J Bangladesh Agril Univ 23(2): 269-280, 2025 https://doi.org/10.3329/jbau.v23i2.82597

ISSN 1810-3030 (Print) 2408-8684 (Online)

Journal of Bangladesh Agricultural University

Journal home page: http://baures.bau.edu.bd/jbau

Research Article

Heavy Metals Contamination in Rohu (*Labeo rohita*) from Fish Ponds of Mymensingh and Cumilla Regions in Bangladesh

Ajmala Aktar[1], Jahid Hasan[2], Tonima Rahman Mim[1], Mohammad Lutfar Rahman[3], Farhana Haque[1] and Md. Emranul Ahsan[1]✉

[1]Department of Fisheries Management, Gazipur Agricultural University, Gazipur-1706, Bangladesh
[2]Department of Aquatic Environment and Resource Management, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh
[3]Department of Genetics and Fish Breeding, Gazipur Agricultural University, Gazipur 1706, Bangladesh

ARTICLE INFO

Article history
Received: 02 February 2025
Accepted: 22 June 2025
Published: 30 June 2025

Keywords
Heavy metals, Pollution, Health hazard, Indian Major Carp, Bioaccumulation

Correspondence
Md. Emranul Ahsan
✉: meahsan@gau.edu.bd

OPEN ACCESS

ABSTRACT

Water quality is a critical concern globally due to increasing threats from human activities. This study analyzed water, sediment, and fish (*Labeo rohita*) samples from the Cumilla and Mymensingh regions of Bangladesh. In this study, focusing on five trace elements (Cd, Cr, Cu, As, and Pb) to assess metal toxicity and identify potential sources. The average concentrations of As, Pb, Cd, Cr, and Cu in water were 4.43, 3.91, 201.00, 5.32, and 19.36 µg/L, respectively, while in sediments, the levels were 4.15, 16.8, 0.1, 17.19, and 23.86 mg/kg. In fish, the average concentrations were 0.97, 2.7, 1.31, 3.63, and 44.87 µg/g, respectively. The estimated daily intake of fish for males in Cumilla and Mymensingh was 0.34 mg/kg/d and 0.78 mg/kg/d, respectively, while for females, it was 0.36 mg/kg/d and 0.81 mg/kg/d, respectively. The hazard quotient assessment indicated that these levels did not exceed the recommended threshold, suggesting that consumers in these regions are unlikely to experience significant health risks from fish consumption. Studying heavy metals in water is crucial for informing policymakers because it provides the scientific foundation for setting safe water standards, protecting public health, and managing environmental impacts.

Introduction

Fisheries play a crucial role in Bangladesh's national economy by contributing to food security, employment, and foreign exchange earnings, making them valuable and highly productive resources (Hasan et al., 2021). Around 12% of the country's population is involved in the fishing sector, either full-time or part-time, for their livelihood. Fish account for approximately 60% of the total animal protein intake in Bangladesh (DoF, 2023). Aquaculture is primarily carried out in rural ponds and lakes, which are mainly replenished by surface water during the monsoon season and supplemented by groundwater in the dry season. However, there is a risk of chemical accumulation, particularly from insecticides and fungicides, which can bioaccumulate in fish. Additionally, artificial pelleted feed serves as a significant source of heavy metals, with uneaten portions settling in the sediment (Tao et al., 2012). The distribution of metals in different fish tissues depends on their concentration in water and feed (Islam et al., 2014; Ali et al., 2013; Rajkowska & Protasowucki, 2013; Hossain et al., 2007).

However, trace metal contamination in fish is increasingly becoming a global concern, as water is highly susceptible to the rising discharge of pollutants worldwide persistence, and tendency to bioaccumulate in the food chain (Ahmed et al., 2015). Public awareness of dietary exposure to environmental contaminants particularly those that can bioaccumulate in fish is

