SEASONAL VARIATIONS AND ANTHROPOGENIC INFLUENCES ON DISSOLVED HEAVY METALS IN COASTAL WATERS OF WEST BENGAL

Manju Das[1], Arpita Saha[1], Jagadish Mandal[1], Nagaraj Sannabhadti[1], Sufia Zaman[1], and Abhijit Mitra[1]

[1]Department of Oceanography, Techno India University, West Bengal, Salt Lake Sector V, Kolkata 700091, India

Abstract

The present study examines the seasonal variations of dissolved heavy metals (Zn, Cu, Pb) in selected stations along the coastal waters of West Bengal. The study, conducted over two years (2021–2022), reveals significant seasonal fluctuations in metal concentrations, with the highest levels recorded during the monsoon, followed by postmonsoon and premonsoon periods. The variations are attributed to hydrological changes, anthropogenic activities, and industrial effluents. The results highlight the necessity for stricter pollution control measures and sustainable management practices to mitigate heavy metal contamination in estuarine ecosystems.

Keywords: Heavy metals, Zn, Cu, Pb, seasonal variation, anthropogenic activities, estuarine pollution

1. Introduction

Heavy metal contamination in estuarine and coastal environments is a growing concern due to its toxic effects on aquatic biota and potential risks to human health. Estuaries act as sinks for anthropogenic pollutants, which accumulate from industrial discharges, urban runoff, and agricultural waste (Mitra et al., 1987; Mitra et al., 1992; Mitra and Choudhury, 1993; Mitra and Choudhury, 1994; Mitra 1998; Mitra et al., 2009; Mitra 2000; Mitra et al., 2009). This study focuses on the spatial and seasonal variations of dissolved Zn, Cu, and Pb in three stations, namely, Diamond Harbour, Kakdwip, and Namkhana, where diverse anthropogenic activities influence heavy metal distribution. Previous studies in West Bengal estuarine waters have indicated substantial impacts of industrial effluents on metal accumulation, necessitating further investigation (Chakraborty et al., 2009).

2. Materials and Methods

2.1. Study Area

The study was conducted at three stations in the coastal West Bengal estuary system:

Station 1 (Diamond Harbour) (22°11'4.2″N; 88°11'22.2″E): Dominated by fish landingactivities and tourism.

Station 2 (Kakdwip) (21°52'35.7″N; 88°11'55.0″E): Influenced by commercial markets and fish landing stations.

Station 3 (Namkhana)(21°45'53.7"N and 88°13'51.5"E): Characterized by shrimp farming, brick kilns, and industrial effluents.

2.2. Sample Collection and Analysis

Monthly water samples were collected from each station using Teflon-lined Go-Flo bottles and filtered through 0.4 µm Nucleopore filters. The samples were acidified with sub-boiling distilled nitric acid and stored in polyethylene bottles for analysis. Heavy metal concentrations were determined using an Atomic Absorption Spectrophotometer (Perkin Elmer: Model 3030). Physicochemical parameters, including temperature, pH, and salinity, were recorded *in situ*.

3. Results

3.1. Dissolved Zn

The concentration of dissolved Zn ranged from 419.78 ppb to 674.90 ppb, following the order: monsoon > postmonsoon > premonsoon. The highest values were recorded at Namkhana during the monsoon season (674.90 ppb). The observed trend suggests that increased riverine input and run-off contribute to elevated Zn levels.

The dissolved Zn ranged from 419.78 ppb to 674.90 ppb in the study area and the order is monsoon > postmonsoon > premonsoon (Table 1 and Fig. 1).

Table 1: Station-wise seasonal variation of dissolved Zn (ppb) during 2021 and 2022

Season	Stn. 1		Stn. 2		Stn. 3	
	2021	2022	2021	2022	2021	2022
Premonsoon	419.78	467.04	521.55	586.05	456.84	595.44
Monsoon	504.22	529.91	593.76	604.71	632.28	674.90
Postmonsoon	485.77	508.96	554.87	595.45	601.19	642.30

