Assessment of Heavy Metal Contamination in Sediments of Diva-Motagaon Creek Thane District, Maharashtra, India

Rajendra Karnik[1], Shantaj Deshbhratar[1] and Suraj Gajbhiye[2]

[1]Department of Zoolog[1],
[2]Department of Botany Bhavan's Hazarimal Somani College, Chowpatty, Mumbai-400007, University of Mumbai
Email:rajendrakarnikbhagu@gmail.com
Corresponding author: dr.shantajmdeshbhratar@bhavanschowpatty.ac

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ABSTRACT

The increasing levels of toxic heavy metals in aquatic environments pose significant threats to ecosystems, biodiversity, and human health. The Diva-Motagaon Creek, located in Thane District, Mumbai, is one such site under investigation in this study, which aims to analyze the concentrations of various toxic heavy metals in sediment samples. As a reliable and accurate method, Atomic Absorption Spectroscopy (AAS) was used to study the effects of long-term pollution load and the buildup of heavy metal contaminants in this estuarine ecosystem.

Sediment samples were collected from four strategically selected stations along the Diva-Motagaon Creek, covering four seasons from January 2023 to December 2023. The four seasons—pre-monsoon, monsoon, post-monsoon, and summer—were chosen to capture the seasonal variations in pollution levels, as aquatic environments are highly dynamic and pollutant concentrations can fluctuate due to factors like rainfall, industrial runoff, and human activities. The collected samples were analysed for the presence of chromium (Cr), copper (Cu), iron (Fe), lead (Pb), and zinc (Zn), which are commonly found in environmental pollution, particularly industrial effluents, urban runoff, and agricultural practices.

The analysis revealed notable variations in the concentrations of these heavy metals across different seasons and geographical locations within the creek. Zinc was found to be the most abundant heavy metal, followed by iron, copper, lead, and chromium, in that order. The fact that the concentration changes with the seasons suggests that the metal levels are affected by things like industrial discharges, monsoon runoff, and human activities in the area, such as religious events like immersing Ganapati idols. Among the studied metals, zinc showed the highest concentrations, which may be attributed to local industrial activities and sewage discharge into the creek.

The results of this study demonstrate that heavy metal pollution in Diva-Motagaon Creek is influenced by a combination of natural processes and anthropogenic activities. High levels of metals like lead, copper, and chromium are especially bad for the environment because they can build up in aquatic organisms and make fish, invertebrates, and other marine life sick. Zinc, while essential in trace amounts for aquatic organisms, can become toxic in higher concentrations, disrupting the health of aquatic ecosystems.

The study's findings are crucial for environmental management and policy development, as they offer a scientific basis for monitoring and controlling pollution in the Diva-Motagaon Creek. The findings indicate the need for immediate action to reduce the heavy metal concentrations in the creek, particularly through effective waste management practices, industrial regulation, and pollution control strategies. The fishing industry is prevalent in the area, and the study's results emphasise the importance of protecting aquatic resources to ensure the safety of local livelihoods and the sustainability of the marine ecosystem.

This study sets a baseline for the current level of pollution, which is very important for future research and actions that will be taken to help the environment and lessen the harmful effects of heavy metal pollution. The results can inform the rational planning of pollution control strategies and support efforts to restore and protect the health of Diva-Motagaon Creek. The results also show how important it is for scientists to keep an eye on things all the time to learn more about how heavy metal toxicity changes over time and how it affects marine and estuarine environments over time.

The increasing levels of toxic heavy metals in aquatic environments threaten ecosystems, biodiversity, and human health. Atomic Absorption Spectroscopy (AAS) is used to look at heavy metal contamination in sediment samples from Diva-Motagaon Creek in Thane District, Mumbai. In 2023, samples were taken from four locations during four seasons: pre-monsoon, monsoon, post-monsoon, and summer. The goal was to see how the concentrations of chromium (Cr), copper (Cu), iron (Fe), lead (Pb), and zinc (Zn) changed with the seasons.

Results revealed significant seasonal and spatial variations, with zinc being the most abundant metal, followed by iron, copper, lead, and chromium. High metal levels, especially during and after the monsoon season, are a sign of pollution from factories, urban runoff, and human activities like immersing Ganapati idols. While zinc is essential in trace amounts, its high concentrations, along with toxic levels of lead, copper, and chromium, pose ecological risks through bioaccumulation in aquatic organisms.

These findings highlight the urgent need for pollution control measures, including industrial regulation, improved waste management, and continuous environmental monitoring. Given the creek's significance to local fisheries, mitigating heavy metal contamination is crucial for preserving marine ecosystems and safeguarding livelihoods. This study establishes a baseline for future research and policy interventions to restore and protect Diva-Motagaon Creek.

