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Assessment of Water Quality and Heavy Metal Contamination in River Water and Fish Species from the Bangshi River, Tangail, Bangladesh

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Abstract: The Bangshi River flows through the industrial regions of Dhaka and Tangail, polluted by various wastes, including industrial effluents. This study assessed water quality and heavy metal concentrations in the river, focusing on two fish species, Tengra (*Mystus nigriceps*) and Tara baim (*Macrognathus aral*). Fish samples were taken from one station during the wet season, whereas water samples were taken from three stations throughout the dry season (June to August 2022) and wet season (February to May 2022). The parameters analyzed included water temperature, pH, dissolved oxygen (DO), biological oxygen demand (BOD), total dissolved solids (TDS), electrical conductivity (EC), alkalinity, and the concentrations of heavy metals such as lead (Pb), cadmium (Cd), copper (Cu), and manganese (Mn). Water temperature ranged from 30.5 to 32.3°C during the wet season and 19.91 to 20.5°C in the dry season, remaining within acceptable limits. pH values were within the standard range. However, EC exceeded irrigation standards during the dry season (828 to 903 µS/cm). TDS levels were 83 to 175 ppm in the wet season and 328 to 563 ppm in the dry season, with most dry season samples exceeding fish culture limits. DO values (1.98 to 4.26 ppm) were consistently below recommended levels, while BOD (2.33 to 4.83 ppm) and alkalinity (80.7 to 382.23 ppm) surpassed permissible thresholds, particularly in the dry season. Heavy metals in water were generally within safe limits except for Pb (4.40 to 5.002 ppm). In fish, Pb concentrations exceeded permissible levels (5.35 ppm in Tengra, 4.46 ppm in Tara baim), while Cd, Cu, and Mn were within acceptable thresholds. The elevated Pb levels likely stem from effluents released by glass, textile, and paint industries. These findings highlight potential risks to human health from consuming water and fish from the Bangshi River, underscoring the urgent need for improved pollution control strategies.

Keywords: Water Pollution; Heavy Metals; Water quality; Bioaccumulation.

INTRODUCTION

The quality of river water is crucial for safeguarding human health and ensuring the sustainability of aquatic ecosystems (Kazi *et al.* 2008). However, increasing anthropogenic activities, urban development, and the discharge of untreated wastewater are contributing to its continuous degradation (Salam *et al.* 2019). Furthermore, heavy metal contamination in water poses a significant threat to both human health and the environment (Saha and Paul 2019). Key contributors to this issue include pollution from municipal, industrial, and agricultural wastewater, as well as leachate from landfills and runoff originating from urban and agricultural areas. These sources introduce heavy metals into water systems, leading to significant ecological and public health challenges (Samadi *et al.* 2009). The toxicity and carcinogenic potential of heavy metals are closely associated with exposure levels, with high concentrations resulting in severe effects on humans and animals (Tsai *et al.* 2017). These effects include increased DNA damage and the development of neuropsychiatric disorders (Ghorini *et al.* 2014). Heavy metal contamination in fish is a global issue, affecting ecosystems and posing health risks to humans through fish consumption. Lead, for instance, can cause kidney failure and liver damage, emphasizing the need to tackle heavy metal pollution in aquatic ecosystems (Rahman *et al.* 2012).

Bangladesh, a densely populated developing country, is struggling with intense water pollution caused by rapid urbanization and industrialization (Sarker *et al.* 2019; Islam et al. 2020). Industrial activities and agricultural practices have emerged as major contributors to heavy metal and organic pollution, posing serious threats to water resources and environmental sustainability (Alam *et al.* 2020). Urban rivers are prone to water quality problems due to untreated domestic and industrial waste discharge, which raises heavy metal levels, worsening pollution and endangering public and environmental health (Hasan *et al.* 2014). The Bangshi River, crucial for irrigation, fisheries, transportation, and recreation in the central part of Bangladesh, is facing deteriorating water quality due to rising industrialization, urbanization, and nearby development (Hossain *et al.* 2012). Although the Bangshi River is of considerable importance, few studies have been conducted on its water quality. This research aims to assess water quality at multiple locations along the river, focusing on heavy metal concentrations in both water and two fish species. The findings are compared to established safety standards to evaluate potential health risks to consumers and offer recommendations for the management and conservation of the river's aquatic resources.

