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Assessment of Contamination Factor of Heavy Metals in Sediment from Adyar Estuary

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Abstract— **The main objective of this study was to assess the pollution indices by the heavy metals and its seasonal variation in sediment. Sediments from the Adyar estuary were collected to evaluate the contamination of sediment by the metals including Arsenic (As), Lead (Pb) and mercury (Hg). Sediment samples were collected in the ten sampling points in the mouth of the estuary. The pollution indices of the Arsenic (As), Lead (Pb) and mercury (Hg) in the sediment were estimated by Contamination factor (CF), Geo accumulation index (I_{geo}), Degree of contamination of sediments (cd) and Pollution load index (PLI). The sediment samples were subjected to a total digestion technique and analysed by Inductively Coupled Plasma Mass Spectrometer (ICP-MS) for metals including As, Pb and Hg. The Adyar estuary sediment has a low level of contamination with respect to Pb and Hg. Among all, Arsenic has the highest in all evaluated method, which shows low to moderate level of pollution.**

Keywords: **sediment, contamination factor, heavy metals, CF, I_{geo}, C_d, PLI.**

I. INTRODUCTION

Sediments are known as "Trace element traps" (1). Sediments ultimately bind in all the contaminants which enter into the aquatic environment. Heavy metals in the sediments lead to greater environmental problems, when the contaminated sediments are resuspended and such metals are taken up by filter feeders. The occurrence of elevated concentrations of trace metals in sediments found at the bottom of the water column can be a good indicator of man induced pollution rather than natural enrichment of the sediment by geological weathering (2). The contamination assessment of the sediment by heavy metals can be assessed in many ways. The most common methods are the Contamination factor (CF), Geo accumulation index (I_{geo}), Degree of contamination of sediments (cd) and Pollution load index (PLI).

Sediments can reflect the quality of the water and it can be used to detect insoluble contaminants (3). Heavy metals concentrations in aquatic ecosystems are usually monitored by measuring their concentrations in water, sediments and biota (4). Sediment are usually regarded as the ultimate sink for heavy metals discharged into the environment (5) and sediments can be sensitive indicators for monitoring contaminants in aquatic environments (6). Pollution index is a powerful tool for processing, analyzing, and conveying raw environmental information (7). Heavy metals have been used as indices of pollution because of the high toxicity to human and aquatic life (8).

II MATERIAL AND METHODS
STUDY AREA

The samples were collected from Adyar estuary, Chennai, Tamilnadu state, India. The samples collected from the mouth of the estuary to head of the estuary. The samples were collected from ten sites within the estuary, the GPS location was marked in 10 different sites during first sample collection and the subsequent collection was performed in the similar location.

SAMPLING

The sediment was collected from 10 different sites of mouth of the Adyar estuary. Four samples were collected within 100 -200 meters to make composite. Approximately 50g of samples were collected from each dig to achieve 200g. The composite sediment samples were mixed well after each collection. The collected samples were transferred to laboratory immediately for analysis (9). The sediment samples were dried and pre heated in oven for 1hr and digested by using concentrated nitric acid and kept in muffle furnace at 540°C for 3hrs. After, complete digestion the samples were estimated in Inductively Coupled Plasma Mass Spectrometer (ICP-MS).

CONTAMINATION FACTOR (CF):

Contamination is described as the contamination of a given toxic substance in a basin

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(10). The level of contamination is expressed by CF (6), which is used as global standard reference for unpolluted sediment. CF was calculated as the ratio between the sediment metal content at a given station and the Normal Concentration Levels (NCLs), reflects the metal enrichment in the sediment.

$$\mathrm{CF} = \frac{\text{Metal concentration in sediment}}{\text{Background value of metal}}$$

The world crustal average contamination of the trace metals under consideration reported by (11) was used for background values of metals. The CF was classified into four groups (6) : 1 ≤ CF - Low contamination factor; 1 ≤ CF <3 - Moderate contamination factor; 3 ≤ CF <6 - Considerable contamination factor; and 6 ≥ CF - Very high contamination factor.

