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STATUS OF HEAVY METAL POLLUTION IN THE SEDIMENT LAYER IN WORLD HERITAGE SITE: INDIAN SUNDARBAN ESTUARINE REGION

Shankhadeep Chakraborty[1, *], Abhijit Mitra[2]

[1] *Techno India University, Salt Lake campus, Kolkata- 700092*

[2] *University of Calcutta, 34, Ballygunge Circular Road, Kolkata- 700019*

[*]Email: *shankhadeepch@gmail.com*

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Abstract. Heavy metals are ecologically significant for their toxicity and accumulative behavior. The geoaccumulation index (I_{geo}) in 12 stations in Indian Sundarbans estuarine region (*i.e* Kakdwip, Harinbari, Chemaguri, Sagar South, Lothian island, Jambu island, Frasergunge, Gosaba, Chotomollakhali, Bali island, Sajnekhali and Bagmara) was calculated in this article. The degree of sediment pollution was investigated by following the concentration of 3 heavy metals namely copper, lead and cadmium. Atomic Absorption Spectrophotometer (AAS) was used for metal analysis. According to the geoaccumulation index (I_{geo}) the results of all the 12 stations were analyzed and discussed in detail. In one of the selected stations- Kakdwip I_{geo} value was 3, which signifies strongly contaminated ambient sediment in this area.

Keywords: Geoaccumulation index, copper, lead, cadmium, Indian Sundarbans, Atomic Absorption Spectrophotometer

Classification numbers: 3.2.3.

1. INTRODUCTION

Oceans and estuarine ecosystems are being exposed to a variety of metals the concentrations of which are regulated by natural processes and also anthropogenic activities [1]. Among these metals some are biologically essential supporting the biological processes upto a certain concentration whereas, other metals are non-essential and in most of the cases found toxic in nature. Estuaries are mixing region in which riverine inputs to the ocean is modified naturally [1, 2, 3]. Sediment concentrations of heavy metals pose a severe problem to the health of estuarine biotic community as the metals are uptaken into the food chain by biotic communities and get accumulated in them. Besides acting as a sink, sediment is also a potential source of contaminants like the heavy metals in aquatic systems [4]. The assessment of heavy metal concentrations in sediments is of prime importance as this can reflect the ecological health of the entire ecosystem [5]. Many methods are there to assess sediment quality such as background enrichment index, contamination indexes and risk assessment indexes though, only a few are practical for the estuarine environment like enrichment factor and geoaccumulation index. Various heavy metals (like- Zn, Cu, Pb, Hg, Cd, Mn, As etc.) are there in this environment continuously causing harmful impacts to the biotic communities but for this study only 3 of these are selected; namely- Cu, Pb and Cd. Above a permissible level these metals act upon the health of organisms creating various physiological disorders (Table 1). The top layer of ecological food chain (like-human being) is affected badly from the toxicity of these metals.

Table 1. Name of selected heavy metals, their permissible levels (as per WHO [6]) and their effects above the permissible level.

Name of heavy metals	Permissible level (ppm dry wt.)	Physiological effects above the permissible level on human being
Cu	30	Anemia, damage to liver and kidney, irritation in stomach and intestine [7]
Pb	0.05	Mental retardation in children, delay in development, fatal encephalopathy in infant, congenital paralysis, sensor neural deafness, chronic or acute damage to the nervous system, epileptics, damage to kidney and gastrointestinal system [8]
Cd	0.05	Kidney damage, acute respiratory syndrome, osteoporosis, intense bone-associated pain, gastro-intestinal disorders, prostate cancer [9, 10]

The sediment compartment can act as a potential indicator of metal flux in long and medium term in estuaries bound by various industries. The environmental chemistry of estuarine basin sediments in Indian Sundarbans has received less attention and very few literatures are available today on this topic [11, 12, 13, 14]. Estimation of geo-accumulation index may reflect an updated real image of current status of pollution in sediment layer in lower Gangetic delta region. This study aims to show the accumulation matrix of some of the major toxic heavy metals namely, Cu, Pb and Cd in this geographical area so that some precautionary measures are taken immediately to control it at source and biotic communities in the ambient media are protected from the very toxic effect of these metals.

2. MATERIALS AND METHODS

2.1. Study area and period of study

Twelve stations were selected from 3 sectors of the estuarine region of Indian Sundarbans with varying degree and types of anthropogenic activities were observed in the selected stations (Table 2).