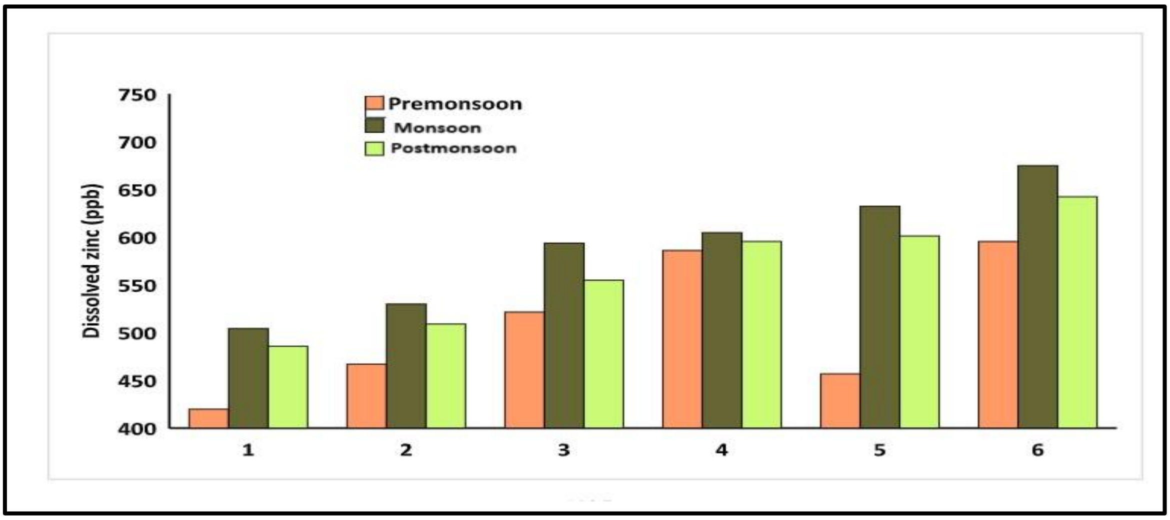

Fig. 1. Dissolved Zn in the selected three sites during study period

3.2. Dissolved Cu

Cu concentrations varied between 87.45 ppb and 301.56 ppb. The highest concentration was observed at Namkhana during monsoon (301.56 ppb). Sources of Cu contamination include antifouling paints, algaecides, and pipeline corrosion.

The dissolved Cu ranged from 87.45 ppb to 301.56 ppb in the study area and the order is monsoon > postmonsoon > premonsoon (Table 2 and Fig. 2).

Table 2: Station-wise seasonal variation of dissolved Cu (ppb) during 2021 and 2022

Season	Stn. 1		Stn. 2		Stn. 3	
	2021	2022	2021	2022	2021	2022
Premonsoon	87.45	96.20	112.88	134.22	156.44	199.48
Monsoon	102.62	158.90	203.34	287.65	297.52	301.56
Postmonsoon	97.43	134.04	189.60	216.62	244.75	265.47

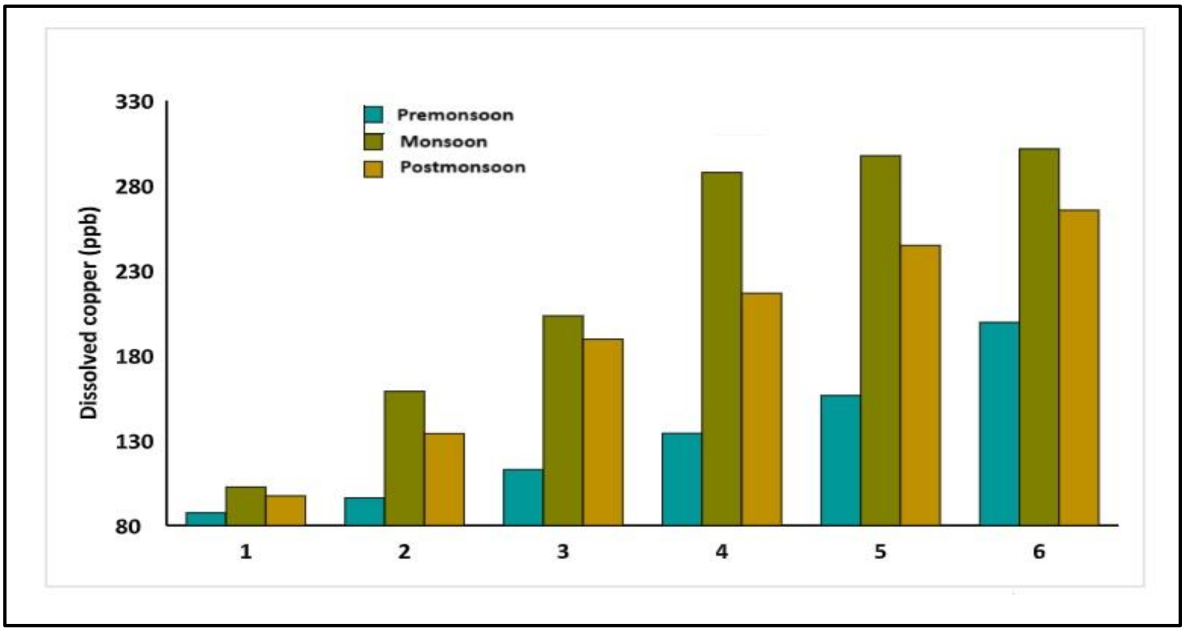

Fig. 2. Dissolved Cu in the selected three sites during study period

3.3. Dissolved Pb

Pb levels ranged from 17.21 ppb to 65.13 ppb, with monsoon recording the highest concentrations. The maximum Pb value was detected at Namkhana (65.13 ppb). Pb pollution stems from battery manufacturing, painting industries, and oil refineries.