GEOACCUMULATION INDEX (I_{geo}):

Geochemical index (I_{geo}) was originally stated by (12) in order to determine and define metal contamination in sediments by comparing metal concentrations with the element's content in "average shale" (13) and and 1.5 is the factor compensating background data (correction factor) due to the lithogenic effect (14). I_{geo} is calculated as follows:

$$I_{geo} = \mathrm{Log2}\,\frac{C}{1.5 \times B}$$

Where, C is the measured sedimentary concentration for metal; B is the background value for the metal; factor of 1.5 was used because of possible variations in background values for a given metal in the environment, as well as very small anthropogenic influences (15). In the present study, I_{geo} has been calculated using background values for world crustal average metal concentrations as presented by (11).

DEGREE OF CONTAMINATION OF SEDIMENTS (C_d):

The degree of contamination (C_d) is defined as the sum of all contaminants factors various heavy metals (16). The degree of contamination (C_d) was originally defined as the sum of all contamination factors.

$$C_d = \sum_{i=1}^{m} C_f^i$$

Where C_f^i is the single index of contamination factor, and m is the count of the heavy metal species. (7) and (6) described the contamination degree as follows; C_d<3 - Low degree of contamination; 10 ≤C_d<6 - Moderate degree of contamination; 20 ≤C_d<12- Considerable degree of contamination; and C_d >24 - Very high degree of contamination

POLLUTION LOAD INDEX (PLI):

PLI for a particular site has been evaluated following the method proposed by (17). PLI was calculated as the root of the product of the single indices. The pollution load index (PLI) provides a simple and comparative means for assessing the level of heavy metal pollution. PLI is expressed as $\mathrm{PLI} = n\sqrt{(CF_1 \times CF_2 \times CF_3 \ldots CF_n)}$Where, n is the number of metals and CF is the contamination factor. The PLI value > 1 is polluted whereas < 1 indicates no pollution (18; 19).

III RESULT

Table I Contamination factor in sediments

Site	Monsoon			Post Monsoon			Pre Monsoon		
	As	Pb	Hg	As	Pb	Hg	As	Pb	Hg
Site 1	1.63	0.31	0.04	1.77	0.29	0.02	1.95	0.31	0.03
Site 2	1.78	0.33	0.04	1.77	0.30	0.02	2.03	0.32	0.03
Site 3	1.55	0.33	0.04	1.57	0.31	0.02	2.22	0.35	0.03
Site 4	1.54	0.30	0.03	1.57	0.30	0.04	2.13	0.31	0.04
Site 5	1.68	0.35	0.03	1.77	0.29	0.04	1.98	0.34	0.04
Site 6	1.53	0.33	0.04	1.70	0.29	0.04	1.68	0.30	0.04
Site 7	1.90	0.31	0.04	1.81	0.29	0.04	1.61	0.33	0.03

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Site 8	1.69	0.28	0.04	1.76	0.30	0.04	2.07	0.30	0.04
Site 9	1.98	0.31	0.04	1.71	0.31	0.05	1.79	0.32	0.03
Site10	1.91	0.32	0.05	1.73	0.31	0.05	1.97	0.34	0.03
Min	1.53	0.28	0.03	1.57	0.29	0.02	1.61	0.30	0.03
Max	1.98	0.35	0.05	1.81	0.31	0.05	2.22	0.35	0.04
Mean	1.72	0.32	0.04	1.72	0.30	0.04	1.94	0.32	0.03
CF	Moderate	Low	Low	Moderate	Low	Low	Moderate	Low	Low

Table: II: Geoaccumulation index in sediments

Site	Monsoon			Post Monsoon			Pre Monsoon		
	As	Pb	Hg	As	Pb	Hg	As	Pb	Hg
Site 1	0.12	-2.29	-5.32	0.23	-2.36	-6.18	0.38	-2.27	-5.73
Site 2	0.25	-2.18	-5.16	0.24	-2.32	-6.03	0.44	-2.24	-5.76
Site 3	0.04	-2.19	-5.17	0.07	-2.26	-5.97	0.57	-2.11	-5.46
Site 4	0.04	-2.32	-5.56	0.06	-2.30	-5.33	0.51	-2.29	-5.37
Site 5	0.16	-2.12	-5.46	0.24	-2.37	-5.30	0.40	-2.13	-5.34
Site 6	0.03	-2.19	-5.33	0.18	-2.36	-5.25	0.16	-2.31	-5.32
Site 7	0.34	-2.29	-5.09	0.27	-2.39	-5.35	0.10	-2.19	-5.52
Site 8	0.17	-2.40	-5.06	0.23	-2.31	-5.16	0.46	-2.31	-5.34
Site 9	0.40	-2.29	-5.31	0.19	-2.29	-4.89	0.25	-2.21	-5.44
Site 10	0.35	-2.23	-4.98	0.21	-2.29	-5.00	0.39	-2.15	-5.47
Min	0.03	-2.40	-5.56	0.06	-2.39	-6.18	0.10	-2.31	-5.76
Max	0.40	-2.12	-4.98	0.27	-2.26	-4.89	0.57	-2.11	-5.32
Mean	0.20	-2.30	-5.20	0.2	-2.30	-5.40	0.40	-2.20	-5.50
I_{geo}	Unpolluted/ Moderate	Unpolluted	Unpolluted	Unpolluted/ Moderate	Unpolluted	Unpolluted	Unpolluted/ Moderate	Unpolluted	Unpolluted

