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ASSESSMENT OF HEAVY METALS POLLUTION OF SEDIMENTS FROM FOSU LAGOON IN GHANA

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ABSTRACT. The distribution of some heavy metals, namely Cu, Pb, Zn, and Fe in sediments of Fosu lagoon of Cape Coast, Ghana was studied in the early summer (November) of 2009. The levels of the selected trace metals were determined using atomic absorption spectrophotometry. The overall mean ± RSD % of Cu, Pb, Zn, and Fe were, respectively 26.4 ± 51.0, 28.1 ± 101.0, 20.90 ± 41.90 and 1.15×10^3 ± 2.02 mg/kg. Fe recorded the highest concentration levels, the distribution of which followed the sequence Fe > Pb > Cu > Zn. Statistical analyses also showed different mean levels of trace metals at the five sites. The heavy metal burdens in the sediments revealed significant variations in the distribution of the metals, with Pb showing the greatest variation and Fe the least. Enrichment level of Fe was minimal; Cu and Zn were significantly enriched and Pb showed very high to extremely high enrichment. The average geoaccumulation values and pollution load index calculated for the five studied sites indicated that the lagoon is practically unpolluted with Fe, Cu and Zn, but moderately polluted with Pb.

KEY WORDS: Fosu lagoon, Heavy metal, Enrichment, Pollution

INTRODUCTION

Both anthropogenic pressures and natural processes account for degradation in surface water and groundwater quality [1]. According to Yu [2], because of anthropogenic activities, industrial and urban wastes are inevitably discharged into water bodies and consequently, heavy metals are frequently detected in water environment and have gradually become a major concern worldwide. Heavy metals can either be adsorbed onto sediment or accumulated by benthic organism to a toxic levels, the bioavailability and subsequent toxicity of the metals being dependent upon the various forms and amount of the metal bound to the sediment matrices. According to Loizidou [3], the contamination of sediment with heavy metals, even in small concentration may lead to serious environmental problem.

Activities of people living or working in the immediate vicinity of Fosu lagoon were contributing a lot to gradual extinction of the lagoon. For instance, through the activities of the mechanical garages, spraying shops, schools and the district hospitals waste were discharge into the lagoon. Such discharges enrich the lagoon sediment with heavy metals. According to Tsai [4] sediments act as both carriers and source of contamination in an aquatic environment; not only play an important role in river water pollution but can also provide a record of pollution history.

Currently a lot of weeds have grown in the lagoon and the surface area has reduced significantly due to siltation. The colour of the lagoon is darker and fish population has diminished at an alarming rate, which might be partly due to the discharge of waste into the lagoon over the years. The current state of the lagoon raises environmental and health concerns.

Dodoo and Adjei [5] investigated the heavy metal levels in sediments of the Fosu lagoon and observed significantly high concentrations at certain points of the lagoon adjacent to human settlements. However the extent of pollution was not assessed. The distribution of heavy metals in sediments can provide evidence of the anthropogenic impact on aquatic and other

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ecosystems, and therefore aid in assessing the risks associated with human induced change [6-11]. Contamination of the sediment matrix by heavy metals may accumulate in fishes and other aquatic resources which may eventually get into human food chains. The purpose of the present study was to determine the distribution and levels of sediment contamination by of some heavy metals namely copper, zinc, lead and iron in sediment in the Fosu lagoon, and the extent of enrichment with a view of providing information on the level of pollution.

EXPERIMENTAL

Sample collection

Soil sediment samples were collected from the Fosu lagoon which lies along the Gulf of Guinea in the ancient city of Cape Coast, Ghana, in the West Africa (Latitude 5°5' and 5°7'N; longitude 1°2' and 1°15'W).

Twenty composite samples of top soil sediments (1-20 cm) were collected at five demarcated sites; S_1 S_2, S_3, S_4 and S_5 with four composite samples from each demarcated sites. Each composite sample consisted of ten samples randomly collected from the demarcated sites. The samples were collected in November 2009.