Introduction:

Heavy metals, including toxic elements like chromium, lead, cadmium, arsenic, and others, are among the most concerning pollutants in environmental sciences. These metals, often originating from both natural and human-made sources, pose serious risks to both human health and aquatic ecosystems. In natural environments, heavy metals may be released through processes such as the weathering of rocks, volcanic eruptions, and erosion. However, the scale of pollution has significantly escalated due to human activities, such as industrial emissions, mining operations, agriculture, and urbanization.In particular, the Diva-Motagaon Creek in Mumbai has become a hotspot for heavy metal contamination due to rapid industrialization and increasing urban runoff, making it an ideal location for studying the effects of such pollution. These metals keep building up and moving around in soils, water, and living things, which can have a big impact on the health of the environment. This can change the biological productivity of aquatic systems and put the ecosystem at long-term risk. Despite being naturally occurring, when these metals accumulate in concentrations that exceed the natural threshold, they become hazardous to ecosystems and human populations. In aquatic ecosystems, particularly, sedimentation in water reservoirs causes the metals to settle into the water bed, which can have harmful effects on aquatic life. The Risks of Heavy Metal Contamination to Aquatic Ecosystems

Heavy metals such as chromium**,** lead**,** cadmium**,** and arsenic—even in trace concentrations—can be extremely toxic to living organisms. These metals have a high affinity for binding to biological tissues, and once they enter the aquatic food chain, they can bioaccumulate in fish, plants, and other organisms. This bioaccumulation leads to biomagnification, where the concentration of these metals increases as they move up the food chain, ultimately reaching apex predators and humans. The health risks of heavy metals for aquatic organisms include reduced growth rates, impaired reproductive success, and compromised immune systems. For example, lead and cadmium can interfere with the neurotransmission in fish, causing neurological damage that can hinder their ability to survive and reproduce.

For humans, the risks are equally significant. Heavy metal contamination in drinking water or the consumption of contaminated seafood can result in toxic effects on human health. Chronic exposure to these metals can lead to conditions such as cancer**,** kidney damage**,** neurological disorders**,** and developmental impairments in children. The exposure pathways often include contaminated drinking water**,** fish consumption, or direct contact with contaminated water bodies.

The Role of Sediments in Heavy Metal Pollution Monitoring

In many aquatic systems, sediments act as a critical repository for contaminants, including heavy metals. Sediment samples often contain concentrations of heavy metals that are orders of magnitude higher than those found in overlying water. This property of sediments makes them highly valuable as indicators of pollution and essential tools for monitoring changes in water quality over time. Sediments can act as both sinks and sources of pollutants. While they may temporarily trap metals from water, they can also release these metals back into the water under certain conditions, a process that could potentially harm aquatic life.The analysis of sediment cores provides a historical record of metal contamination, offering critical insights into the temporal trends of pollution. Such analysis can help scientists understand the trajectory of contamination, how pollutants have spread over time, and whether current pollution control measures are effective. By analyzing heavy metals in sediments, researchers can not only assess the current state of contamination but also predict future risks and inform the design of effective management strategies.In the case of Diva-Motagaon Creek, sediment samples are very important for finding out how much heavy metal is in the water and what the long-term effects of industrial waste and urban runoff are. The rapid urbanization and industrial growth in the area have led to a significant increase in pollution, particularly from industries located in the Dombivli MIDC area, which discharges effluents directly into the creek. These effluents contain a range of toxic substances, including chromium, lead, copper, and zinc, which are harmful to both aquatic organisms and the surrounding human populations.

Research Gap and Objectives of the Study

While extensive research has been conducted on the contamination levels of heavy metals in other parts of Mumbai, such as the Thane-Belapur Industrial Area [Gajbhiye & Bhalerao, 2016] and the Ulhas River near Dombivli [Jadhav & Singare, 2015], the Diva-Motagaon Creek has largely been overlooked. This creek, however, plays an important role in the local economy, particularly in the fishing industry, and is home to a number of sensitive aquatic species. There is a pressing need for a systematic study that specifically focuses on this creek to understand the extent of heavy metal contamination and the associated ecological risks.

This research aims to fill this gap by analyzing the concentrations of chromium, copper, iron, zinc, and lead in sediment samples collected from Diva-Motagaon Creek over the course of a year. The study will also investigate the seasonal variations in contamination levels and assess the potential sources of pollution, including industrial effluents, urban runoff, and agricultural runoff. By providing valuable data on the concentrations and distribution of these metals, this study will contribute to a better understanding of the health of aquatic ecosystems in the region and offer recommendations for future pollution control measures.

The findings from this research will serve as a crucial foundation for the development of targeted pollution control strategies. As industrial pollution continues to increase in the Diva-Motagaon Creek, it is imperative to prioritize the restoration of water quality and the protection of aquatic life. Through continued monitoring, proper waste management, and the implementation of more effective environmental regulations, the health of this important water resource can be preserved. We can lessen the harmful effects of heavy metals and protect Diva-Motagaon Creek's future as an important waterway for people and animals by focussing on where the pollution comes from and regularly checking the quality of the water and sediment.

Significance and Importance of study area

- Ecological and Environmental Importance of Diva and Mothagaon Creek
- Diva and Mothagaon Creek, located in Thane, Maharashtra, are vital estuarine ecosystems that support biodiversity, local livelihoods, and hydrological balance.
- Mangrove Ecosystem
- It serves as a natural buffer against coastal erosion and flooding.
- It provides habitat for marine life and migratory birds.
- Biodiversity Hotspot
- The area is home to diverse aquatic species, including fish, crustaceans, and molluscs.
- It supports avian biodiversity, attracting herons, egrets, and kingfishers.
- Fisheries and livelihoods
- This is essential for local fishing communities, providing sustenance and income.
- Serves as a breeding and nursery ground for fish species.
- Water filtering and carbon sequestration
- Mangroves and wetlands filter pollutants, improving water quality.
- It plays a key role in carbon sequestration, reducing greenhouse gases.
- Flood Control and Hydrological Balance
- It absorbs excess water during high tides and monsoons, thereby reducing flood risks.
- Maintains the balance between saline and freshwater, crucial for estuarine ecology.
- Threats and Conservation Challenges
- Habitat destruction due to urbanization and encroachments.
- Industrial and domestic pollution degrades water quality.
- Illegal land reclamation disrupting ecosystem b

Study Area and Sampling Methodology

Study Area

Diva Creek (19.1869°N, 73.0478°E) to Mothagaon Creek (19.2273°N, 73.0730°E) spans approximately 11 km within Thane Creek (26 km long; 72°55'–73°00'E, 19°00'–19°15'N). Thane Creek connects to Mumbai Harbour in the south and links with the Ulhas River near Thane city in the north. The creek is narrow and shallow at the riverine end due to a geomorphic head near Thane city but widens and deepens toward the sea. It is tidally influenced, with minimal freshwater inflow except during the monsoon. The substratum consists of consolidated and unconsolidated boulders, loose rocks, and occasional sand and gravel, while extensive mudflats along the banks support mangrove growth.