Cite This Article
Aktar, A., Hasan, J., Mim, T.R., Rahman, M.L., Haque, F. and Ahsan, M.E. 2025. Heavy Metals Contamination in Rohu (*Labeo rohita*) from Fish Ponds of Mymensingh and Cumilla Regions in Bangladesh. *Journal of Bangladesh Agricultural University,* 23(2): 269-280. https://doi.org/10.3329/jbau.v23i2.82597

growing and, in turn, affecting fish consumption patterns (Markert, 1993). Their primary natural sources in aquatic environments include rock weathering, soil leaching, and the dissolution of atmospheric aerosol particles. Heavy metal contamination results from excessive accumulation of toxic metals in the environment, mainly due to human activities. The main anthropogenic sources include industrial and domestic waste, along with the increased use of metal-based pesticides and fertilizers in agriculture (Papafilippaki et al., 2008; Debels et al., 2005; USDA, 2000). Some heavy metals, such as cobalt, copper, iron, manganese, nickel, and zinc, are essential for the growth and proper functioning of living organisms (Tolkou et al., 2023). However, certain heavy metals can be biologically toxic. Contamination of aquatic ecosystems by heavy metals has become a major concern, reaching alarming levels (Kabir et al., 2020), with most of these pollutants originating from human activities (Malik et al., 2010). The accumulation of toxic substances in the human body poses serious health risks. Contaminated food, especially with hazardous trace metals, can cause severe damage to critical human organs, including the liver, kidneys, central nervous system, mucosal tissues, intestinal tract, and reproductive system when consumed on a large scale (Siddique et al., 2012). Even at low concentrations, trace metals can be detrimental to the health of both aquatic species and humans (Gu et al., 2017). Therefore, continuous monitoring and assessment of heavy metal concentrations are crucial to detect and manage potential fluctuations (Lawson, 2011; Asaolu et al., 1997).

Indian Major Carp (*L. rohita)* is a highly valued and widely preferred fish, known for its desirable traits that make it an excellent choice for aquaculture (Abidi and Khan, 2010). Among the three major Indian Carp species used in Carp polyculture systems, Indian Major Carp (*Labeo rohita*) is the most prominent. There are some scattered works on the determination of heavy metals in water, sediments, and different fish muscles in polyculture system (Ahsan et al., 2022; Mansur et al., 2021; Mohanta et al., 2019; Sultana et al., 2017; Sarker et al., 2016). However, none of the study was carried out to determine the heavy metals in water, sediments, and different fish muscles in Indian Major Carp monoculture system. This study aimed to determine heavy metal concentrations in ponds by analyzing water and sediment, assess the bioaccumulation of heavy metals in the muscle tissue of farmed Indian Major Carp (*L. rohita)*, and evaluate potential health risks associated with its consumption, with a focus on human safety concerns.

Materials and Methods

Study area and sample collection

This study was conducted in 16 fish ponds at the final stage of the fish production cycle within commercial aquaculture facilities. Samples were collected from ponds in the Mymensingh and Cumilla regions between November and March (Fig. 1), with coordinates recorded using a Global Positioning System (GPS). These areas chosen based on high aquaculture activity and production return. Water samples (250 ml) were taken from the pond surface using plastic bottles between 9 AM and 10 AM. Sediment samples were collected with a sediment corer to a depth of 0-5 cm and stored in polyethylene plastic bags. Marketable-sized Indian Major Carp were also sampled from each pond. In the present study, Indian Major Carp (*Labeo rohita*) fish species was selected as this species contributed most to the total fish production in these two regions (DoF, 2023). All samples were transported to the laboratory and refrigerated at 4°C, filtered using a membrane filter, and preserved at -20°C for further analysis.

Heavy metals concentration were determined with the help of a ICP-MS in which acetylene gas and air were used as fuel and oxidizer, respectively. The concentrations of heavy metals were determined with the support of calibration curves. Calibrations were done by using standard solutions following manufacturer's protocol. Three replications of each sample were used to determine the average metal value. After establishment of the calibration curves, the limit of detection (LOD) were measured for the heavy metals of interest of AAS. Detection limit of the spectrophotometer is unique for each metal which is given the following table and the concentrations below the limit were termed as Below Detectable Limit (BDL). All chemicals and reagents were of analytical reagent grade quality. Before using, all glass and plastic ware were soaked in 14% HNO_3 for 24 h. The washing was done with distilled water.

Heavy metal determination of water

After collection, the water samples were filtered using the Millipore Filtration system with a 0.2 µm membrane filter. The filtrate was then acidified with concentrated HNO_3 to lower the pH below 2. Sample digestion was carried out using ultra-pure HNO_3.