MATERIALS AND METHODS

Study Area

The study was conducted over a seven-month period along the Bangshi River in Mirzapur, Tangail, Bangladesh, with sampling carried out from February to May 2022 (dry season) and June to August 2022 (wet season). Three locations along the river were selected for sample collection all within the Mirzapur Upazila of Tangail District, as shown in Figure 1.

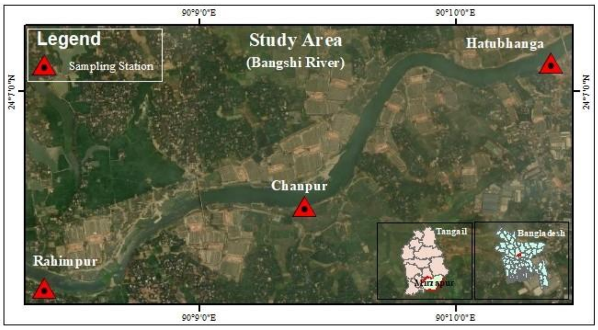

Figure 1. Map of the study area showing the Bangshi River in Tangail, Bangladesh. (Satellite Image Source: Service Layer Credits: <dyn type="document" property="service layer credits" separator="\n" showLayerNames="false" layerNameSeparator=": "/>)

Sample Collection Process

Water samples were collected from three sites along the Bangshi River during both the wet and dry seasons. The samples were gathered in pre-rinsed 500 ml plastic bottles, sealed securely, and labeled with identification numbers. Additionally, two fish species, Tengra (*Mystus nigriceps*) and Tara baim (*Macrognathus aral*), were collected during the wet season. The fish samples were immediately stored in ice boxes, labeled, and preserved at -20˚C. Heavy metal analysis (Pb, Cd, Cu, and Mn) of the samples was conducted at the Bangladesh Council of Scientific and Industrial Research (BCSIR) laboratory at the University of Rajshahi.

Analysis of heavy metals in water samples

Heavy metal concentrations were measured using the atomic absorption spectrophotometry (AAS) method. Each 500 mL water sample was filtered through Whatman No. 41 filter paper and acidified with 1 mL of 65% HNO3. The acidified filtrate was divided into two 250 mL portions, which were then heated on a hotplate to reduce the volume to 25 mL. The concentrated samples were subsequently analyzed for Pb, Cd, Cu, and Mn using an atomic absorption spectrophotometer.

Analysis of heavy metals in fish samples

Fish samples were prepared by washing, cutting into small pieces (2-3 cm), air drying, and then oven-drying at 105°C for three days to achieve a constant weight. The dried samples were cooled, ground into a powder, homogenized, and stored in airtight vials in desiccators. For heavy metal analysis, 0.5 g of powdered fish was digested with concentrated H_2SO_4 and HNO_3, followed by slow heating in an oil bath and the addition of 3–4 drops of H_2O_2 until the solution became clear. After further heating, the solution was cooled, diluted with deionized water, and filtered into a 50 mL flask. The metal concentrations were determined using an Atomic Absorption Spectrophotometer. Data analysis and presentation were performed using Microsoft Office Excel and SPSS IBM v26 software.

RESULTS AND DISCUSSION

Temperature

The average water temperatures were 31.33°C during the wet season and 20.54°C during the dry season. The recorded temperature ranges were 30.5 to 32.3°C in the wet season and 19.91 to 21.21°C in the dry season (Figure 2). All water temperatures across the stations were within the acceptable limits.