Sample treatment

The samples were air-dried and also at 100 °C for 48 hours in the oven. The dried samples were passed through standard screen to remove large particles. For the digestion of the sediment sample, one gram of dried and homogenized sediment samples was weighed and placed in to acid washed Teflon vessels. The digestion was performed with a mixture HNO_3 and $HClO_4$ acid. The digested samples were analyzed for heavy metals by Varian 235 AAS [12]. The analytical precision and accuracy of the method was accomplished by analyzing a blank and four replicate samples of IAEA certified material, Soil-7. The Varian 235 AAS was used for the metal analysis.

The enrichment factor was calculated using the relation, $EF = [C_n/C_{ref}]/[B_n/B_{ref}]$ where C_n is content of the examined element in the examined environment, C_{ref} is content of the examined element in the reference environment, B_n is content of the reference element in the examined environment and B_{ref} is content of the reference element in the reference environment. Five contamination categories were recognized on the basis of the enrichment factors; EF < 2 – depletion to minimal enrichment; EF = 2–5 – moderate enrichment; EF = 5–20 – significant enrichment; EF = 20–40 - very high enrichment; EF > 40 – extremely high enrichment [13].

Geo-accumulation index was calculated using the formula $I_{geo} = \log_2 [C_n/1.5B_n]$ where C_n is the measured concentration of the element in soil or sediment, B_n is the geochemical background value and 1.5 is a constant. The geo-accumulation index consists of 7 grades or classes; I_{geo} value of < 0, practically unpolluted; > 0–1, unpolluted to moderately polluted; > 1–2, moderately polluted; > 2–3, moderately and > 5 very strongly polluted [8].

Contamination factor (CF) is the ratio obtained by $CF = [C_{heavy\ metal}]/[C_{background}]$. The contamination levels may be classified based on their intensities on a scale ranging from 1 to 6 (0 = none, 1 = none to medium, 2 = moderate, 3 = moderately to strong, 4 = strongly polluted, 5 = strong to very strong, 6 = very strong [9]. Pollution load index (PLI) for the entire sampling site, PLI was determined as the nth root of the product of the n CF.

$PLI = (CF_1 \times CF_2 \times CF_3 \times \cdot\cdot \cdot\times CFn)^{1/n}$. This empirical index provides a simple, comparative means for assessing the level of heavy metal pollution [14].

The experimental data were treated statistically using Microsoft Excel 2007and SPSS software (version 16.0 for Windows). The statistical relationship between the metals was determined by bivariate correlation using the Pearson coefficient in a two-tailed test, $p \leq 0.05$.

RESULTS AND DISCUSSION

The results of the determination of the analytical precision and accuracy of the method are given in Tables 1 and 2.

Table 1. Results of amount of metal recovered from 5.0 mg/L spiked distilled water.

Metal	Fe	Cu	Zn	Pb	Al
No. of samples	4	4	4	4	4
Mean (mg/L)	4.99	4.99	5.01	4.99	4.99
SD	0.0022	0.0057	0.0008	0.0013	0.0006
Standard error	0.0011	0.0029	0.0004	0.0015	0.0003
CV	0.044	0.114	0.16	0.026	0.012
Recovery (%)	99.70	99.90	100.00	99.90	99.9

Table 2. Results of metal recovered from IAEA certified material.

Metal	Fe	Cu	Zn	Pb
No. of samples	4	4	4	4
Mean (mg/L)	0.996	0.996	0.981	0.986
SD	0.017	0.017	0.011	0.03
Standard error	0.005	0,005	0.003	0.009
CV	1.71	1.71	1.121	3.04
Recovery (%)	99.6	99.6	98.1	98.6

Table 3. Concentration of Fe, Cu, Zn, Pb and Al in Fosu lagoon.