The dissolved Pb ranged from 17.21 ppb to 65.13 ppb in the study area and the order is monsoon > postmonsoon > premonsoon (Table 3 and Fig. 3).

Table 3: Station-wise seasonal variation of dissolved Pb (ppb) during 2021 and 2022

	Stn. 1		Stn. 2		Stn. 3	
	2021	2022	2021	2022	2021	2022
Premonsoon	17.21	29.06	35.16	42.88	40.77	48.92
Monsoon	36.08	54.17	57.60	59.36	62.40	65.13
Postmonsoon	24.59	37.22	50.73	54.82	51.69	58.00

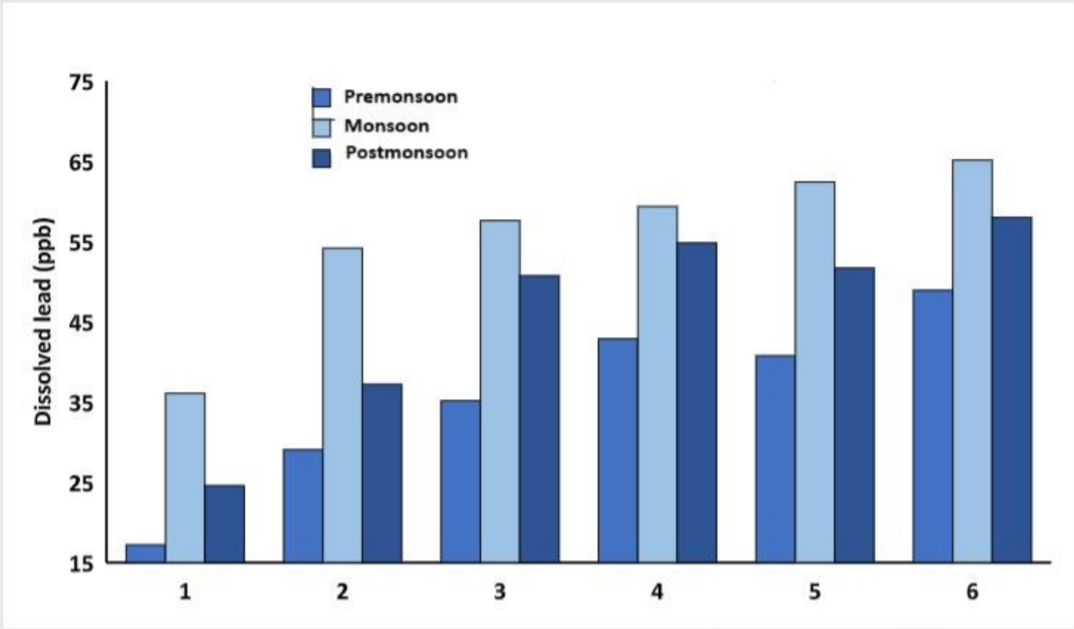

Fig. 3. Dissolved Pb in the selected three sites during study period

4. Discussion

The root cause behind this negative scenario in context of dissolved heavy metals is the variation in the degree of anthropogenic activities in these stations. Station 1 (Diamond Harbour) has fish landing station and tourism units. Station 2 (Kakdwip) is also having fish landing along with busy market places, while station 3 (Namkhana) is noted for the presence of fish landing stations, tourism activities, shrimp farms, brick kilns *etc*. (Mitra, 2013; Mitra and Zaman, 2014; Mitra and Zaman, 2015; Mitra and Zaman, 2016; Nair, 1984; Parker, 1989). All these anthropogenic activities generate huge load of heavy metals into the aquatic ecosystem, which finally get separated into aquatic phase and sediment compartment depending on the pH (Mitra and Zaman, 2021).

Heavy metals enter inside the fish tissues through gills from the aquatic phase and through their food materials that are distributed over the sediment compartment. Thus, the food intake pattern also governs the magnitude of deposition of heavy metals in the fish muscle.

Of the three metals studied in the present research programme, Zn and Cu are essential elements, while Pb is non-essential and toxic in nature. The concentrations of Zn and Cu in all the fish samples are relatively higher compared to Pb. This is because Zn and Cu are essential elements required by animals for metabolic process (Mitra et al., 2012a), while Pb is a toxic metal not required in any steps of metabolism. Zinc and copper appear to diffuse passively through the gradients created by adsorption of membrane surface and are found in blood proteins metallothionines.

The primary sources of zinc in the present study are the galvanization units, paint manufacturing units and pharmaceutical processes, which are mainly concentrated in the Haldia industrial sector (Table 4).