Heavy metal determination of sediment

Heavy metal analysis of sediment samples was performed following the ICP-MS method described by Gilbert and Oldewage (2014). The upper 0-5 cm of sediment (approx. 500 g) was collected at the same point as the water samples using a VanVeen grab sampler, repeated three times, and stored in polyethylene bags. Samples were collected for laboratory analysis. The sediment samples were taken to the laboratory. Once at the laboratory, each sample was stored at 4ºC until further analysis. The sediment samples were air-dried, then passed through a 2-mm nylon sieve to remove large particles, and subsequently transferred to an oven to dry at 50°C until a constant weight was reached. Then these samples were ground and passed through a 100-mesh sieve prior to analysis. The method of extracting the total metal concentrations in sediment was based on Zhang et al., 2012. For sediment analysis, the quality assurance and quality control (QA/QC) procedures were conducted by using standard reference materials: GSD-2a and GSD3a (geochemical standard sediment). The accuracy of the results was controlled by using blank samples as control samples and by digesting duplicate samples. Recoveries varied but all fell within the range of 90-105%, and the relative standard deviation (RSD) was within 5%.

Heavy metal determination of fish tissue

Fish sample analysis for heavy metals was carried out using the ICP-MS method. A 1-gram fish tissue sample was dried in an oven at 100°C. The dried tissue was then ground using a porcelain crusher and pestle. The powdered samples were weighed and placed in Teflon microwave digestion flasks, where they were treated with 65% Suprapur nitric acid. Digestion was performed using an Ethos Advance microwave station. After removal from the oven, 100 µl of indium (1000 mg/kg) was added as an internal standard before transferring the samples into a 50-ml volumetric flask. The samples were then dissolved in 50 ml of Milli-Q water and stored at 4°C in 50 ml Cellstar® tubes until analysis.

Fulton's condition factor (K)

Fulton's condition factor was determined using fish biometric data (Froese, 2006).

$$K = 10^2 \times \frac{W}{L^3}$$

Metal pollution index (MPI)

The metal pollution index (MPI) was calculated using the technique established by Usero et al., (1997) to compare the total metal concentration across various fish tissues.

$$MPI = (C_{b1} \times C_{b2} \times C_{b3} \times \dots C_{bn})^{1/n}$$

Where, C_{bn} is the concentration of metal n in the analyzed tissue (mg/g dry weight)

Bioconcentration factor (BCF) and biota-sediment accumulation factor (BSAF)

$$BCF = \frac{C_b}{C_w}$$

$$BSAF = \frac{C_b}{C_s}$$

Where, C_b, C_w, and C_s are the mean metal concentrations in the biota, water, and sediments, respectively.

Estimated daily intake (EDI) (mg/kg/d)

$$EDI = \frac{C_{b,muscle} \times DC_{fish}}{BW}$$

Where,

Cb_{muscle} = fish muscle metal concentration (mg/g wet weight),

DC_{fish} = per capita per day (g/day) fish consumption, and

BW = mean body weight of the adult population (kg)

The hazard quotient (HQ)

The hazard quotient (HQ) was determined by dividing the estimated daily intake (EDI) by the established reference dose (RfD), enabling the evaluation of health risks linked to the eating of pangasius and tilapia by adults.

$$HQ = \frac{EDI}{RfD}$$

Statistical analysis

All values are expressed as means ± standard deviation (SD) based on descriptive statistics using SPSS Version 23. Significant differences in the average metal concentrations across different tissues, water, and sediment among the study locations were evaluated using a one-way analysis of variance (ANOVA) at a 95% confidence level. Tukey's HSD test was applied for post hoc analysis to identify significant pairwise comparisons between regions. The Pearson correlation test was conducted to examine relationships between various factors at significance levels of 99% ($p<0.01$) and 95% ($p<0.05$).