Metal (mg/kg)	Sampling site				
	S_1	S_2	S_3	S_4	S_5
	1.18	1.13	1.10	1.14	1.16
	1.15	1.15	1.17	1.20	1.12
Fe (mg/kg)	1.16	1.19	1.16	1.13	1.15
$\times 10^3$	1.16	1.14	1.14	1.13	1.15
Mean	1.16	1.15	1.14	1.15	1.15
CV (%)	0.96	2.22	2.65	2.92	1.29
	18.5	15.3	21.4	34.8	13.29
	16	21	33.5	16.4	46.5
	22.5	29.1	12.1	20.4	10.1
Cu (mg/kg)	14.5	45.3	53.1	36.5	47.8
Mean	17.9	27.7	30.0	27.0	29.4
CV (%)	19.6	47.1	56.9	37.4	69.7
	15.2	14.5	20.2	30.01	24.4
	15.2	17.2	42.6	21.5	16.1
	15	21.5	12.1	13.4	34.4
Zn (mg/kg)	15.1	24.3	14	14.2	36.9
Mean	15.1	19.4	22.2	19.8	28.9
CV (%)	0.632	22.6	63.1	39.1	34.2
	9.7	2.5	7.5	15.3	17.2
	18.3	9.7	21.1	1.7	30
	91.7	18.1	11.4	10.0	85.3
Pb (mg/kg)	11.9	46.1	52.2	17.5	84.4
Mean	32.9	19.1	23.1	11.1	54.2
CV (%)	117.0	99.9	87.9	63.2	65.9

	2.95	2.01	1.96	2.36	3.35
	2.68	2.62	2.36	1.39	1.61
Al (mg/kg)	2.76	3.38	1.75	1.04	1.81
$\times 10^3$	2.92	1.87	1.83	2.03	1.94
Mean	2.83	2.47	1.98	1.70	2.18
CV (%)	4.51	28.0	13.7	35.1	36.4

Table 4. Mean concentration of some metals in Fosu lagoon.

	Concentration of metal (mg/kg)				
	Fe	Cu	Zn	Pb	Al
Mean	1.15×10^3	26.4	20.9	28.1	2.23×10^3
RSD %	2.02	51.0	41.88	101.3	28.5

The results of the analysis of Fe, Cu, Zn and Pb in the sediments samples from the five studied sites in the Fosu lagoon are presented in Tables 3-4. Fe was the most abundant metal measured and there were slight variations in the level of Fe among sites. The mean Fe levels (mg/kg) at various sites were S_3 ($1.14 \times 10^3 \pm 2.65$) < S_5 ($1.15 \times 10^3 \pm 1.29$) < S_4 (1.15×10^3. 5 ± 2.92) < S_2 ($1.15 \times 10^3 \pm 2.22$) < S_1 ($1.16 \times 10^3 \pm 0.96$). The sites S_1 and S_2 recorded the highest mean Fe value and this may be due to discharges of untreated wastes from the school laboratories and the District Hospital which are the main sources of waste into that section.

The average Cu levels (mg/kg) for the five studied sites were as follow: S_1 (17.9 ± 19.56) < S_4 (27.0 ± 37.4) < S_2 (27.7 ± 47. 1) < S_5 (29. 4 ± 69.7) < S_3 (30. 0 ± 60.0). The sites S_3 and S_5 recorded almost equal levels of Cu in sediment. S_5 is close to a cluster mechanical and automobile fitting shop; predominant industrial activities include car fitting, metal fabrication (welding, painting etc), repair of car brakes and tyres (since about 90% of Cu are released from car brakes and tyres and also waste water run-off (rain may be entered the lagoon along that site). At site S_3 which is near to the bridge at the southern side of the lagoon also recorded another highest Cu level in sediment. The relatively high prevalence of Cu distribution in site seems to be mainly attributable to the release from brakes of vehicles that ply the road everyday across the lagoon. Also, the southern segment of the lagoon receives high amount of domestic effluents and sewage from nearby settlements as well as lecheates of garbage through gutters from certain part of cape coast. The site S_1 recorded the least means concentration of 17.9 mg/kg probable because is further away from the road and also receive very little waste from the garages and the municipality.