In a similar study, Rehnuma *et al.* (2016) reported water temperatures in the Bangshi River ranging from 30.4 to 32.9°C in the wet season and 19.3 to 21.1°C in the dry season. Yasmeen *et al.* (2012) observed water temperatures in the Buriganga River ranging from 31 to 33°C in the wet season and 21.9 to 22.4°C in the dry season. Hoque *et al.* (2012) found the average water temperature to be 30.9°C during the monsoon season and 21.5°C during the winter in the Bansi River. Saifullah *et al.* (2012) recorded water temperatures between 18.2°C (dry season) and 27.04°C (wet season) in the Buriganga River. These temperature ranges are consistent with the findings of the current study.

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Total Dissolved Solid (TDS)

The TDS values were observed to be higher during the dry season compared to the wet season (Figure 2). The average TDS concentrations were 120.33 ppm in the wet season and 460 ppm in the dry season. The range of TDS values varied from 83 to 175 ppm in the wet season and 328 to 563 ppm in the dry season.

According to ADB (1994), the recommended TDS levels are 1000 ppm for drinking water, 2000 ppm for irrigation, and less than 400 ppm for fish culture. With the exception of station 1 during the dry season, all other samples exceeded the fish culture standard for TDS levels. In a study by Rehnuma *et al.* (2016), the TDS values in the Bangshi River ranged from 62 to 142 ppm in the wet season and 408 to 561 ppm in the dry season. Yasmeen *et al.* (2012) reported TDS concentrations in the Buriganga River ranging from 378.75 to 616.75 ppm during the dry season and 205 to 290.5 ppm during the wet season, which were above the standard levels for both seasons. These findings are largely consistent with the results of the current study.

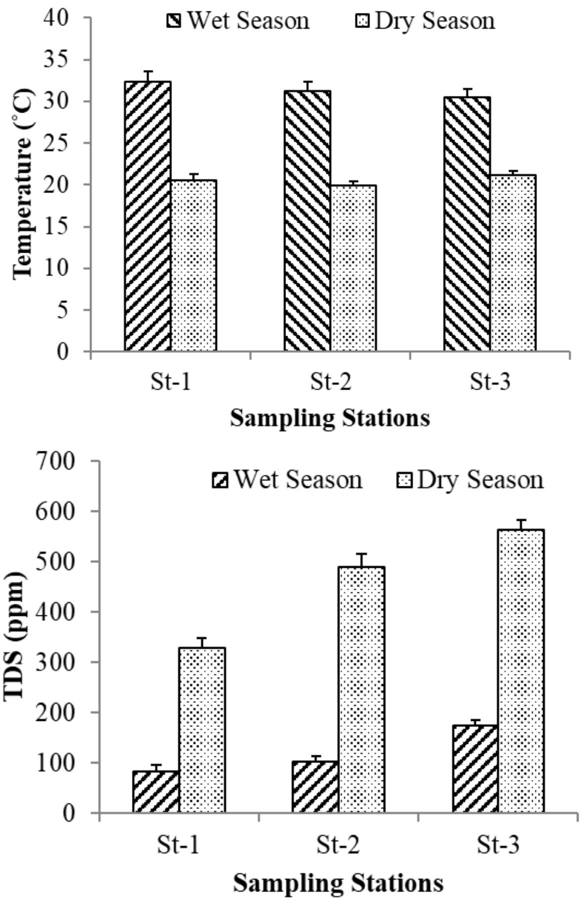

Figure 2. Water temperature and TDS values at various sampling stations during the wet and dry season.

Electrical Conductivity (EC)

The EC values were higher during the dry season compared to the wet season (Figure 3). The average EC concentrations were 186.67 µS/cm in the wet season and 875.33 µS/cm in the dry season. The recommended EC levels for irrigation and fishing are 750 and 1000 µS/cm, respectively (ADB, 1994) (Table 1). However, the EC values at all stations exceeded the irrigation standard during the dry season, suggesting an increased ionic load and higher concentrations of inorganic pollutants, likely due to industrial and agricultural discharges. A positive correlation was observed between EC and TDS, with EC values increasing as TDS concentrations rose.