Sample Collection

Soil samples were collected from four stations along the creek in March, June, September, and December, representing pre-monsoon, early monsoon, and post-monsoon seasons. Sampling was conducted using local ferry services. All chemicals and reagents used were of analytical grade. Laboratory glassware was pre-soaked in nitric acid, rinsed with tap water and deionized water, and dried in a clean environment before use.

Sediment Sampling and Preparation

Sediment samples were collected using 7 cm diameter plastic core tubes, inserted as deep as possible. In the laboratory, cores were sliced into sections:

- **0–15 cm:** 1 cm intervals
- **15–25 cm:** 2 cm intervals
- **Beyond 25 cm:** 5 cm intervals.

Samples were transported in iceboxes and later ground into a fine powder using an alumina mortar, passed through a 2 mm mesh screen, and stored in polyethylene bags in a dry place until analysis.

Sample Digestion and Analysis

Well-mixed 2 g sediment samples were digested in 250 mL glass beakers with 8 mL aqua regia on a sand bath for two hours. After evaporation to near dryness, 10 mL of 2% nitric acid was added. The solution was filtered (Whatman No. 1) and diluted with deionized water based on suspected metal concentrations.

For further digestion, samples underwent microwave-assisted nitric acid digestion (30 bar pressure, 700W power). A 400-mL sample was mixed with 10 mL of 2% ammonium pyrrolidine dithiocarbamate, 4 mL of 0.5M HCl, and 10 mL of methyl isobutyl ketone (MIBK). The sample was then shook very hard and the phases were separated. The MIBK extract was diluted as needed and analyzed using an atomic absorption spectrophotometer via an air-acetylene flame.

Figure 1. Map Showing Sampling Stations along diva - Motagaon Creek Vicinity Thane

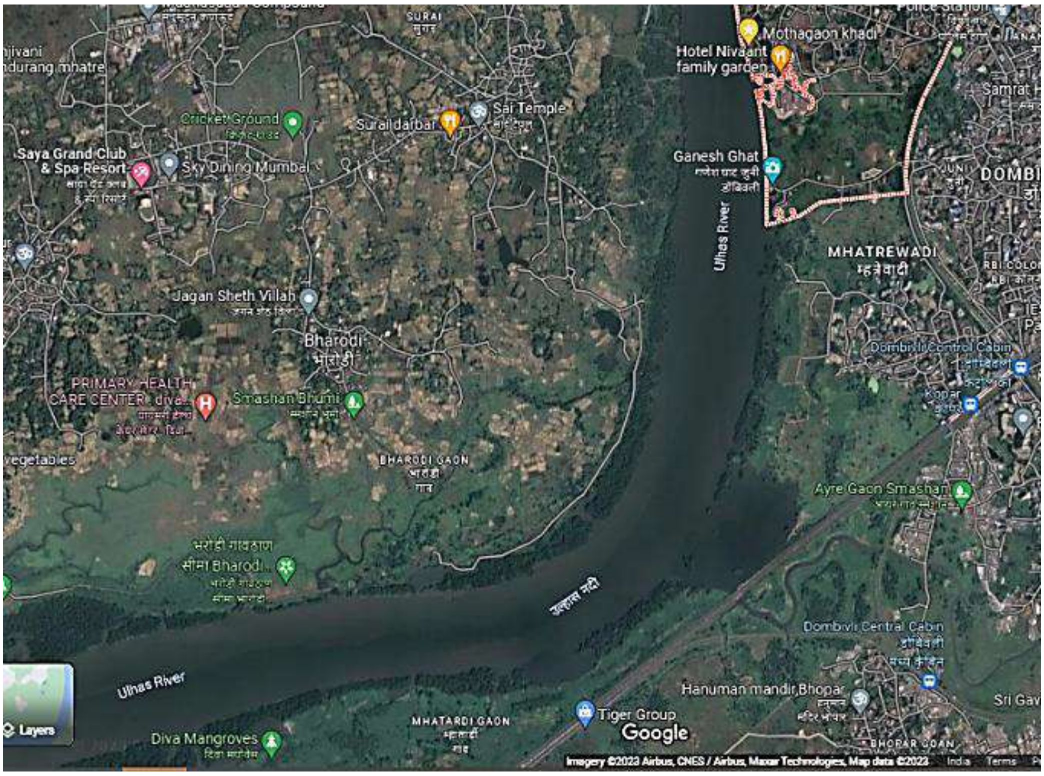


Figure 1a: Map and Photographs of area and station
Analysis of heavy metals using the Atomic Absorption Spectroscopy (AAS) technique.

