

Evaluation of the water quality and bioaccumulation of heavy metals in selected fish species of Chaltia Bil, Murshidabad, West Bengal, India

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ABSTRACT

Background: Heavy metal contamination in the aquatic ecosystem poses severe ecological and health risks. The present study evaluates the water quality and bioaccumulation of heavy metals in two commercially important fish species (*Labeo rohita* and *Hypophthalmichthys molitrix*) from Chaltia Bil, a significant wetland in Murshidabad, West Bengal. **Materials and Methods:** Water and fish samples were collected from Chaltia Bil in accordance with standard protocols outlined by the APHA (2023) and the FSSAI Lab Manual (2016). The concentrations of heavy metals, including arsenic, lead, cadmium, and mercury, were analyzed using Atomic Absorption Spectroscopy (AAS). Physiological parameters, including temperature, pH, dissolved oxygen, total dissolved solids, biochemical oxygen demand (BOD), chemical oxygen demand (COD), and nutrient levels, were also measured using standard protocols to assess overall water quality. **Results:** The findings indicate a significant bioaccumulation of heavy metals in fish tissues, with a twelve-fold increase compared to water samples. Lead and arsenic were detected at concerning levels, exceeding WHO and FSSAI permissible limits. Physicochemical analysis revealed variations across sampling points, characterized by high BOD and COD, indicating the presence of organic pollution. **Conclusion:** The study underscores the urgent need for regular monitoring and mitigation measures to control heavy metal pollution in Chaltia Bil. The bioaccumulation of toxic metals in fish species poses substantial risks to aquatic life and human consumers.

Keywords: Heavy metals, toxicity, bioaccumulation, water quality, Chaltia Bil, fish contamination, environmental pollution.

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INTRODUCTION

Good quality water is essential for disease prevention and improving life quality. Natural water contains various impurities, including heavy metals that enter water sources through rock weathering, soil leaching, atmospheric particles, and human activities like mining and metal processing. These heavy metals can be absorbed by aquatic plants and animals, eventually reaching humans through the consumption of marine organisms. The increasing use of metal-based fertilizers in agriculture may lead to rising heavy metal pollution levels in freshwater reservoirs through water runoff, creating ongoing environmental and health concerns.¹

Chaltia Bil, a significant wetland located under Bhakuri Gram Panchayat, adjacent to Berhampore municipality in Murshidabad district, West Bengal, is under active management by Bhakuri Matsyajibi Samabay Samity Ltd., a fisherman's cooperative society that cultivates Indian and exotic carp fish species.² The direct discharge of untreated sewage water from the municipality into the Bil and the usage of heavy metals-contaminated groundwater for agricultural purposes have raised concerns regarding bioaccumulation in the ecosystem.³

Labeo rohita (Rohu) and *Hypophthalmichthys molitrix* (Silver carp) were selected for this study due to their significant commercial importance in the region's aquaculture industry and their different feeding habits, which make them excellent bioindicators for heavy metal contamination assessment.^{3,4} *L. rohita* is a column feeder that primarily consumes phytoplankton and detritus, while *H. molitrix* is a filter feeder

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that feeds on phytoplankton and organic matter suspended in water.⁴ These contrasting feeding behaviors provide insights into bioaccumulation patterns across different trophic levels within the aquatic food web.

Heavy metal exposure poses severe toxicological risks to both aquatic organisms and human consumers.⁵ Chronic exposure to arsenic is associated with various health issues, including cancer, skin lesions, cardiovascular diseases, and neurological effects.⁶ Lead toxicity can cause developmental disorders, neurological impairment, and reproductive dysfunction.⁶ Cadmium accumulation leads to kidney damage, bone disorders, and potential carcinogenic effects.⁷ Mercury exposure results in neurological damage,

particularly affecting the central nervous system.⁸ The bioaccumulation of these heavy metals in aquatic food chains represents a critical pathway for human exposure, making bioaccumulation assessments essential for both ecological monitoring and public health risk evaluation.⁹⁻¹¹

The objective of the present study is to measure the levels of heavy metal concentration in the water and fish samples (*Labeo rohita*, *Hypophthalmichthys molitrix*) of Chaltia Bil and examine the bio-concentration via the food chain, along with the analysis of physicochemical parameters of water quality.