Results

Heavy metal concentration in water

The average concentration of arsenic was greater at Cumilla (4.49±3.12 µg/l) and lesser at Mymensingh (4.37±2.73 µg/l) for Indian Major Carp farms. The maximum Pb content was 6.1±2.91 µg/l in Cumilla, while the minimum was 1.67±1.42 µg/l in Mymensingh. The concentration of cadmium (Cd) in water was highest in Cumilla at 400.23±128.65 µg/l, while the lowest quantity was recorded in Mymensingh at 1.77±1.18 µg/l (Table 1). Notable changes ($p<0.05$) were seen in the amounts of As, Pb, Cd, and Cr across several sections of pond water. The average concentration of Cu in the Indian Major Carp farms was greater in Mymensingh (11.7±9.62 µg/l) and lesser in Cumilla (17.02±7.73 µg/l). No significant variation ($p>0.05$) in Cu levels was observed across the various regions. The concentration of metals in water was ranked in descending order as follows: Cd > Cu > Cr > As > Pb. The average concentration of Cr was greater at Cumilla (8.29±5.55 µg/l) and lesser at Mymensingh (2.35±1.44 µg/l) for Indian Major Carp farms (Table 1).

Table 1. Mean heavy metal Concentrations (mean±SD in µg/l) in the water

Regions	Species (*Labeo rohita)*	Arsenic (As)	Lead (Pb)	Cadmium (Cd)	Chromium (Cr)	Cupper (Cu)
Cumilla	(n=8)	4.49± 3.12	6.16±2.91	400.23±128.65	8.29 ±5.55	11.7±9.62
Mymensingh	(n=8)	4.37±2.73	1.67±1.42	1.77±1.18	2.35±1.44	17.02±7.73

Heavy metal concentration in sediment

Table 2 presents the amounts of heavy metals and the analysis results from 16 sediment samples of Indian Major Carp cultivation ponds. The mean concentration of arsenic was highest in Mymensingh (4.37 ± 0.97 mg/kg) and lowest in Cumilla (3.934±0.711 mg/kg). The concentration of Pb ranged from 10.01 to 23.8 mg/kg in Cumilla, whereas the maximum value recorded was between 7.8 to 32.3 mg/kg in the Mymensingh district. The content of Cd ranged from 0.049±0.0856 mg/kg in Cumilla to 0.153±0.09 mg/kg (Table 2). Cu concentrations in sediments from different sampling sites varied from 8.2 to 31.7 mg/kg in the Cumilla region and from 12.3 to 38.5 mg/kg in the Mymensingh region. The Cumilla region exhibited the lowest copper concentration at 19.94 mg/kg, whilst the Mymensingh region recorded the highest value at 27.79 mg/kg. Marked differences were observed ($p<0.05$) for nearly all metals in sediment across the various regions. The Cumilla region exhibited the greatest chromium concentration at 20.53 mg/kg, whilst the Mymensingh region recorded the lowest at 13.85 mg/kg (Table 2). The metal concentration in sediment was ranked as follows: Cu > Cr > Pb > As > Cd.

Table 2. Mean heavy metal Concentrations (mean±SD in mg/kg dry weight) in the sediment

Regions	Species (*Labeo rohita*)	Arsenic (As)	Lead (Pb)	Cadmium (Cd)	Chromium (Cr)	Cupper (Cu)
Cumilla	(n=8)	3.93±0.711	17.11±5.054	0.05±0.0856	20.53±12.03	19.94±7.06
Mymensingh	(n=8)	4.37 ± 0.97	16.49 ± 8.79	0.153 ± 0.09	13.85 ±8.38	27.79±8.27

Heavy metals concentration in fish tissues

The kidney of Indian Major Carp fish in Mymensingh exhibited the greatest values of As (3.01±0.82 µg/g), Pb (7.93±2.07 µg/g), Cd (6.49±3.65 µg/g), and Cr (9.61±7.86 µg/g) relative to other organs across all sample sites (Table 3). In the Cumilla region, arsenic concentrations in muscle and chromium concentrations in liver were elevated compared to Mymensingh, with arsenic in muscle measuring 0.158±0.03 µg/g and chromium in liver measuring 0.703±0.85 µg/g (Table 3). In Mymensingh, concentrations of Muscle, Liver, Kidney Pb, and Cu in Muscle, Liver, and Kidney were considerably elevated compared to other regions of Cumilla ($p<0.05$). Indian Major Carp sourced from the Cumilla region exhibited moderately lower quantities of metals compared to those from the Mymensingh region in Bangladesh. The sequence of average metal content in fish tissue was Cr>Cu>Pb>As>Cd.