3.4 Trace Metal Analysis Methodology

Trace metals, including cadmium (Cd), chromium (Cr), lead (Pb), manganese (Mn), and mercury (Hg), were analyzed using a Perkin Elmer ASS-280 Flame Atomic Absorption Spectrophotometer. This system is equipped with an atomic fluorescence detector for enhanced sensitivity. Specifically, mercury (Hg) was analyzed using the cold-vapor technique, which is ideal for detecting low concentrations of mercury.

Calibration and Standards:
The analysis was performed by preparing calibration curves using standard solutions of varying concentrations. A reagent blank was included in each batch to account for any potential contamination or interference. The results for each metal were averaged from three replicate measurements to minimize errors arising from reagent impurities and environmental factors.

3.5 Quality Control and Assurance

Quality control measures were carefully implemented throughout the sediment sample collection and analysis process:

Sample Collection:
All sediment samples were collected using plastic implements to prevent contamination from metals or other organic compounds. The samples were stored in polythene bags, which were free from heavy metals and other contaminants, and kept well-covered during transport from the field to the laboratory to avoid exposure to environmental pollutants.

Reagents and Instrument Calibration:
All reagents were standardized using primary standards to ensure the accuracy of their concentrations. Prior to use, all instruments were thoroughly calibrated, and tools and work surfaces were meticulously cleaned between each sample preparation step to prevent cross-contamination during grinding.

Precision and Validation:
Replicate samples were analysed to assess the precision of the analytical method and the instruments. A spike recovery test was also done on certain metals, including arsenic (As), cadmium (Cd), chromium (Cr), lead (Pb), manganese (Mn), and mercury (Hg), to make sure the results were correct and the overall analytical process was valid.

Table 1: Analytical Method and Permission Levels for Heavy Metals

Note: This table provides the specific analysis methods and permissible levels for each heavy metal, ensuring compliance with relevant environmental standards.

Heavy Metal	Cadmium (Cd)	Arsenic (As)	Zinc (Zn)	Lead (Pb)	Iron (Fe)	Chromium (Cr)	Copper (Cu)	Mercury (Hg)	Dissolved Oxygen (DO)	Manganese (Mn)
Method Analysis	IS:3025 (Part 41)	IS:3025 (Part 37)	IS:3025 (Part 49)	IS:3025 (Part 47)	IS:3025 (Part 53)	IS:3025 (Part 52)	IS:3025 (Part 42)	IS:3025 (Part 48)	IS:3025 (Part 38)	IS:3025 (Part 59)
Permissible Limits	0.1	0.05	5	0.1	0.3	0.05	0.05	0.002	40	0.1

Statistical Analysis Descriptive statistics (mean, standard deviation) of the data obtained were calculated. Correlations between the heavy metals in soil and water were done by using the software PAST version 2.3 (13).

Results and Discussion

The concentration of various heavy metals at different sampling stations was analysed on a monthly basis, with results presented in Tables 1–4. Seasonal variations in heavy metal concentrations are summarised in Table 5.

There are graphs of the average concentrations of each heavy metal across all stations in the figures below. These graphs show the changes and trends that were seen during the study period. These trends reflect the influence of factors such as tide cycles, freshwater flow (particularly during the monsoon), and potential anthropogenic inputs.

Key Observations:

• Changes from month to month: The amounts of heavy metals found changed at different stations. Some metals had higher concentrations in some months, which may have something to do with changes in rainfall or tides.

Seasonal Variations: The seasonal data demonstrated how the monsoon and dry periods impacted the concentration of metals, with noticeable increases in specific metals during the wet season due to runoff and freshwater influx.

Interpretation:

The data from both monthly and seasonal analyses offer insight into the dynamics of heavy metal distribution in the Diva and Mothagaon creeks, allowing for the assessment of potential environmental impacts and the identification of periods with elevated contamination levels:

Chromium Contamination in Diva- Motagaon Creek

Sources & Concentration
Chromium, found in industrial alloys, coatings, and fossil fuel emissions, enters aquatic environments through industrial discharge, urban runoff, and atmospheric deposition. In Diva and Mothagaon Creek, chromium levels range from 0.03 to 0.047 mg/L, well below the MoEF limit of 2 mg/L. Concentrations rise slightly in the summer due to evaporation and industrial activity.

Ecological & Health Impact

- **Aquatic Life:** Chromium (especially hexavalent Cr VI) affects fish and invertebrates, causing respiratory and reproductive issues.
- **Bioaccumulation:** Chromium accumulates in organisms, posing risks to higher predators, including humans.
- **Water Quality:** Chromium binds to sediments, affecting benthic species and nutrient balance.
- **Human Health:** Long-term exposure can lead to carcinogenic effects and organ damage.

Pollution Control & Management

- **Industrial Regulations:** Stricter effluent treatment (e.g., reverse osmosis, chemical precipitation).
- **Monitoring & Enforcement:** Regular water quality assessments and compliance checks.
- **Cleaner Practices:** Adoption of non-toxic alternatives in industries.
- **Public Awareness:** Promoting responsible waste disposal and pollution prevention.

Copper Contamination in Diva-Motagaon Creek

Copper in marine environments primarily originates from antifouling paints used on ships, buoys, and submerged structures, as well as industrial and coastal runoff (Gharedaashi et al., 2013). The study recorded copper concentrations between 0.05 and 1.58 mg/L, well below the MoEF standard of 3 mg/L for marine waters.

Seasonal Copper Levels

- **Summer Season**
  - Diva Station: 0.1 mg/L
  - Motagaon 1 Station: 0.3 mg/L
  - Elevated copper levels in summer may result from evaporation-driven concentration effects but remain within safe limits.