METHODS

This was an observational, cross-sectional study conducted across four sampling points of Chaltia Bil for one year (August 2022 to August 2023). The Chaltia Bil is one of the important wetlands in Murshidabad district, West Bengal, and is located under Bhakuri Gram Panchayat (Latitude: 24° 4' 2" N to 24° 4' 45" N; Longitude: 88° 14' 33" E to 88° 15' 43" E and total water area of 0.59 sq. km./0.23 sq. miles).

Sample Collection and Analysis

Water and fish samples were collected from four sampling points (SP1, SP2, SP3, and SP4) in Chaltia Bil following the standard protocol of the American Public Health Association.^{12,13} SP1 point was located near Raghunath Tala, SP2 point was located near Chaltia Durga Temple, SP3 point was located near Fishermen Cooperative Office and SP4 was located near Radha Madhav temple at Ayodhya Nagar. The concentration of heavy metals in water and fish species was examined using atomic absorption spectroscopy¹⁴ at Qualissure Laboratory Services, Kolkata-107.

To estimate As, Pb, Cd, and Hg in water samples, 3114C, 3111C, 3111B, and 3112B Test Methods from APHA 24th Edition, 2022 were used, respectively.¹² Similarly, to estimate the same metal samples in fish samples (*Labeo rohita* and *Hypophthalmichthys molitrix*), the test methods were adopted from the FSSAI Lab Manual for Metals.¹³

Physicochemical Parameters

Water quality parameters including temperature, pH, transparency, total dissolved solids (TDS), dissolved oxygen (DO), free CO₂, alkalinity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonia, phosphate, and nitrate were analyzed following standard protocols outlined in APHA 24th Edition.¹²

RESULTS

Analysis of Physicochemical Parameters of Water Quality

Table 1 summarizes the mean values and standard deviations of various physicochemical water quality parameters across four sampling points (SP1, SP2, SP3, and SP4), providing a comprehensive view of the water quality differences across the Chaltia Bil sites.

Overall, this analysis suggests that SP1 and SP2 may be experiencing higher pollution levels (as indicated by elevated BOD, COD, TDS, and nutrient concentrations) compared to SP3 and SP4, which exhibit better water quality with higher dissolved oxygen and lower nutrient concentrations.

Analysis of Heavy Metal Concentration in Water and Fish Samples

The analysis results of heavy metals in water and two fish species highlight significant bioaccumulation in the tissues of aquatic organisms, posing serious health risks to both aquatic life and humans who consume these fish.¹⁵ This indicates a multifold increase in metal concentration from water to fish, suggesting significant bioaccumulation of heavy metals within the ecosystem of Chaltia Bil.¹⁶

DISCUSSION

The physicochemical parameters revealed significant variations across sampling points, indicating differential pollution loads at different locations within Chaltia Bil. The

Table 1: Analysis of physicochemical parameters of water quality

Parameters	SP1	SP2	SP3	SP4
Temperature (°C)	27.42 ± 4.58	27.75 ± 4.61	28.11 ± 4.71	28.33 ± 4.80
pH	8.70 ± 0.26	8.88 ± 0.34	7.83 ± 0.31	7.69 ± 0.23
Transparency (cm)	47.03 ± 10.58	45.91 ± 10.63	50.89 ± 11.11	49.85 ± 10.96
TDS (mg/L)	228 ± 45.12	251 ± 49.67	155 ± 47.02	149 ± 48.92
Dissolved O ₂ (mg/L)	2.36 ± 0.14	2.91 ± 0.27	4.39 ± 0.24	3.68 ± 0.23
Free CO ₂ (mg/L)	10.29 ± 0.38	10.71 ± 0.59	10.36 ± 0.47	10.61 ± 0.42
Alkalinity (mg/L)	203 ± 23.12	210 ± 30.89	197 ± 26.43	192 ± 24.91
BOD (mg O ₂ /L)	146.92 ± 10.72	110.81 ± 10.64	85.63 ± 9.02	85.24 ± 8.83
COD (mg O ₂ /L)	209.72 ± 12.45	215.47 ± 13.27	136.55 ± 12.47	120.47 ± 12.31
Ammonia (mg/L)	6.12 ± 1.02	6.42 ± 1.07	4.65 ± 0.34	4.70 ± 0.31
Phosphate (mg/L)	6.19 ± 0.52	7.38 ± 0.81	3.41 ± 0.48	4.05 ± 0.43
Nitrate (mg/L)	4.61 ± 0.41	4.57 ± 0.37	3.05 ± 0.25	3.02 ± 0.29