Table 2. Coordinate of selected stations and major activities in the stations.

Stations	Latitude	Longitude	Major activities
Kakdwip	21°52′06″N	88°11′12″E	1. Fish landing station 2. Tourism 3. Passenger vessel jetties 4. Repairing and conditioning of boats and fishing vessels

Harinbari	21°47'01.36" N	88°04'52.98" E	Unorganized fish landing activities
Chemaguri	21°38'25.86"N	88°08'53.55" E	1. Repairing and conditioning of boats and fishing vessels 2. Fish landing activities 3. Market related activities 4. Shrimp farming
Sagar South	21° 38' 54.37" N	88° 03' 6.17" E	1. Pilgrims 2. Tourism 3. Adjacent to navigational channel
Lothian island	21° 39' 1.58" N	88° 22' 13.99" E	Minimum human interference due to its location within the protected area
Jambu island	21°35'42.03"N	88°10'22.76"E	Minimum human interference through enforcement of strict laws
Frasergunge	21° 33′ 47.76″ N	88° 15′ 33.98″ E	1. Fish landing station 2. Tourism 3. Passenger vessel jetties 4. Repairing and conditioning of boats and fishing vessels 5. Marketing of fish and forestry related products
Gosaba	22° 15' 45" N	88° 39' 46" E	1. Unorganized fish landing 2. Shrimp culture 3. Tourism (very few in number)
Chotomollakhali	22º10'21.74"N	88º53'55.18"E	1.Unorganised fish landing activities 2. Shrimp culture 3. Tourism (very few in number)
Bali island	22º04'35.17"N	88º44'55.70"E	Tourism
Sajnekhali	22º05'13.4" N	88 º 46'10.8" E	Minimum human interference due to its location within the protected area
Bagmara	23°59' 00"N	90°11' 00" E	Minimum human interference due to its remoteness

2.2. Metal analysis

Using Ekman Grab sampler (15.2 × 15.2 cm) sediment samples were collected during low tide at daytime form the selected stations. These collections were done in the month of April (premonsoon season), 2016 in all the selected stations. After retrieving the sampler, the water was drained off, avoiding any disturbance of the surface layer preserved samples using nylon zipper-sealed bags (17.7 × 20.3 cm. Then the samples were placed in an ice box until reaching the lab. Before analysis, the sediment samples were dried in an oven at 50 °C overnight, grinded very finely in an agate mortar and then sieved through a 63 μm plastic sieve. Metal analyses were done as per the standard method described by Radojevic and Bashkin, using the concentrated (70 % w/v) nitric acid, hydrogen peroxide (35 %) and hydrochloric acid (38 %) for digestion of sediment samples [15]. Each sample was analyzed for Cu, Pb and Cd against standard concentration of each metal on a Perkin Elmer Atomic Absorption Spectrophotometer (Model 3030) equipped with a HGA – 500 graphite furnace atomizer and a deuterium background corrector. Blank correction was done to bring accuracy to the results. Analyses were done triplicate and the average of these were taken finally to bring much more accuracy in the result. The accuracy of analytical procedure followed here was checked using the standard reference material, sediment (BCSS-1) obtained from National Research Council, Canada (NRCC) (Table 3**)**.

Table 3. Accuracy of analytical procedure estimated using Standard Reference materials, sediment (BCSS-1).

Element	Certified value (μg g-1)	Laboratory results (μg g-1)
Cu	18.5	20.4
Pb	22.7	20.8
Cd	0.25	0.27

2.3. Estimation of geoaccumulation index (I_{geo})

The superficial layer of sediments constitutes the largest heavy metals reservoir in aquatic ecosystems as per the basis of weight per square meter. After accumulation in sediments, the metals continue to pose a threat to aquatic biotic communities because of re-suspension process into the water matrix by phenomenon like geochemical re-cycling and through food chain transfer, including organic elements [16, 17]. In order to measure the degree of anthropogenic influence on concentration of heavy metals in the sediments I_{geo} was used.

Table 4. The degree of metal pollution in terms of distinguished enrichment classes [20].