Ecological Impact of Copper

- **Fish**: Copper disrupts enzyme activity, affecting growth and reproduction.
- **Invertebrates**: Interferes with feeding and filtering mechanisms, impacting the food web.
- **Microorganisms**: Toxic to bacteria involved in nutrient cycling**,** potentially altering ecosystem balance.
- **Bioaccumulation**: Copper accumulates in aquatic organisms, posing long-term risks to wildlife and humans consuming seafood.

Sources of Copper Pollution

- **Antifouling Paints**: Used on ships to prevent biofouling but leach copper into the water.
- **Coastal Runoff**: Industrial discharge, stormwater, and untreated wastewater contribute to copper contamination.

Pollution Control Measures

- **Alternatives to Copper-Based Antifouling Paints**:
  - Use of biodegradable coatings **or** ultrasound technology to prevent biofouling.
- **Enhanced Wastewater Treatment**:
  - Stricter industrial regulations and improved filtration technologies.
- **Stormwater Management**:

- Improved coastal planning and runoff control to reduce copper influx.

Iron Contamination in Diva-Motagaon Creek

Iron occurs naturally in aquatic environments, primarily as oxides, and is essential for biological processes such as oxygen transport and photosynthesis (Elinder, 1986). This study recorded iron concentrations between 0.55 and 1.58 mg/L**,** well below the MoEF standard of 3 mg/L for marine and coastal waters.

Ecological Role of Iron

- **Nutrient for Aquatic Life**: Essential for phytoplankton growth, influencing primary productivity.
- **Microbial Metabolism**: Supports bacteria involved in nitrogen fixation and sulfur cycling.
- **Sediment Interaction**: Can bind with heavy metals, reducing their bioavailability.

Potential Environmental Risks

- **Excessive Iron**: Can cause water discoloration, reduce sunlight penetration, and lead to oxygen depletion.
- **Algal Blooms**: Elevated iron from industrial or agricultural runoff may trigger eutrophication.
- **Heavy Metal Dynamics**: While iron can neutralize some toxins, excessive levels may increase metal toxicity.

Sources of Iron Pollution

- **Industrial Effluents**: Steel production, mining, and construction activities.
- **Agricultural Runoff**: Fertilizers and soil erosion contribute iron to water bodies.
- **Urban Runoff**: Rusting infrastructure and stormwater drainage increase iron levels.

Management Strategies

- **Wastewater Treatment**: Stricter industrial regulations and improved filtration technologies.
- **Erosion Control**: Sustainable farming practices to reduce iron-rich runoff.
- **Urban Stormwater Management**: Green infrastructure (wetlands, bioswales) to filter pollutants.

Lead Contamination in Diva-Motagaon Creek

Lead enters the environment through natural processes and human activities, accumulating in organisms due to its 20-year biological half-life (Frances, 2008). This study found lead levels ranging from 0.2 to 0.4 mg/L**,** well below the MoEF standard of 2 mg/L (MoEF, 1993).

Potential Sources of Lead

- **Industrial Discharge**: Battery manufacturing, construction, and metal processing.
- **Vehicle Emissions**: Runoff from residual leaded fuel.

- **Lead-based Paints**: Contamination from aging infrastructure.
- **Agricultural Runoff**: Use of lead-based pesticides.

Environmental & Health Risks

- **Aquatic Life**: Lead is toxic even at low concentrations, affecting growth, reproduction, and behavior.
- **Bioaccumulation**: Lead builds up in the food chain, posing long-term ecological threats.
- **Human Health**: Exposure through contaminated water and seafood can lead to **neurological disorders** and developmental issues.

Zinc Contamination in Diva-Motagaon Creek

Zinc is essential for animal growth (Shankar & Parsad, 1998), but excessive levels can be harmful. This study recorded zinc concentrations ranging from 4.23 to 6.78 mg/L, exceeding the MoEF standard of 5 mg/L in multiple locations.

Seasonal Zinc Levels (mg/L)

- **Pre-Monsoon**: Diva (6.01), Retibunder (8.6), Motagaon 1 (8), Motagaon 2 (6.7)
- **Post-Monsoon (After Ganapati Festival)**: Diva (7.06), Retibunder (9.1), Motagaon 1 (10), Motagaon 2 (1.0)
- **Industrial Effluent Impact**: Diva (8), Retibunder (10.4), Motagaon 1 (10), Motagaon 2 (7)

Key Findings

- Zinc levels exceeded the MoEF standard across several locations, particularly post-monsoon and after industrial discharge.
- A notable spike was observed after Ganapati idol immersion, indicating a link to religious activities.
- Industrial effluents further increased contamination, posing ecological risks.

Recommendations

Stricter regulations, improved waste management, and pollution control measures are essential to mitigate zinc contamination and protect the creek’s ecosystem.

This study found elevated levels of chromium (0.03–0.047 mg/L), copper (0.05–1.58 mg/L), iron (0.55–1.68 mg/L), lead (0.2–0.4 mg/L), and zinc (4.23–6.87 mg/L) in creek sediments. These metals, especially copper, chromium, and zinc, can disrupt aquatic organisms' growth, reproduction, and metabolism.

To mitigate pollution, a multi-pronged approach is needed:

- **Technological Solutions**: Chemical treatments (coagulation, ion exchange), biological methods (phytoremediation, bacterial remediation), and mechanical solutions (dredging, filtration).

- **Regulatory & Community Action**: Stricter industrial regulations, waste management improvements, public awareness, and scientific monitoring.