Figure 1: (a) Google Earth view of Chaltia Bil with spots of sample collection. Fish samples – (b) *Labeo rohita* and (c) *Hypophthalmichthys molitrix*

Table 2: Heavy metal concentrations in water and fish samples with regulatory limits

Heavy Metals	Water Samples	Fish Samples		WHO Limits (Water)	FSSAI Limits (Fish)
		<i>Labeo rohita</i>	<i>H. molitrix</i>		
Arsenic	< 0.01 mg/L	0.12 mg/kg	0.1 mg/kg	0.01 mg/L	0.1 mg/kg
Lead	0.16 mg/L	0.12 mg/kg	0.1 mg/kg	0.01 mg/L	0.05 mg/kg
Cadmium	< 0.002 mg/L	< 0.05 mg/kg	< 0.05 mg/kg	0.003 mg/L	0.05 mg/kg
Mercury	< 0.001 mg/L	0.03 mg/kg	0.05 mg/kg	0.006 mg/L	0.5 mg/kg

temperatures range from 27.42 to 28.33°C, with SP4 showing the highest mean temperature. The pH levels vary across the points, with SP2 having the most alkaline conditions (pH 8.88), while SP4 has the lowest pH (7.69), indicating slightly more acidic conditions compared to the other sites. SP3 has the most excellent transparency (50.89 cm), whereas SP2 shows the lowest (45.91 cm). TDS levels are highest at SP2 (251 mg/L) and lowest at SP4 (149 mg/L). SP3 exhibits the highest DO levels (4.39 mg/L), while SP1 records the lowest (2.36 mg/L), indicating poorer oxygenation at SP1. Similar levels are observed across the points, ranging from 10.29 to 10.71 mg/L. Alkalinity levels are relatively consistent, with SP2 having the highest (210 mg/L) and SP4 the lowest (192 mg/L). SP1 shows a notably higher BOD (146.92 mg O₂/L), suggesting a higher level of organic pollution, while SP3 and SP4 have lower values around 85 mg O₂/L. COD levels are highest at SP1 (209.72 mg O₂/L) and lowest at SP4 (120.47 mg O₂/L), reflecting organic and inorganic pollutant variations. SP2 records the highest ammonia concentration (6.42 mg/L), while SP3 and SP4 show lower levels, suggesting reduced nitrogen pollution at these sites. While SP3 has the lowest (3.41 mg/L), indicating variation in nutrient inputs. Similar trends are observed for nitrate, with SP1 and SP2 having higher concentrations (~4.61 mg/L), while SP3 and SP4 show lower levels (~3.05 mg/L).

SP2 has the highest phosphate levels (7.38 mg/L). Overall, this analysis suggests that SP1 and SP2 may be experiencing higher pollution levels (as indicated by elevated BOD, COD, TDS, and nutrient concentrations) compared to SP3 and SP4, which exhibit better water quality with higher dissolved oxygen and lower nutrient concentrations. This variation might be due to the close proximity of municipal sewage discharging sites to SP1 and SP2 sampling points.

