that the concentration of Fe, Ni, Cd and Mn detected in these test animals during the 1995 survey were not significantly different ($P > 0.05$) from the lower concentrations detected in animal samples collected during the 1991 ecosurvey from equivalent zones (Table 4).

TABLE 2

Comparison between the mean concentrations {µg/g ±SD} of heavy metals in water samples collected from different zones of the Lagos lagoon in February {1991&1995} and July {1990* &1995}.*

Zones	Zn				Pb			
	P>0.05		P<0.05		P<0.05		P<0.05	
	Feb 91	Feb 95	Jul 90	Jul 95	Feb 91	Feb 95	Jul 90	Jul 95
1	8.3±4.85a	41.67+2c	12.0+2.3a	46.0+3d	11.9+1.21a	237.0+23b	10.02+0.58a	229.7+37b
2	8.1±1.56a	19.67+3d	16.2+1.8a	21.17+2a	15.0+1.68a	240.3+16b	9.7+0.29a	255.3+7b
3	7.4±1.57a	19+1d	7.0+1.8b	19.67+1a	13.4+1.04a	236.0+19b	11.1+0.58a	262.0+11b
4	8.5±5.09a	12+3a	6.5+2.5b	16.00+4a	11.9+1.85a	121.0+29c	9.8+0.59a	139.3+40c
5	5.7±2.02b	13.3+4a	6.1+0.8b	11.17+1a	11.8+1.85a	51.3+4d	9.3+0.46a	88.7+10c
Zones	**Cu**				**Mn**			
	P>0.05		P<0.05		P<0.05		P<0.05	
	Feb 91	Feb 95	Jul 90	Jul 95	Feb 91	Feb 95	Jul 90	Jul 95
1	9.2+0.29	8.33±1	8.0+0.75	9.73±1	32.2+20.1a	25.67±1a	11.8+1.68	26.93±1
2	8.7+0.63	6.70±2	7.6+0.52	8.17±2	10.8+0.58b	32.50±0a	29.4+12.6	41.50±2
3	7.4+0.29	7.13±3	7.4+0.63	7.98±2	9.7+0.29b	60.33±2c	19.3+2.43	66.40±2
4	8.3+0.17	5.03±2	7.5+0.29	6.63±0	11.3+0.69b	23.30±1a	41.1+18.21	35.91±1
5	7.8+0.23	3.87±1	11.4+2.37	5.37±0	9.9+1.1b	26.30±1a	56.8+19.88	32.80±1
Zones	**Cr**				**Fe**			
	P>0.05		P<0.05		P<0.05		P<0.05	
	Feb 91	Feb 95	Jul 90	Jul 95	Feb 91	Feb 95	Jul 90	Jul 95
1	10.0+2a	19.60±1b	16.1+11.9b	13.90±2a	42.7+9.83a	150.00±7b	119.6+17.8	236.33±8
2	9.8+1.09a	19.93±2b	6.2+6.18a	15.40±2a	45.3+8.7a	137.67±9b	222.9+14.3	219.33±5
3	5.9+1.56a	22.53±2b	7.2+5.38a	14.30±1a	47.8+13.9a	158.33±6b	273.6+22.3	193.67±7
4	6.9+3.76a	18.23±1b	1.5+1.5c	14.13±2a	47.3+11.16a	145.67±9b	286.5+54.8	187.33±10
5	8.6+1.68a	15.67±1b	ND c	13.73±1a	62.3+9.9a	143.00±11b	209.2+13.9	177.40±9
Zones	**Cd**				**Ni**			
	P>0.05		P<0.05		P<0.05		P<0.05	
	Feb 91	Feb 95	Jul 90	Jul 95	Feb 91	Feb 95	Jul 90	Jul 95
1	1.0+0.9	0.77±0	3.4+3.3	0.87±0	39.0+3.2	43.60±1	21.9+5.7a	22.43±1a
2	0.03+0.03	0.66±0	0.2+0.2	0.81±0	31.7+2.1	33.93±2	11.7+4.6b	21.80±1a
3	2.0+1.96	0.86±0	1.6+1.6	0.92±0	22.7+0.9	33.75±1	7.0+1.8b	23.00±1a
4	0.03+0.03	0.14±0	0.06+0.03	0.23±0	25.7+5.8	24.47±3	6.5+2.5b	12.37±3b
5	0.06+0.03	0.15±0	0.1+0.12	0.20±0	18.1+3.0	22.47±1	6.1+0.8b	8.65±1b

ND - Not detected

Means without identical letters in vertical column are significantly {$P < 0.01$} different from themselves based on LSD following ANOVA.