Rehnuma *et al.* (2016) found the EC of the Bangshi River ranged from 121 to 169 µS/cm in the wet season and from 722 to 869 µS/cm in the dry season. Yasmeen *et al.* (2012) reported that the EC of the Buriganga River ranged from 763 to 1206 µS/cm in the dry season, exceeding the 700 µS/cm standard (EQS, 1997), which can negatively affect aquatic organisms. In the study by Rehnuma *et al.* (2024), the EC of the Meghna River ranged from 460 to 480 µS/cm in the dry season, and from 219 to 250 µS/cm in the wet season. These results are similar to the findings in the current study.

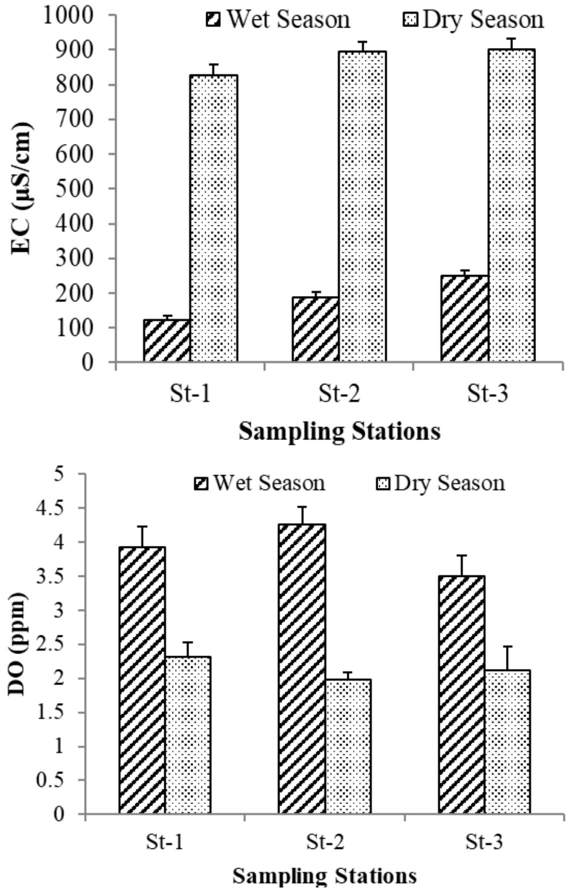

Figure 3. EC and DO values at various sampling stations during the wet and dry season.

Dissolved Oxygen (DO)

The DO values were higher during the wet season compared to the dry season (Figure 3). The average DO concentrations were 3.89 ppm in the wet season and 2.14 ppm in the dry season. Sufficient DO is crucial for maintaining good water quality, supporting aquatic life, and enabling the decomposition of organic matter by microorganisms (Islam *et al.* 2010). DO levels below 2 ppm can be harmful, potentially causing the death of most freshwater fish species (EGIS II, 2002). According to the

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ECR (1997) guidelines for Bangladesh, the minimum DO required for inland surface waters used for various purposes is 5 ppm. However, all the observed DO values were below the standard (Table 1), suggesting a higher level of pollution in the river.

Rehnuma *et al.* (2016) reported that the DO in the Bangshi River ranged from 3.50 to 4.90 ppm in the wet season and from 1.9 to 2.8 ppm in the dry season. Islam *et al.* (2012) found the DO concentrations in the Dhaleshwari River varied from 1.22 to 3.66 ppm. Bakali *et al.* (2014) observed that DO values in surface water samples from the Turag River ranged from 0.4 to 6.2 ppm. These findings are consistent with those of the present study.

Table 1. Comparison of investigated values with standard levels for drinking, irrigation, and fisheries.