I_{geo} Value	I_{geo} Class	Designation of sediment quality
0<	0	Not contaminated
0-1	1	Uncontaminated to contaminated moderately
1-2	2	Contaminated moderately
2-3	3	Moderately to strongly contaminated
3-4	4	Strongly contaminated
4-5	5	Strongly to extremely contaminated
>5	6	Extremely contaminated

The I_{geo} was calculated by following the Muller and Abrahim & Parker method as:

$$I_{geo} = \log_2 ([\text{sediment}]/ 1.5* [\text{reference sample}]).$$

The factor 1.5 is generally used to lower down the effect of possible variations in the background values due to to lithologic variations in the sediments [18, 19]. According to Bradl, the reference samples were for Cu: 50 µg/g, Pb: 20 µg/g and Cd: 0.3 µg/g [20]. Generally, the I_{geo} consists of 7 classes (Table 4).

3. RESULTS

I_{geo} value ranged from In case of Cu, I_{geo} value ranged from 0.54 (at Bagmara) to 2.43 (in Kakdwip) whereas, for Pb the value was found to range from 0.48 (at Bagmara) to 2.16 (in Kakdwip). In case of Cd, highest value of I_{geo} was observed as 2.03 (in Kakdwip) and lowest value was observed as 0.30 (in Bagmara) (Figure 1-3).

I_{geo} classes for selected metals in selected stations are shown in Table 4. For Cu, Kakdwip, Harinbari and Sagar south fall under class 3, Bali island and Bagmara fall under class 1 whereas, rest of the stations fall under class 2.

In case of Pb, only the station Kakdwip falls under class 3. All other stations fall under class 2 except Bali island, Bagmara and Gosaba which fall under class 1.

Kakdwip falls under I_{geo} class 3 for Cd whereas, 5 stations namely Harinbari, Chemaguri, Sagar south, Jambu island and Frasergunj fall under class 2. Remaining stations fall under class1 (Table 5).

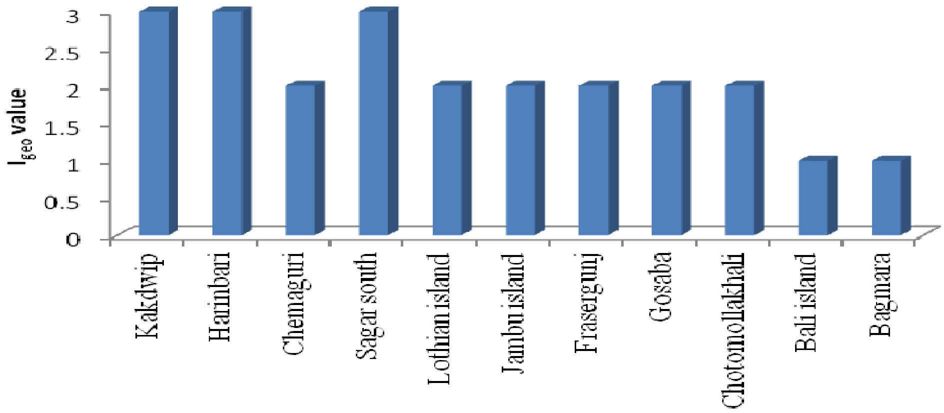

Figure 1. Variation in I_{geo} values for Cu in selected stations for 2016.

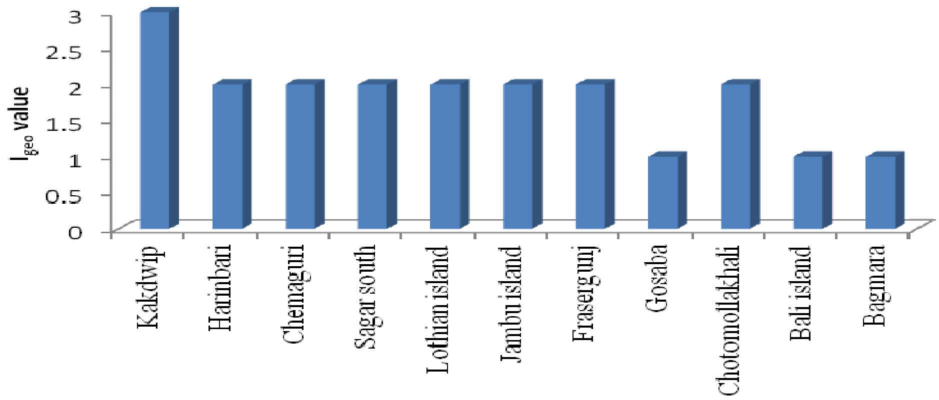

Figure 2. Variation in I_{geo} values for Pb in selected stations for 2016.