A continuous monitoring program is essential to assess pollution trends, evaluate remediation efforts, and safeguard the creek's biodiversity and community benefits. Through proactive interventions, Diva-Motagaon Creek's ecological balance can be restored for future generations.

Table 1: Results of monthly variation of heavy metal Concentration (mg/L) found in station Diva

	March	June	September	December	Permissible Limits	Method Analysis
Cadmium (Cd)	BDL	0.01	0.01	0.01	0.1	IS:3025 (Part 41)
Arsenic (As)	0.05	0.05	0.07	0.07	0.05	IS:3025 (Part 37)
Zinc (Zn)	0.25	6.01	7.06	8	5	IS:3025 (Part 49)
Lead (Pb)	0.15	0.05	0.5	0.4	0.1	IS:3025 (Part 47)
Iron (Fe)	0.1	0.5	1.74	1.7	0.3	IS:3025 (Part 53)
Chromium (Cr)	0.01	BDL	0.055	0.05	0.05	IS:3025 (Part 52)
Copper (Cu)	0.1	0.02	0.05	0.04	0.05	IS:3025 (Part 42)
Mercury (Hg)	BDL	BDL	0.02	0.02	0.002	IS:3025 (Part 48)
Dissolved Oxygen (DO)	2.7	2.4	1.7	0.9	40	IS:3025 (Part 38)
Manganese (Mn)	0.05	0.02	0.05	0.3	0.1	IS:3025 (Part 59)

Table 2: Results of monthly variation of heavy metal Concentration (mg/L) found in station Retibundar

Test Parameters	March	June	September	December
Cadmium (as Cd)	0.01	0.02	0.01	0.02
Arsenic (as As)	0.05	0.06	0.06	0.07
Zinc (as Zn)	0.65	8.6	9.1	10.4
Lead (as Pb)	0.2	0.2	0.2	0.3
Iron (as Fe)	0.2	1.2	1.3	2
Chromium (as Cr)	0.07	0.05	0.05	0.06
Copper (as Cu)	0.3	0.05	0.04	0.04
Mercury (as Hg)	BDL	0.002	0.001	0.001
Dissolved Oxygen (as DO)	0	0.0	0.04	0.46
Manganese (as Mn)	0.1	0.2	0.2	0.2

Table 3: Results of monthly variation of heavy metal Concentration (mg/L) found in station Motagaon 1

Test Parameters	March	June	September	December
Cadmium (as Cd)	0.02	0.01	0.01	0.02
Arsenic (as As)	0.1	0.06	0.07	0.1
Zinc (as Zn)	0.35	8	10	1
Lead (as Pb)	0.1	BDL	0.3	0.21
Iron (as Fe)	0.3	1	1.4	1.2
Chromium (as Cr)	0.08	0.01	0.03	0.04
Copper (as Cu)	0.25	0.04	0.05	0.06
Mercury (as Hg)	BDL	BDL	0.02	0.001
Dissolved Oxygen (as DO)	2.8	1.8	1.5	1.2
Manganese (as Mn)	0.05	0.2	0.4	0.5

Table 4: Results of monthly variation of heavy metal Concentration (mg/L) found in station Motagaon 2

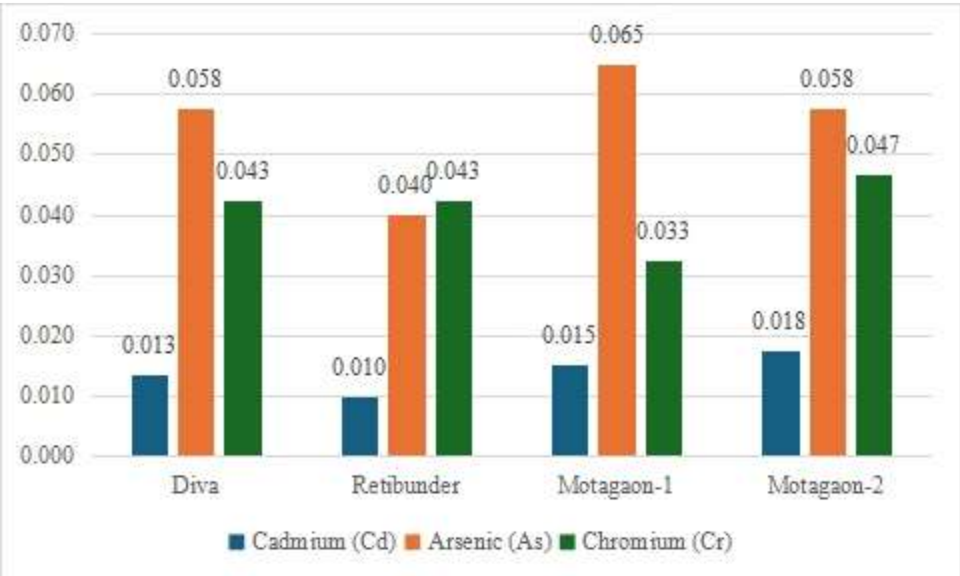
Test Parameters	March	June	September	December
Cadmium (as Cd)	0.01	0.01	0.02	0.02
Arsenic (as As)	0.1	0.05	0.05	0.07
Zinc (as Zn)	0.5	6.7	6.57	7
Lead (as Pb)	0.1	0.1	0.1	0.2
Iron (as Fe)	0.3	0.7	0.4	1.64
Chromium (as Cr)	0.04	0.02	0.02	0.03
Copper (as Cu)	0.05	0.04	0.04	0.02
Mercury (as Hg)	BDL	BDL	0.001	0.001
Dissolved Oxygen (as DO)	0.55	0.5	0	0
Manganese (as Mn)	0.0	0.2	0.2	0.3