Parameters	Investigated Seasonal Water Quality (Mean Values)		Standard levels			References
	Dry	Wet	Drinking	Irrigation	Fisheries	
Temperature (ºC)	20.54	31.33	25	-	25	ECR (2023), EPA (2018)
TDS (ppm)	460	120.33	1000	2000	<400	ADB (1994)
EC (µS/cm)	875.33	186.67	-	750	800-1000	ADB (1994), EQS (1997)
pH	7.74	6.54	6.5-8.5	6.5-8.5	6.5-8.5	ECR (2023), EQS (1997)
DO (ppm)	2.136	3.89	6	5	4.0-6.0	ECR (2023), EQS (1997)
BOD (ppm)	4.06	2.62	-	10 or less	(-) or below 2	ECR (2023), EQS (1997)
Alkalinity (ppm)	274.65	115.83	-	-	80-200	Bhatnagar *et al.* (2004)

Biological Oxygen Demand (BOD)

The BOD values of water samples from the three stations were found to be higher during the dry season compared to the wet season (Figure 4). The average BOD concentration was 2.62 ppm in the wet season and 4.06 ppm in the dry season. According to the ECR (1997), the standard BOD levels for drinking water and fisheries are <2 ppm and <6 ppm, respectively. The Bangshi River exceeded the drinking water standard for BOD during the dry season due to a higher amount of organic waste in the water (Table 1). High BOD levels can lead to a reduction in DO, as oxygen is consumed by microorganisms decomposing the organic material (McCarty *et al.* 2003).

Rehnuma *et al.* (2016) found that BOD values in the Bangshi River ranged from 0.7 to 2.9 ppm during the wet season and from 2.6 to 5.6 ppm during the dry season. Meghla *et al.* (2013) reported elevated BOD concentrations in all seasons in the Turag River, linked to a greater presence of organic waste. These results are similar to those of the current study.

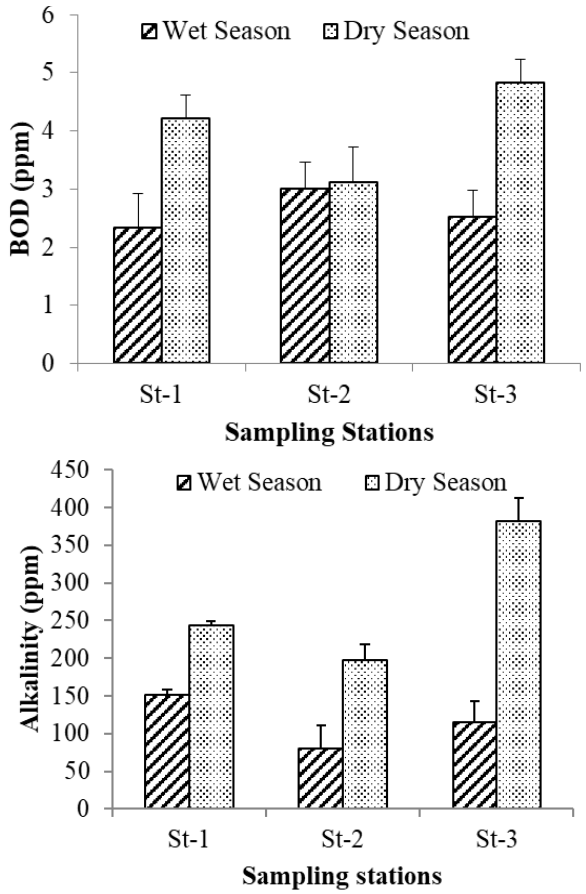

Figure 4. BOD and Alkalinity concentrations at various sampling stations during the wet and dry season.

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Alkalinity

The alkalinity values were higher during the dry season compared to the wet season (Figure 4). The average alkalinity concentrations were 115.83 ppm in the wet season and 274.65 ppm in the dry season. Except for station 2, all stations showed alkalinity levels exceeding the standard for surface water during the dry season, while the values were within the standard during the wet season. This suggests that the water contained higher concentrations of carbonates and bicarbonates, along with pollutants. The seasonal variation is likely due to the accumulation of waste effluents in the lower water volume during the dry season, while pollutants were diluted during the wet season due to heavy rainfall and upstream water runoff.