Table 3. Metal concentrations (Mean±SD, µg/g dry weight) in different tissues of Indian Major Carp (*Labeo rohita)*

Metals	Tissue	Cumilla	Mymensingh
As	Muscle	0.158±0.03	0.096±0.04
	Liver	0.047±0.015	0.15±0.097
	Kidney	2.39±0.7	3.01±0.82
Pb	Muscle	0.46±0.086	0.73±0.30
	Liver	0.28±0.23	0.49±0.41
	Kidney	6.33±1.21	7.93±2.07
Cd	Muscle	0.04±0.01	0.064±0.015
	Liver	0.037±0.025	1.23±0.83
	Kidney	0.015±0.004	6.49±3.65
Cr	Muscle	0.703±0.92	1.55±1.25
	Liver	0.703±0.85	0.589±0.47
	Kidney	8.67±8.33	9.61±7.86
Cu	Muscle	0.49±0.51	1.44±1.07
	Liver	85.91±99.7	144.31±109.85
	Kidney	10.12±13.29	26.97±30.73

Fulton's condition factor (K) and metal pollution index (MPI)

Table 4 shows the average body weight, length, and Fulton's condition factor (K). The muscle, liver, and kidney MPI (Metal Pollution Index) values for Indian Major Carp fish from different locations are depicted in Fig. 2. The MPI for muscle was lower than that for the liver and kidney. The MPI for muscle ranged from 0.000 to 0.603, for liver from 0.000 to 0.317, and for kidney from 0.515 to 12.98. The results revealed that the average MPI for tissues, ranked from highest to lowest, were as follows: kidney (4.35) > liver (1.2) > muscle (0.27) for Indian Major Carp fish (Fig. 2).

Figure 1. Study area

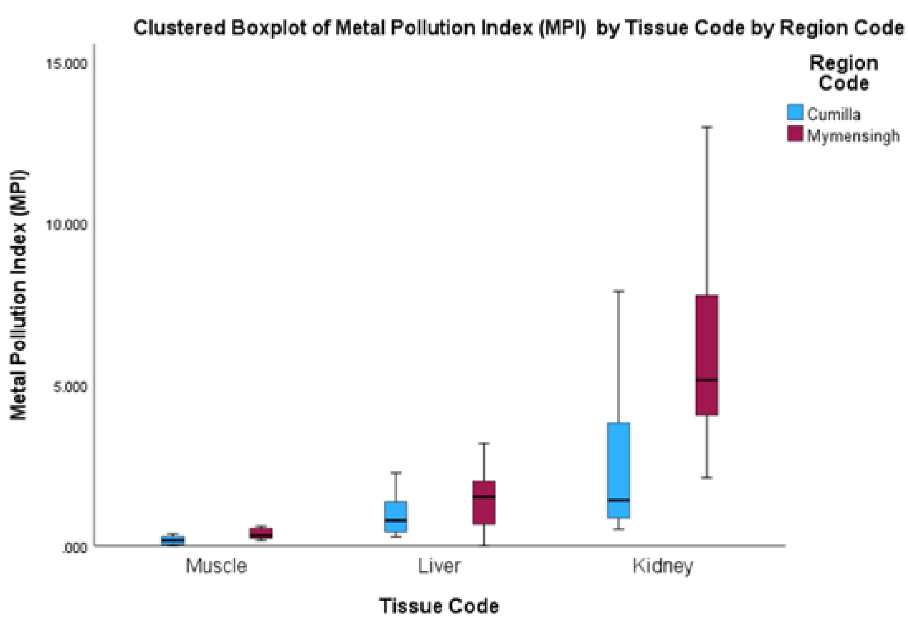

Figure 2. Mean metal pollution index (MPI) of Indian Major Carp (*Labeo rohita)*

Table 4. Fulton's condition factor (K) of Indian Major Carp (*Labeo rohita)*

Regions	Species (*Labeo rohita)*	Length (cm)	Weight (g)	Fulton's condition factor
Cumilla	(n=8)	34.13	1155	2.90
		33.07	985	2.72
		36.05	1215	2.59
		36.1	1230	2.61
		34.45	1125	2.75
		35.08	1205	2.79
		34.85	1170	2.76
		33.43	1005	2.69
Mymensingh	(n=8)	33.01	980	2.72
		37.08	1350	2.64
		33.53	1020	2.70
		34.89	1180	2.77
		33.57	950	2.51
		35.31	1240	2.81
		34.57	1130	2.73
		36.28	1270	2.65

Bioconcentration factor (BCF) and biota-sediment accumulation factor (BSAF)

Fig. 3 shows the distribution of the bioconcentration factor (BCF) in different tissues of Indian Major Carp fish, based on the average metal concentrations in water (Table 1) and fish tissue (Table 3). The results revealed that the BCF for cadmium (Cd) was highest in the muscle and kidney tissues. The distribution of metals in sediment and tissue was determined using the average metal concentration in soil (Table 2) and fish tissue (Table 3). The biota-sediment accumulation factor (BSAF) for various tissues of Indian Major Carp is shown in Fig. 4.