Table 4: List of industries situated near Haldia port-cum-industrial complex

Sl. No.	Name of Industry	Product
1.	Indian Oil Corporation Ltd., Haldia	L.P.G., Motor Gasoline, Naptha, ATF, MTO, HSD, JBO, Kerosene, Furnace Oil, Lubes, Bitumen
2.	KoPT/Haldia Dock Complex	Port Services
3.	Tata Chemicals Ltd., Haldia	Industrial Phosphate and Acids.
4.	Exide Industries Ltd., Haldia	Automotive Batteries, Heavy Duty Batteries, Containers, Special Types of Separators, *etc*.
5.	Shaw Wallace, Haldia	Pesticides
6.	MCC PTA India Corpn. Pvt. Ltd., Haldia	P.T.A
7.	Haldia Petrochemicals Ltd., Haldia	LLDPE, HDPE, Naptha Cracker *etc.*
8.	IOCL, Paradip-Haldia Oil Pipeline	Petroleum Storage and Transportation
9.	IOC Petronas Ltd., Haldia	L.P.G
10.	Shamon Ispat Ltd.	Steel Rolling
11.	Dhunseri Petrochem and Tea Ltd.	Petroleum residues
12.	Greenways Shipping Agencies Pvt. Ltd.,	Containers Freight Station (CFS)
13.	IOC Ltd., Haldia	Petroleum Storage
14.	Hindustan Petroleum Corporation Ltd.	Petroleum and allied products
15.	Bharat Petroleum Corporation Ltd., Haldia	Petroleum and allied products.
16.	Hindustan Unilever Limited.	Detergents
17.	Marcus Oils and Chemical Pvt. Ltd.	Polyehylene Waxes
13.	IOC Ltd., Haldia	Petroleum Storage
18.	Ruchi Soya Industries Ltd.	Edible Oil
19.	Manaksia Ltd.	Aluminum and Steel
20.	Sanjana Cryogenic Storages Ltd	Ammonia Storage and handling terminal
21.	R. D. B. Rasayans Ltd.,	PP Jumbo Bag and Small bag.
22.	Reliance Industries Limited	Storage and handling Petroleum Product
23.	Adani Wilmar Ltd.	PEdible Oil Refinery
24.	Electrosteel Castings Ltd.	Coke Oven Plant, sponge iron plant, power plant
25.	URAL India Ltd.	Automobile
26.	K.S. Oils Ltd.	Edible Oil Refinery

27.	DPM Net Pvt. Ltd.	Fishing net
28.	Hooghly Met Coke and Power Co. Ltd.	Coke Oven Plant
29.	Ruchi Infrastructure Pvt. Ltd.	3rd Party liquid storage tank terminal.
30.	Shree Renuka Sugars Ltd.	Sugar Refinery and Food Complex.
31.	Gokul Refoils and Solvent Ltd.	Edible Oil Refinery
32.	Emami Biotech Ltd.	Bio-diesel Plant.
33.	Ennore Coke Private Ltd.,	Coke Oven Plant.
34.	West Bengal Waste Management Ltd.	Industrial waste / municipal waste management complex.
35.	Lalbaba Seamless Tubes Pvt. Ltd.	Seamless Tube
36.	Modern India Con-cast Ltd.	Ferro Alloy Plant
37.	Rohit Ferro Tech Ltd.	Ferro Alloy”

Source*: Haldia Development Authority - An Autonomous Body under Government of West Bengal, India (www.nltr.org)*

The main sources of copper in water are antifouling paints, paint manufacturing units, pipeline corrosion and algaecides used in the fish farming sector (Mitra et al., 2010).

Lead is a toxic heavy metal, which finds its way in the estuarine water of the present study area through the discharge of industrial waste water that contain residues of painting units, dyeing, battery manufacturing units and waste from oil refineries etc.

To ensure human health security, it is therefore the need of the hour to check the release of heavy metals from point and non-point sources through implementation of treatment plants, scale up bioremediation process, and strict legal actions to cap the discharge of wastes from industrial and other anthropogenic sources.

The seasonal variations in dissolved heavy metals can be attributed to hydrodynamic factors such as freshwater influx, precipitation, and tidal mixing. The monsoon period exhibits elevated metal concentrations due to increased runoff and reduced salinity, enhancing the dissolution of metal precipitates. Conversely, premonsoon periods show lower concentrations due to high salinity and metal precipitation. Industrial discharges from Haldia and adjacent regions significantly contribute to Zn, Cu, and Pb pollution. The correlation between pH, salinity, and metal levels suggests that chemical speciation and precipitation-dissolution equilibrium play crucial roles in metal distribution.

5. Conclusion

This study underscores the influence of anthropogenic activities on heavy metal contamination in coastal waters. Implementing pollution control measures, bioremediation strategies, and stringent industrial regulations are imperative to mitigate heavy metal influx into estuarine ecosystems.

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