Table 1: Mean and Standard Deviation of Heavy Metal Concentration (mg/L) across Four Seasons for All the Stations

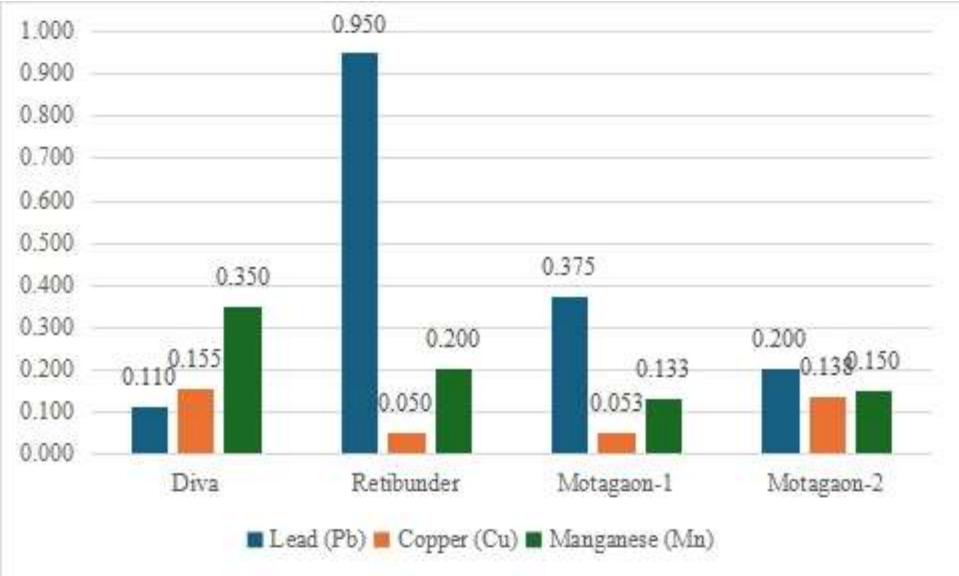
Test Parameters	Mean ± SD				Permissible Limits	Method of Analysis
	Diva	**Retibunder**	**Motagaon-1**	**Motagaon-2**		
Cadmium (Cd)	0.013 ± 0.006	0.01 ± 0	0.015 ± 0.006	0.018 ± 0.005	0.1	IS:3025 (Part 41)
Arsenic (As)	0.058 ± 0.01	0.04 ± 0.008	0.065 ± 0.024	0.058 ± 0.005	0.05	IS:3025 (Part 37)
Zinc (Zn)	6.735 ± 4.276	6.63 ± 0.452	5.825 ± 1.956	4.233 ± 3.808	5	IS:3025 (Part 49)
Lead (Pb)	0.11 ± 0.066	0.95 ± 0.071	0.375 ± 0.486	0.2 ± 0.082	0.1	IS:3025 (Part 47)
Iron (Fe)	0.713 ± 0.361	1.588 ± 0.566	0.55 ± 0.058	0.725 ± 0.403	0.3	IS:3025 (Part 53)

Chromium (Cr)	0.043 ± 0.021	0.043 ± 0.024	0.033 ± 0.005	0.047 ± 0.006	0.05	IS:3025 (Part 52)
Copper (Cu)	0.155 ± 0.231	0.05 ± 0.008	0.053 ± 0.005	0.138 ± 0.103	0.05	IS:3025 (Part 42)
Mercury (Hg)	0.007 ± 0.011	0.001 ± 0	0.001 ± 0.001	0.001 ± 0	0.002	IS:3025 (Part 48)
Dissolved Oxygen (DO)	1.975 ± 0.377	0.05 ± 0.1	1.805 ± 0.01	0.503 ± 0.005	40	IS:3025 (Part 38)
Manganese (Mn)	0.35 ± 0.173	0.2 ± 0	0.133 ± 0.047	0.15 ± 0.058	0.1	IS:3025 (Part 59)

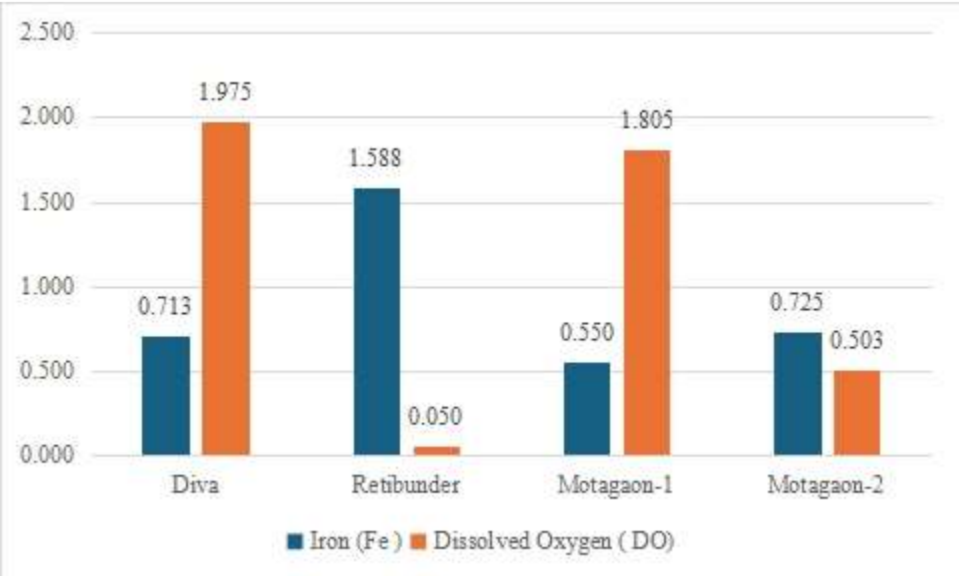
Graph 1: Mean values of Cadmium, Arsenic and Chromium across four seasons for all the stations