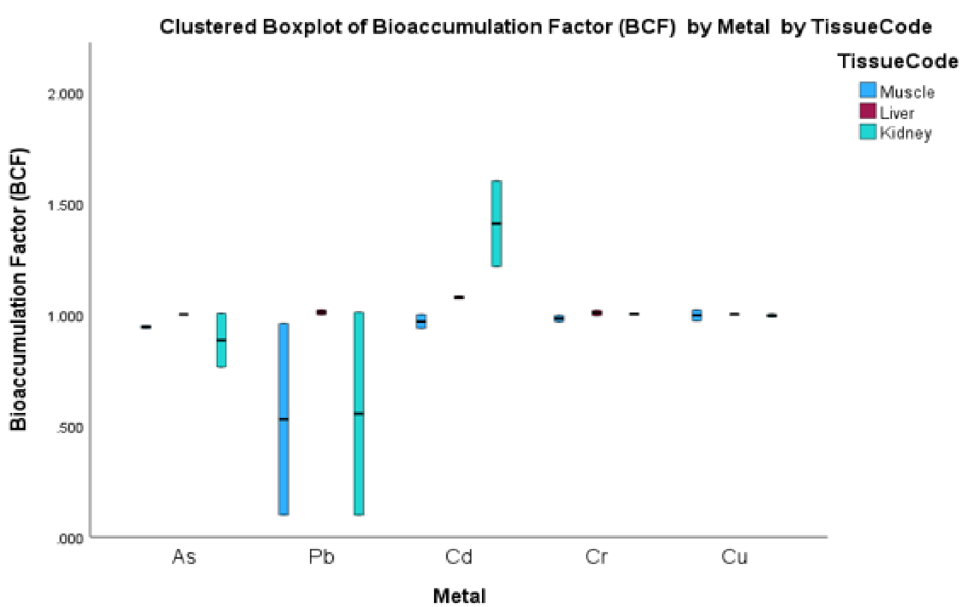

Figure 3. Box and whisker plots of bioaccumulation factors of Indian Major Carp (*Labeo rohita)*

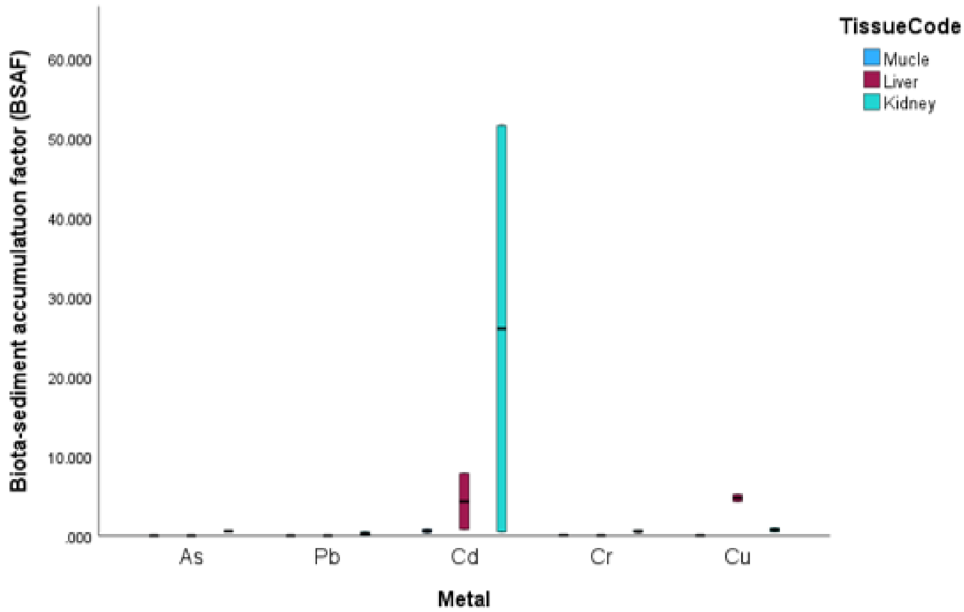

Figure 4. Box and whisker plots of biota-sediment accumulation factors of Indian Major Carp (*Labeo rohita)*