Rehnuma *et al.* (2016) reported that alkalinity concentrations in the Bangshi River ranged from 53.3 to 165 ppm in the wet season and 216.6 to 371.2 ppm in the dry season. Islam *et al.* (2012) found that alkalinity concentrations in the Dhaleshwari River varied from 126 to 200 ppm in the monsoon, 150 to 595 ppm in the post-monsoon, and 450 to 640 ppm in the pre-monsoon season, which is relatively higher than the present study. Yasmeen *et al.* (2012) observed that the mean alkalinity of the Buriganga River ranged from 168 to 248 ppm in the dry season and from 158 to 240 ppm in the wet season, which is quite similar to the findings of the current study.

Water pH

The pH levels at all sampling sites were higher during the dry season compared to the wet season (Figure 5). The average pH values were 6.54 in the wet season and 7.74 in the dry season. According to the ECR (1997), the recommended pH range for inland surface water is between 6.5 and 8.5. The pH values in all water samples fell within this standard range.

Rehnuma *et al.* (2016) found that the pH of the Bangshi River ranged from 7.64 to 7.84 in the wet season and from 7.76 to 8.47 in the dry season. Saifullah *et al.* (2012) also noted that pH levels at all sampling sites in the Buriganga River were higher during the dry season than in the wet season. Hoque *et al.* (2012) recorded pH values of 7.6 during the monsoon and 8.5 during the winter in the Bansi River. These findings are generally consistent with those observed in the present study.

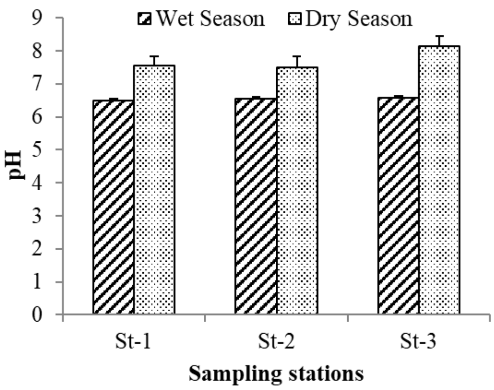

Figure 5. pH values at various sampling stations during the wet and dry season.

Concentration of Heavy Metals in Water

The average concentration of lead (Pb) in the water was 4.64 ppm (Table 2), which exceeds the acceptable limits set by ECR (2023), WHO (2004), and ADB (1994) for drinking water, irrigation, and fishing at all locations. Major sources of lead include vehicle emissions, metal plating, wastewater discharge, and the use of fertilizers (Karrari *et al.* 2012). Exposure to lead interferes with heme biosynthesis and erythropoiesis, leading to anemia and a range of health problems. Long-term lead exposure has been linked to cancers, reproductive issues in men, hormonal imbalances, and developmental delays such as reduced IQ in children, posing significant public health risks (Siddiqui *et al.* 2002).

The average concentration of cadmium (Cd) in the water was 0.003 ppm (Table 2), which is below the permissible levels defined by ECR (2023), WHO (2004), and ADB (1994) during the wet season. Cadmium primarily comes from sources like metal industries, coal combustion, and waste disposal (Rzętała, 2016). As a known carcinogen, cadmium disrupts bone metabolism, causes toxic effects in several organs, damages kidney function, and impacts reproductive and endocrine systems. Exposure to cadmium can lead to calcium loss, resulting in skeletal demineralization and an increased risk of bone fractures (Wu *et al.* 2001). Moreover, prenatal cadmium exposure has been linked to lower birth weights and a higher risk of premature death, emphasizing its serious health risks (Henson and Chedrese, 2004).

The average concentration of copper (Cu) in the water during the wet season was 0.014 ppm (Table 2), which is within the permissible limits set by ECR (2023), WHO (2004), and ADB (1994). Copper typically enters the environment through agricultural runoff, agrochemical industries, and urban sewage (Islam *et al.* 2015). High copper intake can lead to serious health issues such as organ damage, nausea, vomiting, kidney failure, hemolytic jaundice, and central nervous system depression, making it important to monitor copper levels in the environment (Hashem *et al.* 2011).