TABLE 3

Comparison between the mean concentrations{μg/g±SD} of heavy metals in whole body samples of T. fuscatus *collected from different zones of the Lagos lagoon in February {1991*&1995} and July {1990* & 1995}*

Zones	Zn				Pb			
	P>0.05		P<0.05		P<0.05		P<0.05	
	Feb 91	Feb 95	Jul 90	Jul 95	Feb 91	Feb 95	Jul 90	Jul 95
1	17.95+2.43a	31.33±9c	17.84+2.14a	28.37±6c	6.445+0.77a	14.87±2c	6.25+0.69a	13.43±2c
2	19.14+1.97a	42.80±2c	18.44+1.80a	33.50±2c	6.40+0.73a	16.37±1c	6.20+0.73a	14.87±0c
3	19.16+2.10a	32.80±2c	18.35+2.30a	27.80±1c	6.45+1.46a	15.50±1c	6.14+1.36a	13.60±1c
4	12.84+2.4b	20.37±1a	12.75+1.5b	17.70±1a	2.15+0.09b	10.77±1d	2.44+0.05b	10.33±0d
5	14.9+1.78b	16.53±0a	13.91+1.77b	15.47±0a	1.96+0.15b	9.73±1d	2.45+0.14b	9.93±0d
Zones	**Cu**				**Mn**			
	P>0.05		P<0.05		P<0.05		P<0.05	
	Feb 91	Feb 95	Jul 90	Jul 95	Feb 91	Feb 95	Jul 90	Jul 95
1	27.46+1.28	32.17±1	26.95+1.11	30.70±1	53.45+1.98	63.53±5	52.93+1569	57.30±1
2	29.82+1.40	32.97±2	26.93+1.50	32.20±1	55.24+1.74	68.17±2	53.93+186	59.30±0
3	29.65+1.50	32.77±1	27.95+1.44	32.07±1	56.43+2.30	66.80±2	54.92+2.60	58.20±1
4	29.20+1.36	30.60±1	26.90+1.13	30.43±0	60.32+1.78	49.87±1	50.64+1.78	46.80±1
5	25.63+1.54	30.93±1	23.22+1.33	30.50±0	50.83+2.06	53.63±3	50.74+1.49	51.87±2
Zones	**Cr**				**Fe**			
	P>0.05		P<0.05		P<0.05		P<0.05	
	Feb 91	Feb 95	Jul 90	Jul 95	Feb 91	Feb 95	Jul 90	Jul 95
1	1.95+0.75	4.1±00	1.80+0.84	3.10±0	142.45+5.26	169.33±5	137.48+4.86	160.00±5
2	2.98+0.78	4.53±0	2.24+0.65	3.47±0	143.81+4.8	162.67±2	156.92+3.92	154.00±3
3	3.42+1.10	4.07±0	2.63+0.90	3.27±0	149.21+5.4	167.00±10	148.62+4.80	162.33±9
4	2.42+0.66	3.27±0	2.31+0.64	2.40±0	150.32+5.14	143.67±3	149.61+4.52	135.67±4
5	2.25+0.83	2.90±0	2.14+0.78	2.67±0	153.61+5.2	143.00±8	149.81+5.20	135.67±9
Zones	**Cd**				**Ni**			
	P>0.05		P<0.05		P<0.05		P<0.05	
	Feb 91	Feb 95	Jul 90	Jul 95	Feb 91	Feb 95	Jul 90	Jul 95
1	0.04+0.07	0.08±0	0.04+0.006	0.06±0	6.26+0.64	10.33±1	5.55+0.52	9.53±1
2	0.03+0.003	0.10±0	0.01+0.0	0.08±0	5.79+0.39	10.80±0	5.14+0.48	9.90±0
3	0.04+0.005	0.09±0	0.03+0.005	0.08±0	5.84+0.79	10.47±0	5.42+0.84	9.87±0
4	ND	0.02±0	ND	0.02±0	7.74+0.96	8.30±0	6.23+0.74	8.08±0
5	ND	0.02±0	ND	0.01±0	5.26+0.78	8.49±0	4.65+0.69	7.37±0

ND – Not detected

Means without identical letters in vertical column are significantly $\{P < 0.01\}$ different from themselves based on LSD following ANOVA.