Relationship between condition factor and MPI (metal pollution index)

To assess environmental factors such as pollution, growth rate, feeding, and reproduction in Indian Major Carp, length-weight relationships can be useful, along with stock evaluations and management strategies (Vajargah et al., 2020). Linear regression analyses were performed to explore the relationship between heavy metal concentrations and the body size of Indian Major Carp, as shown in Figures 5, 6, and 7. Spearman's rank correlation analysis revealed a positive correlation between the condition factor of Indian Major Carp and the Metal Pollution Index (MPI) for muscle, with r = 0.305 (R^2 = 0.008, p>0.01) (Fig. 5). A positive correlation was also observed between the liver's MPI and Fulton's condition factor, with r = 0.415 (p>0.01, R^2 = 0.093) (Fig. 6). However, the MPI of the kidney showed a negative correlation with Fulton's condition factor, with r = -0.312 (p<0.01, R^2 = 0.093) (Fig. 7).

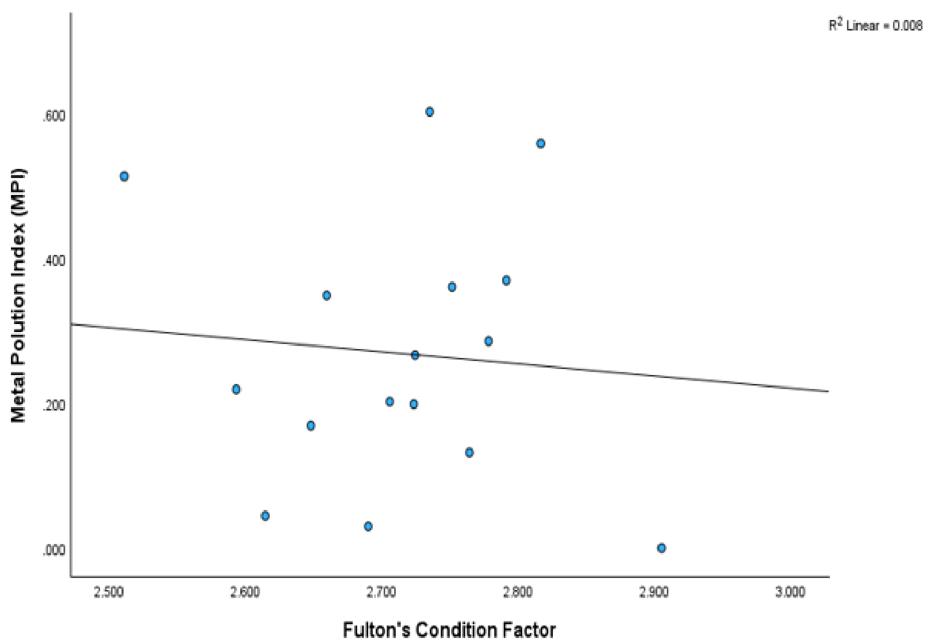

Figure 5. Correlations between metal pollution index (MPI) of Muscle and Fulton's condition factor (K)