The heavy metal contamination analysis revealed alarming levels of bioaccumulation. Lead concentrations in water (0.16 mg/L) exceeded WHO permissible limits (0.01 mg/L) by sixteen-fold, representing a severe contamination issue.⁵ More concerning is the bioaccumulation pattern observed in fish tissues, where lead levels in both species (0.12 mg/kg in *L. rohita* and 0.1 mg/kg in *H. molitrix*) exceeded FSSAI safety limits for fish consumption. Although arsenic remained below detection limits in water samples, its presence in fish tissues at levels approaching regulatory thresholds demonstrates the efficiency of bioaccumulation processes in aquatic organisms.¹⁶ The twelve-fold increase in heavy metal concentrations from water to fish tissue represents a significant biomagnification factor, consistent with established patterns of heavy metal accumulation in aquatic food webs.^{15,16} This bioaccumulation efficiency

varies between the two studied species, with *L. rohita* showing slightly higher metal concentrations than *H. molitrix*, possibly due to their different feeding strategies and habitat preferences within the water column.⁴ The contamination sources can be attributed to anthropogenic activities, particularly the discharge of untreated municipal sewage from Berhampore municipality and agricultural runoff containing metal-contaminated groundwater.^{3,17} These pollution sources create a continuous influx of heavy metals into the aquatic system, leading to persistent contamination and subsequent bioaccumulation in the food web. The following ecological implications can be derived from the present study.

Bioaccumulation Patterns

The observed twelve-fold increase in heavy metal concentration from water to fish indicates efficient bioaccumulation processes within the Chaltia Bil ecosystem.¹⁶ This concentration factor suggests that even relatively low environmental concentrations can result in significant tissue burdens in aquatic organisms, highlighting the sensitivity of fish species to heavy metal contamination.¹⁵

Health Risks

The bioaccumulation of metals in fish poses significant health risks to human consumers. Chronic exposure to arsenic can lead to various health complications, including cancer, cardiovascular diseases, and neurological disorders.⁶ Lead toxicity affects neurological development and function, while cadmium exposure can cause kidney damage and bone disorders.⁷ Mercury accumulation primarily affects the nervous system, making regular consumption of contaminated fish particularly hazardous for vulnerable populations.^{8,9}

Ecosystem Impact

The heavy metal contamination affects not only the studied fish species but potentially the entire aquatic ecosystem.¹⁸ The different contamination levels between *L. rohita* and *H. molitrix* suggest that feeding behavior and trophic position influence bioaccumulation patterns, indicating that various species within the ecosystem may face different levels of exposure and risk.^{19,20}

Comparative Studies

Similar studies conducted in other regions have reported comparable levels of heavy metal accumulation in aquatic ecosystems, reinforcing the need for continuous monitoring and effective pollution control strategies.^{3,11,16,20}

CONCLUSION

This study demonstrates significant heavy metal contamination and bioaccumulation in the Chaltia Bil ecosystem. The multi-fold increase in metal concentrations from water to fish tissues indicates efficient bioaccumulation processes that pose serious threats to both aquatic organisms

and human health. Lead contamination exceeds international safety standards in both water and fish samples, while arsenic levels in fish approach regulatory limits despite being below detection in water samples. These findings underscore the need for comprehensive studies and effective management strategies to address the issue of heavy metal contamination in freshwater bodies and protect both environmental and public health. Future research should investigate seasonal variations in contamination levels and expand monitoring to include additional fish species and other aquatic organisms to develop comprehensive ecosystem management strategies. Continued study and proactive measures are essential to mitigate the risks associated with heavy metal bioaccumulation in aquatic environments.

The differential pollution patterns across sampling points suggest localized contamination sources, primarily from municipal sewage discharge and agricultural activities. Immediate implementation of pollution control measures by the local authorities is essential, including improved wastewater treatment, regulation of raw sewage discharge, controlled agrarian practices, and continuous monitoring of heavy metal levels to save the aquatic health of Chaltia Bil. Public awareness programs should inform local communities about the health risks associated with consuming fish from contaminated water bodies. Educational programs and community involvement can play a significant role in reducing human exposure to toxic heavy metals.

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PEER-REVIEWED CERTIFICATION

During the review of this manuscript, a double-blind peer-review policy has been followed. The author(s) of this manuscript received review comments from a minimum of two peer-reviewers. Author(s) submitted revised manuscript as per the comments of the assigned reviewers. On the basis of revision(s) done by the author(s) and compliance to the Reviewers' comments on the manuscript, Editor(s) has approved the revised manuscript for final publication.