The average Zn levels (mg/kg) measured for the five sites were S_1 (15.1 ± 0.63) < S_2 (19. 4 ± 22. 6) < S_4 (19. 8 ± 39. 1) < S_3 (22.2 ± 36.1) < S_5 (28.0 ± 34.2). There were variations in the Zn levels at the five sites S_5 which is close to cluster of mechanical workshops recorded the highest concentration of Zn. S_1 recorded the least means concentration of Zn. The mean concentration of Zn sediment for S_2 was higher than $S_{1;}$ S_2 is the point site behind a recreational area for secondary school where laboratory waste from this institution is discharge directly without treatment to the lagoon. This supports the conclusion from an earlier investigation that some of the input of Zn into the lagoon sediment is from the school laboratories [5]. The higher level of Zn at S_3 compared to S_2 could be due to the proximity of S_3 to the road.

The mean Pb concentration for the five (5) sites were S_4 (11.1 ± 63.2) < S_2 (19. 1 ± 99.9) < S_3 (23. 1 ± 87.9) < S_1 (32.9 ± 9.66) < S_5 (54. 2 ± 65.9) mg/kg. There was large variability in the level of Pb amongst the sites. The highest contamination of Pb was at site $S_{5,}$ which is close to a cluster mechanical and automobile fitting shop, where automobile repair and related activities (e.g. disposal of over used batteries.

The heavy metal concentrations in the Fosu lagoon sediments are being normalized using Al as a conservative element to evaluate anthropogenic sources of the metal, despite the possible anthropogenic contribution to the lagoon The mean levels of Al (mg/kg) at the five sites were $(1.70 \times 10^3 \pm 35.1) < S_3\ (1.98 \times 10^3 \pm 13.7) < S_5\ (2.18 \times 10^3 \pm 36.4) < S_2\ (2.47 \times 10^3 \pm 28.0) < S_1\ (2.83 \times 10^3 \pm 4.51)$.

The enrichment factor and geo-accumulation index values of the metals are shown in Table 5. The enrichment factor, which is the index of contamination for sediment samples, revealed that the extent of enrichment of Fe was minimal, the order of Fe enrichment at the sites was S_1 (0.69) < S_2 (0.83) < S_5 (0.96) < S_3 (0.99) < S_4 (1.27). The enrichment factor values for Cu were, S_1 (11.3) < S_2 (21.6) < S_3 (27.1) < S_5 (28.1) < S_4 (28.5); Cu enrichment at S_2, S_3, S_4 and S_5 were very high but significant at S_1. The sites S_3 and S_1 indicated moderate enrichment of zinc as compare to S_2, S_4 and S_5 which had significant enrichment of the metal. The enrichment factors were, S_3 (2.26) < S_1 (4.51) < S_2 (6.98) < S_4 (10.1) < S_5 (11.6). The calculated mean Pb enrichment values were S_4 (26.0) < S_2 (35.0) < S_1 (47.4) < S_3 (47.8) < S_5 (114.0). The sites S_4, and S_2 have a very high enrichment of the Pb, while $S_{1,}$ S_3 and S_5 had extremely high Pb enrichment in the sediments.

Table 5. Enrichment factors and geoaccumulation index values of Fe, Cu, Zn, and Pb in sediment from Fosu lagoon.