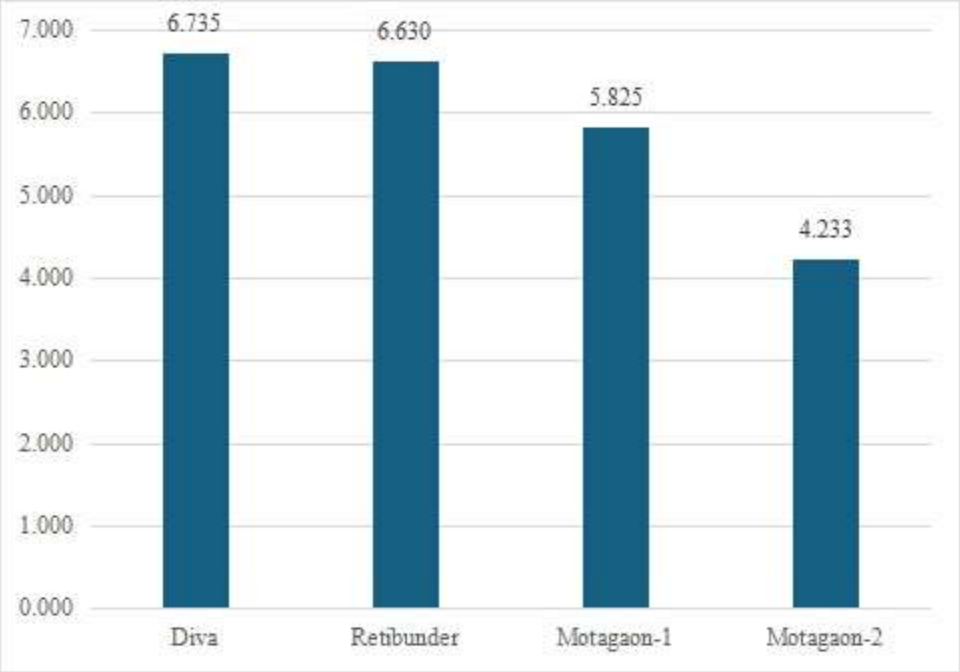
Graph 2: Mean values of Lead, Copper and Manganese across four seasons for all the stations



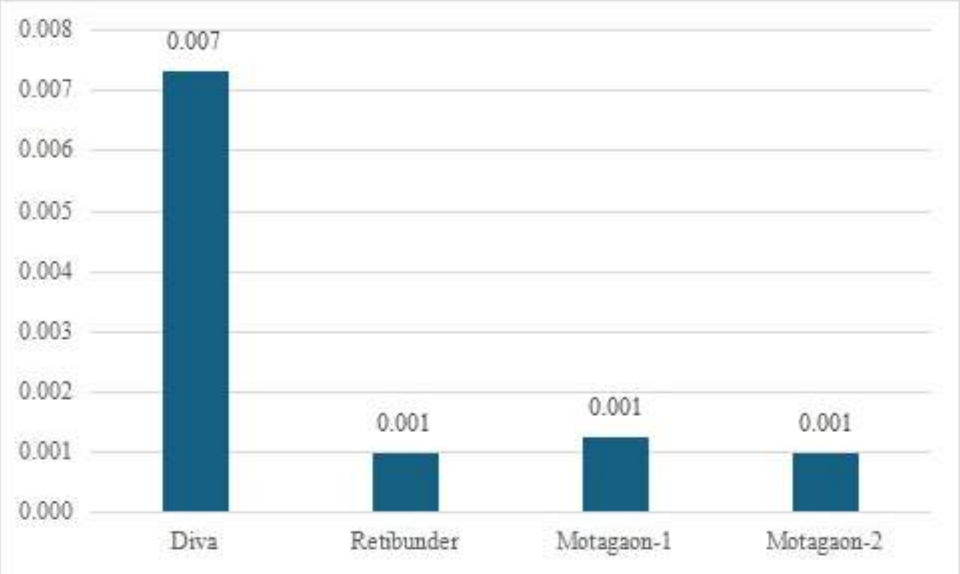
Graph 3: Mean values for of Iron and Dissolved Oxygen across four seasons for all the stations



Graph 4: Mean values of Zinc across four seasons for all the stations



Graph 5: Mean values of Mercury across four seasons for all the stations



Conclusion

In India, the CPCB regulates pollution control under the 1974 Water Prevention and Control of Pollution Act, ensuring water and sediment quality in aquatic ecosystems. Creek sediments act as both sinks and sources of pollutants, accumulating toxic heavy metals like lead, chromium, copper, zinc, and iron from industrial discharge, urban runoff, and agriculture. These contaminants persist long-term, affecting water quality and aquatic life. Preventing sediment pollution entirely is challenging, but measures like efficient waste management, stricter regulations, and remediation technologies help minimise contamination. Regular sediment monitoring, especially in sensitive areas like Diva-Mothagaon Creek, is crucial for effective pollution control and ecosystem preservation.

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