TABLE 4

Comparison between the mean concentrations{μg/g±SD} of heavy metals in whole body samples of C. africanus *collected from different zones of the Lagos lagoon in February {1991*&1995} and July {1990* & 1995}*

Zones	Zn				Pb			
	P>0.05		P<0.05		P<0.05		P<0.05	
	Feb 91	Feb 95	Jul 90	Jul 95	Feb 91	Feb 95	Jul 90	Jul 95
1	39.26+2.9a	73.30±6c	36.72+2.40a	66.10±4c	6.45+0.92a	11.37±2c	6.84+0.84a	10.00±1c
2	57.24+3.9b	85.17±2c	55.83+3.80b	78.70±1c	7.70+1.12a	10.40±0c	7.70+1.14a	9.30±0c
3	58.95+4.4b	82.40±2c	56.24+3.40b	76.77±3c	7.22+0.87a	10.40±0c	6.50+0.96a	9.43±0c
4	54.81+2.44b	64.87±1b	52.62+2.33b	62.63±1c	5.40+0.06b	6.83±0a	4.81+0.07b	6.40±0a
5	55.17+1.96b	54.80±4b	52.46+2.60b	52.77±4b	4.42+0.09b	5.73±1b	3.62+0.06b	5.20±1b
Zones	Cu				Mn			
	P>0.05		P<0.05		P<0.05		P<0.05	
	Feb 91	Feb 95	Jul 90	Jul 95	Feb 91	Feb 95	Jul 90	Jul 95
1	30.16+1.55a	44.80±3b	27.95+1.36a	38.60±2b	57.76+1.87	64.93±2	56.88+1.99	60.73±2
2	29.37+1.50a	43.80±2b	28.95+1.40a	39.30±2b	54.64+2.42	66.13±4	55.85+1.97	61.63±2
3	31.12+1.82a	43.13±3b	28.93+1.44a	35.27±2b	55.94+2.93	60.00±2	55.33+2.50	57.50±2
4	24.92+1.56a	40.43±2b	23.24+1.36a	35.63±1b	52.45+2.18	45.60±2	51.84+2.44	42.20±1
5	27.34+1.50a	33.77±3a	25.65+1.40a	29.60±4a	56.93+2.56	47.87±1	54.42+2.44	44.57±1
Zones	Cr				Fe			
	P>0.05		P<0.05		P<0.05		P<0.05	
	Feb 91	Feb 95	Jul 90	Jul 95	Feb 91	Feb 95	Jul 90	Jul 95
1	2.97+0.70a	7.50±1b	2.48+0.54a	6.37±0c	160.20+5.28	161.33±7	158.90+4.42	167.67±9
2	2.76+0.80a	7.37±0b	2.26+0.80a	6.17±0c	160.31+3.91	171.00±5	152.80+4.96	168.33±4
3	3.54+0.99a	7.47±0b	2.73+0.99a	6.27±0c	158.31+4.86	164.00±5	154.62+3.99	167.67±6
4	2.32+0.57a	5.33±0c	1.42+0.68b	4.73±0d	148.83+5.19	165.67±4	150.42+5.60	167.67±3
5	2.44+0.78a	3.63±1a	1.75+0.92b	3.40±1a	140.21+5.33	168.67±2	150.60+4.87	166.00±4
Zones	Cd				Ni			
	P>0.05		P<0.05		P<0.05		P<0.05	
	Feb 91	Feb 95	Jul 90	Jul 95	Feb 91	Feb 95	Jul 90	Jul 95
1	0.28+0.04	0.57±0	0.26+0.04	0.51±0	1.16+0.05a	5.70±1b	5.94+0.91	5.23±1
2	0.49+0.04	0.70±0	0.42+0.03	0.61±0	3.55+1.26b	6.67±0c	6.43+1.45	5.97±1
3	0.52+0.09	0.69±0	0.36+0.07	0.61±0	5.53+2.08b	6.20±0c	7.32+1.92	5.53±0
4	0.08+0.03	0.33±0	0.08+0.01	0.31±0	9.24+1.44c	12.67±0d	7.22+1.34	10.57±0
5	1.20+0.04	0.22±0	1.25+0.04	0.22±0	6.25+0.93b	13.37±1d	5.94+0.84	11.0±1

ND – Not detected

Means without identical letters in vertical column are significantly {$P < 0.01$} different from themselves based on LSD following ANOVA.