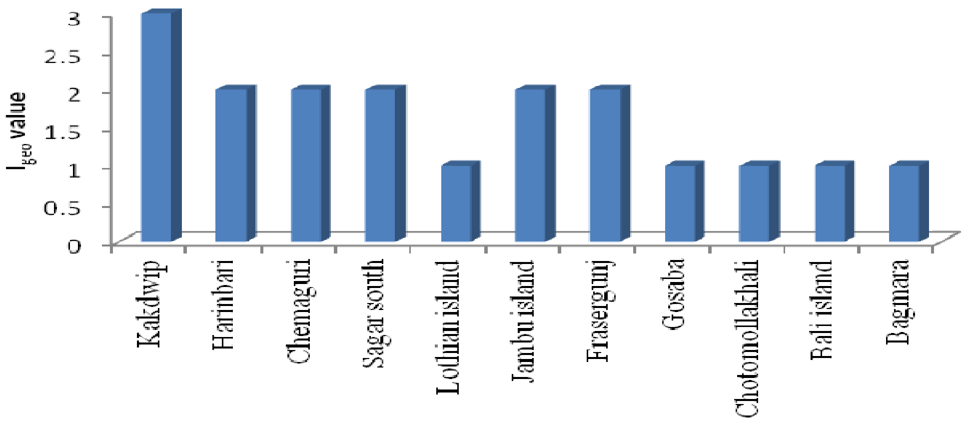

Figure 3. Variation in I_{geo} values for Cd in selected stations for 2016.

Table 5. I_{geo} classes for selected stations and metals for the year 2016.

Stations	I_{geo} class for Cu	I_{geo} class for Pb	I_{geo} class for Cd
Kakdwip	3	3	3
Harinbari	3	2	2
Chemaguri	2	2	2
Sagar south	3	2	2
Lothian island	2	2	1
Jambu island	2	2	2
Frasergunj	2	2	2
Gosaba	2	1	1
Chotomollakhali	2	2	1
Bali island	1	1	1
Bagmara	1	1	1

4. DISCUSSION

Researches organized in different region of the world have notably used the sediment matrix of the wetlands as pollution indicator [14, 21, 22, 23]. Among the selected heavy metals in this study copper is biologically essential element whereas, lead and cadmium are non-essential toxic elements. The main sources of copper in this study region is the anti-fouling paints used for trawlers and fishing vessels whereas, among the major sources of lead in this geographical area painting, dyeing, battery manufacturing units and oil refineries etc. are important. For cadmium, the main sources are various kinds of industries like electroplating, metal refining, battery manufacturing, fertilizer industry etc. [12].

From the study of I_{geo} value, it is clear that the station Kakdwip is moderately to strongly contaminated by all the selected heavy metals. It may be due to greater anthropogenic activities mentioned in Table 2. Discharges from newly established Haldia port-cum-industrial complex and cities like Kolkata and Howrah are responsible for the higher degree of pollution in this station. The stations Harinbari and Sagar south are moderately to strongly contaminated by Cu due to the same reasons. Stations in the eastern Indian Sundarbans namely Sajnekhali and Bagmara are uncontaminated to moderately contaminated due to minimum human interference

(Table 5). All the remaining elected stations are moderately contaminated by the selected heavy metals. Time-series analyses are essential to monitor the status of heavy metal pollution in this study area.

5. CONCLUSION

Overall results suggest that the stations in the western sector of Indian Sundarbans estuarine system is under moderate to rich polluted zone followed by the central sector. The eastern sector is still under 'not polluted' caption as per the I_{geo} result and hence this region is supportive for the biodiversity to reach its optimum level. The coastal zone dwellers are directly dependent on the natural aquatic products like- food and drink for their daily life. Hence, this kind of pollution may yield detrimental effects on their health. Strict enforcement of existing laws to control the effluent discharge from point sources coupled with mass awareness programmes involving the grass-root level stakeholders (preferably fisherman, aquaculturists, fishing boat and trawler manufacturers) may be a realistic road map to control the pollution level in the aquatic system of this mangrove dominated World Heritage Site. Station like Kakdwip is showing the I_{geo} value > 3 indicating bad condition of the sediment layer. It may be the result of excessive pressure from a big local fish market, unplanned tourism and heavy industrial activities in nearby metropolitan cities like Kolkata and Howrah. This finding should be taken seriously by Govt. and NGOs who can take immediate planned action in order to check the deleterious impact of this malady.

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