The average concentration of manganese (Mn) in the water during the wet season was 0.0092 ppm (Table 2), which is within the acceptable levels set by ECR (2023) and WHO (2004). Manganese in surface water exists in various oxidation states, which can be influenced by microbial activity and dissolved oxygen levels (Tobiason *et al.* 2016). While manganese is an essential nutrient in trace amounts, excessive exposure can result in toxicity and health risks. Long-term exposure to high manganese levels has been linked to iron-deficiency anemia and disruption of copper-dependent enzyme activity, underlining its potential negative effects on human health (Crossgrove and Zheng, 2004).

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Table 2. Comparison of Heavy Metal Concentrations (ppm) in Bangshi River Water with Standard Limits

Heavy metals	Average Concentration(ppm)	Standard levels (ADB, 1994)	
		Irrigation	Fishing
Pb	4.64	0.1	0.05
Cd	0.003	0.01	-
Cu	0.014	0.2	0.4
Mn	0.009	-	-

Heavy metals concentration in fish

During the wet season, the concentration of lead (Pb) in Tengra (*Mystus nigriceps*) and Tara Baim (*Macrognathus aral*) from the Bangshi River was 5.35 ppm and 4.46 ppm, respectively. The FAO (2003) sets the permissible limit for lead concentration in fish at 0.2 ppm. Both species showed Pb concentrations significantly exceeding the FAO standard during the wet season (Table 3).
The cadmium (Cd) concentrations in Tengra *(Mystus nigriceps*) and Tara Baim (*Macrognathus aral*) were 0.0013 ppm and 0 ppm, respectively, in the wet season, both of which were well below the FAO standard (Table 3). Copper (Cu) levels in Tengra (*Mystus vittatus*) and Tara Baim (*Macrognathus aral*) were 0.006 ppm and 0.04 ppm, respectively, which are also much lower than the FAO standard for the wet season (Table 3).
Manganese (Mn) concentrations in Tengra (*Mystus nigriceps*) and Tara Baim (*Macrognathus aral*) were 0.09 ppm and 0.27 ppm, respectively. Studies have shown that manganese uptake in aquatic fish increases with temperature and decreases with pH, although dissolved oxygen does not significantly affect manganese uptake (Miller *et al.* 2003; Rouleau *et al.* 1996). These results highlight the complex interactions between pollutants in the river system, influenced by industrial discharges and environmental conditions that affect the distribution of heavy metals and their accumulation in fish.

Table 3. Concentration of Heavy Metals in Tengra (*Mystus nigriceps*) and Tara Baim (*Macrognathus aral*) from the Bangshi River, compared with values reported in other studies.

Fish Species	River Name	Pb	Cd	Mn	Cu	References
Tengra (*Mystus nigriceps)*	Bangshi River	5.35	0.0013	0.09	0.006	Present study
	Dhaleshwari River	0.218	0.011	-	-	Ahsan *et al.* (2018)
	Bangshi River	0.180	0.023	5.670	0.770	Rehnuma *et al.* (2016)
	Mrigi River	0.450	0.022	4.790	0.670	Mazumder (2024)
Tara Baim *(Macrognathus aral)*	Bangshi River	4.46	0	0.27	0.04	Present study
	Khiru River	0.0010	0.0043	27.52	2.82	Rashid *et al.* (2012)
Standard Level (ppm)		0.2	0.05	-	30	FAO (2003)

CONCLUSION

This study reveals that industrial discharges, waste disposal, and agricultural runoff are significant sources of heavy metal contamination in the Bangshi River. The analysis of two fish species, *Mystus nigriceps* and *Macrognathus aral*, indicated that the accumulation of heavy metals followed the pattern: Pb > Mn > Cu > Cd. The elevated lead levels, in particular, pose serious health risks to the local population. Based on these findings, it is crucial for authorities to take swift action to regulate unauthorized industries along the riverbanks, enforce stricter controls on untreated wastewater discharges, and adopt effective strategies to reduce heavy metal pollution. These steps are essential to protect both the river ecosystem and public health.

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Conflict of Interest

There are no conflicts of interest declared by the authors.

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