Table: III: Degree of contamination in sediments

Seasson	Arsenic	Lead	Mercury	C_d	C_d Ranking
Monsoon	1.72	0.32	0.04	2.08	Moderate
Post monsoon	1.72	0.30	0.04	2.05	Moderate
Pre monsoon	1.94	0.32	0.03	2.30	Moderate

Table IV: Pollution load index

Seasson	Arsenic	Lead	Mercury	PLI	PLI Ranking
Monsoon	1.72	0.32	0.04	0.01	Not polluted
Post monsoon	1.72	0.30	0.04	0.01	Not polluted
Pre monsoon	1.94	0.32	0.03	0.01	Not polluted

IV DISCUSSION

The determination of contamination factor of heavy metals is an important aspect that indicates degree of risk of heavy metals to environment in relation with its retention time (20). The contamination factors of heavy metals in the sediments during monsoon, postmonsoon and premonsoon were presented in the Table I**.** The contamination factors of As were observed highest (>1) at all the sampling sites in all seasons. A high contamination factor of heavy metal shows low retention time and high risk to the environment time (Wu *et al.*, 2010). Whereas Pb and Hg was <1 during monsoon, postmonsoon and premonsoon. According to Hakanson , C*f* has been classified into four groups: C*f* <1 low contamination factor, 1≤ C*f* <3 moderate contamination factor, 3≤ C*f* <6. According to Hakanson classification, Arsenic shows moderate CF, Lead and Mercury shows low CF.

Index of geo-accumulation permits assessment of the level of sediment contamination with respect to global standards. Igeo index demonstrated that the majority of the undertaken metals have index value below zero, whereas As has the Igeo value between 0 and 1, and falls in class 1 (Table II). This indicates that the adyar estuary sediment is uncontaminated at most of the sites. Several negative Igeo values were noted for all considering metals at many sites and showed that the Adyar estuary bed sediment is uncontaminated for most of the trace metals in the study area. The high concentrations of heavy metals in sediments may not necessarily indicate anthropogenic contamination, because of different background levels in parent materials and sediment properties (21).

The C_d value of Arsenic, Lead and Mercury shows the moderate contamination (Table III) in the sediments of adyar estuary. The metal shows the moderate contamination in monsoon, post- monsoon and pre- monsoon. The degree of contamination (C*d*) is defined as the sum of all contaminant factors of heavy metals (16). The metal shows the moderate contamination of class 2 (moderate) contamination in adyar estuary.

The PLI is used to assess the overall toxicity and quality status of the samples and furthermore it is a consequence of the contribution of the few metals (17). The PLI of the sediment is presented in Table IV. The PLI value of 0.01 is observed for Arsenic, Lead and Mercury during monsoon, premonsoon and postmonsoon. The PLI <1 value indicates the unpolluted state of Adyar estuary.

V CONCLUSION

Sediment pollution in the present study was assessed using Contamination factor (CF), Geo accumulation index (Igeo), Degree of contamination of sediments (Cd) and Pollution load index (PLI). The CF results revealed that the sediments are low level of contamination with respect to Pb and Hg and moderate level of contamination factor with As. Similar condition was observed in Igeo, where the sediments are unpolluted with respect to Pb and Hg and unpolluted to moderately polluted with As. The Cd ranking illustrated that the sediments are moderately contaminated with As, Pb and Hg. The PLI values revealed that the sediments were non polluted.

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