Sampling site	EF_{Fe}	EF_{Cu}	EF_{Zn}	EF_{Pb}	$Igeo_{Fe}$	$Igeo_{Cu}$	$Igeo_{Zn}$	$Igeo_{Pb}$
	0.68	11.16	4.34	13.16	-5.91	-1.87	-3.23	-1.63
S_1	0.73	10.6	4.78	27.3	-5.94	-2.08	-3.23	-0.71
	0.71	14.5	4.57	133.0	-5.93	-1.58	-3.25	1.61
	0.67	8.83	4.36	16.3	-5.94	-2.22	-3.24	-1.33
	0.95	13.6	6.09	4.99	-5.97	-2.14	-3.30	-3.58
S_2	0.75	14.3	5.53	14.8	-5.94	-1.68	-3.05	-1.63
	0.59	15.3	5.35	21.4	-5.90	-1.21	-2.73	-0.73
	1.03	43.1	11.0	98.7	-5.96	-0.58	-2.55	0.62
	0.95	19.4	8.66	15.3	-6.01	-1.66	-2.82	-2.00
	0.84	25.2	15.2	35.8	-5.92	-1.01	-1.74	-0.51
S_3	1.12	12.3	5.81	26.0	-5.94	-2.48	-3.56	-1.40
	1.06	51.6	6.45	114.0	-5.96	-0.35	-3.35	0.80
	0.82	26.2	10.7	25.9	-5.96	-0.96	-2.25	-0.97
S_4	1.46	21.0	13.0	4.89	-5.89	-2.04	-2.73	-4.14
	1.84	34.9	10.9	38.5	-5.97	-1.73	-3.41	-1.58
	0.94	32.1	5.91	34.6	-5.98	-0.89	-3.33	-0.78
	0.59	7.06	6.14	20.6	-5.93	-2.34	-2.55	-0.80
S_5	1.19	51.5	8.44	74.7	-5.98	-0.54	-3.15	0.00
	1.07	9.91	16.0	188.0	-5.95	-2.74	-2.05	1.51
	1.00	43.8	16.0	174.0	-5.94	-0.50	-1.95	1.49

The average geo-accumulation values suggest that the lagoon is practically unpolluted with Cu, Zn and Fe but moderately polluted, particularly at S_5 which is close to cluster of mechanical and automobile workshop. The pollution load index (PLI) calculated for the five studied sites (Table 6) indicated that the lagoon is practically unpolluted with Fe, Cu and Zn, but moderately polluted with Pb. Generally the site S_5 had the highest level of metal pollutants, and the PLI was in the order $S_5 > S_2, S_3 > S_1 > S_4$

In the regression and bivariate correlation analysis, no significant correlation was found to exist between any two of the metals Fe, Cu, Zn and Pb. Indicating that there is no mutual relationship among the metals and hence the prediction of the level of any of the metals from the others is impossible. A fluke relationship was however found to exist between Fe and Al.

Table 6. Contamination factors and pollution load index of the metals.

Site	CF_{Fe}	CF_{Cu}	CF_{Zn}	CF_{Pb}	CF_{Al}	PLI
S_1	0.02	0.40	0.16	1.65	0.04	0.14
S_2	0.02	0.62	0.20	0.96	0.03	0.15
S_3	0.02	0.67	0.23	1.15	0.02	0.15
S_4	0.02	0.60	0.21	0.56	0.02	0.12
S_5	0.02	0.65	0.29	2.71	0.03	0.19

CONCLUSIONS

The overall mean of Cu, Pb, Zn, and Fe were respectively 26.4 ± 51.0, 28.1 ± 101.0, 20.9 ± 41.9 and $1.15 \times 10^3 \pm 2.02$ mg/kg. The concentration of metals followed the sequence Fe > Pb > Cu > Zn. Trends in heavy metal burdens in the sediments revealed significant variations in the distribution of the metal, with Pb showing the greatest variation and Fe the least. Enrichment level of Fe was minimal; Cu and Zn were significantly enriched and Pb showed very high to extremely high enrichment. The average geo-accumulation values and pollution load index calculated for the five studied sites indicated that the lagoon is practically unpolluted with Fe, Cu and Zn, but moderately polluted with Pb. No significant correlation was found to exist between any two of the metals.

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