Discussion

The concentration of heavy metals detected in all the three principal media (water, sediment and animal) of the Lagos lagoon between 1989/91 and 1994/95 sampling regimes showed that there was a distinct upward trend in the concentrations of heavy metals in the lagoon only when data from equivalent samples collected 5 years apart were compared. The observed increasing concentrations of heavy metals in the media of the Lagos lagoon over an extended time of 5 years is not surprising because the discharge of metal-laden industrial and domestic effluents entering the lagoon *via* drainage channels and streams continued unabated over the sampling period (Oyewo, 1998).

Additionally, the non-degradable nature of heavy metals and possibly slow rate of dispersion into the sea may have led to the observed consistent and significant increases in metal levels over the 5-year period. The implication of these findings is that the prevailing effluent limitation standards enforced by the regulatory agency since 1999 is inadequate and requires urgent review to make it stricter and effective.

Comparison of the levels of some of the metals detected in the lagoon ecosystem with the results of toxicological evaluations of the metals against laboratory test animals such as *Tilapia guineensis, Mugil* sp., *Neritina senegalensis*, and *Cypris* sp. (Oyewo, 1998) revealed that concentrations of many of the metals are close to toxic levels in the laboratory toxicology evaluations. This observation, therefore, provides the needed biological reason to ensure the urgent formulation of water quality criteria and standards that will limit the levels of metals and other pollutants in bodies of water such as the Lagos lagoon. Furthermore, the observation gives greater credibility to the call to abolish the existing effluent limitation guidelines, which were set rather arbitrarily by relying on standards imported from Europe, USA and India (FEPA, 1991). The new set of effluent limitation guideline will no doubt benefit from the empirical data now available, as in this study and many other earlier studies, such as those of Oyewo (1998), Enajekpo (2000), Otitoloju (2002, 2003), Otitoloju & Don-Pedro (2002ab, 2003), and many others.

The biological significance of the increasing concentrations of heavy metals with time in the Lagos lagoon are the danger or risk of potential disruption of the delicate ecological balance of the ecosystem, which may occur when the concentrations in the waterbody reach levels that will cause harmful effects. These harmful effects may lead to a reduction in population of organisms which, if sustained, will subsequently lead to the loss of the already depleted biological diversity of the lagoon ecosystems (Singh *et. al.*, 1995; Oyenekan 1975). Furthermore, the possibility of bioaccumulation of some of these metals and their movement in the food web involving plants and animal species, particularly in the edible species such as *Tympanotonus fuscatus* (Periwinkle) could result in the transfer of such toxic metallic loads to human consumers of shell fishes. This may cause public health problems similar to those observed much earlier in Japan (Kurdland, 1960). Certainly, the increased amounts of metal load observed in periwinkles and hermit crabs collected in the 1995 samples, compared to the 1991 samples from equivalent zones, is good empirical data to support the hypothesis that under higher levels of metals in sediment, benthic animals may accumulate high enough levels to pose unacceptable public health hazards. Furthermore, these observations establish the need to include regular biological monitoring using edible accumulators of priority pollutants as indicator species in a more effective bid to prevent or minimize environmental degradation and food poisoning in humans.

Conclusion

The results obtained in this study established that there was a distinct upward trend in the concentrations of heavy metals (Zn, Cu, Pb, Fe, Ni, Co) in all the three principal media (water, sediment and biota) over the 5-year observation period. The sediment, water and animal samples collected from zones I-III of the Lagos lagoon, off the Iddo-Yaba-Ikorodus axis, which received most industrial effluents, generally had higher concentrations of most metals sampled for (Zn, Cu, Pb, Fe, Ni, Co) than the samples collected from zones IV and V that were off the Egbin-Palaver Islands-Aja axis, which received fewer or no industrial effluents.

The highest concentrations of heavy metals were detected in the sediment followed by the test benthic animals, and finally the water column in a decreasing order of concentration. The heavy metal concentrations during the wet seasons sampling regime (July) were found to be consistently (though not significantly) higher than the concentrations detected during the dry season (February) measurements. This upward trend of metal levels observed during the surveys indicates that there is an urgent need to formulate new and more effective water quality criteria and standards that will limit the levels of metals and other pollutants in the Lagos lagoon ecosystem.

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