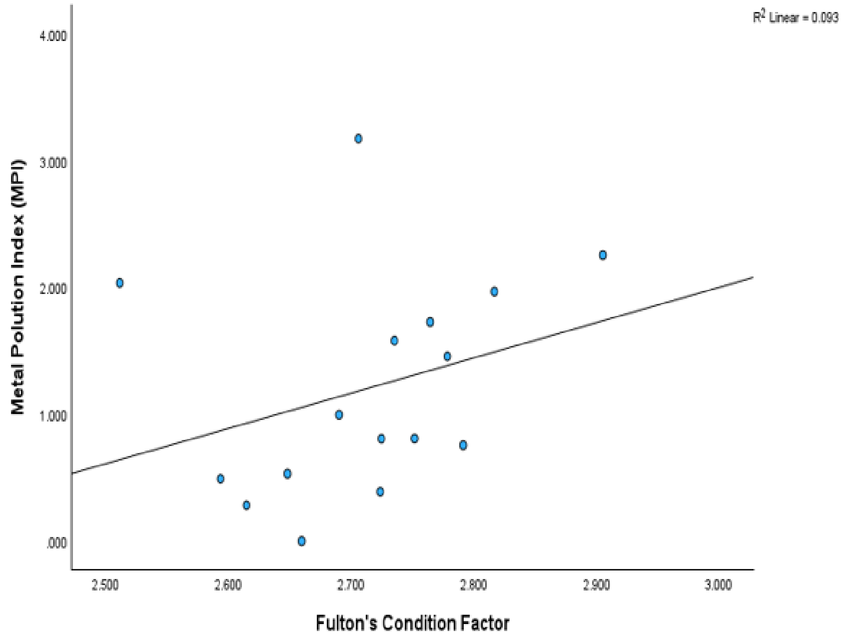

Figure 6. Correlations between the metal pollution index (MPI) of the Liver and Fulton's condition factor (K)

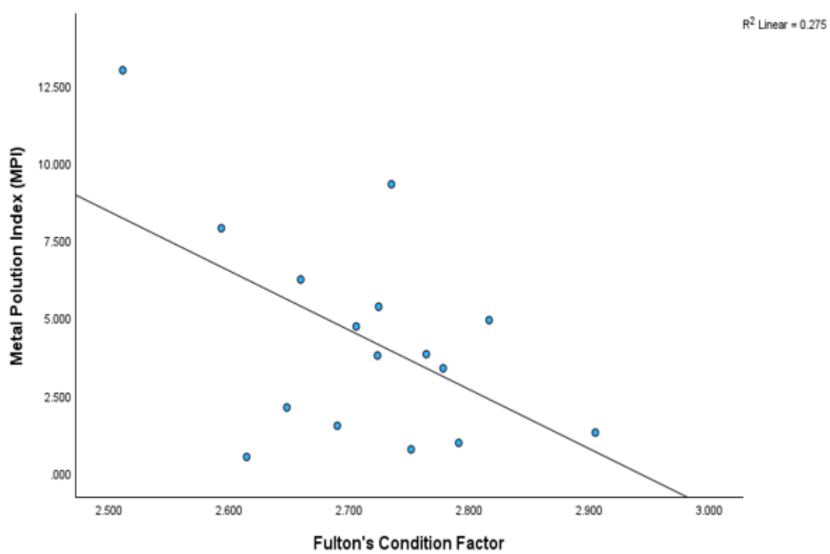

Figure 7. Correlations between metal pollution index (MPI) of Kidney and Fulton's condition factor (K)

Human health risk assessment

To evaluate the health risks linked to the long-term consumption of Indian Major Carp in two areas of Bangladesh, the estimated daily intake (EDI) (mg/kg/d) for the Bangladeshi population and the hazard quotient (HQ) were calculated. No significant risk to human health from fish consumption is identified when the HQ value is below one. The estimated daily intake of Indian Major Carp fish in different regions of Bangladesh is shown in Table 5. The estimated daily intake for males in Cumilla and Mymensingh was 0.34 mg/kg/d and 0.78 mg/kg/d, respectively. For females in Cumilla and Mymensingh, the estimated daily intake was 0.36 mg/kg/d and 0.81 mg/kg/d, respectively (Table 5). The highest HQ value was for chromium (Cr) at 0.326, while copper (Cu) had the lowest value at 0.012 (Table 6).

Table 5. Estimated daily intake of Indian Major Carp (*Labeo rohita*)

Regions	Metal	Concentration	Weight of Female	Weight of Male	Average daily intake	EDI Female	EDI Male
	As	0.15	59.43	62.58	62.58	0.158	0.15
	Cd	0.04	59.43	62.58	62.58	0.042	0.04
Cumilla	Cr	0.703	59.43	62.58	62.58	0.740	0.703
	Cu	0.488	59.43	62.58	62.58	0.514	0.488
	As	0.096	59.43	62.58	62.58	0.101	0.096
	Cd	0.064	59.43	62.58	62.58	0.067	0.064
Mymensingh	Cr	1.55	59.43	62.58	62.58	1.632	1.55
	Cu	1.44	59.43	62.58	62.58	1.516	1.44

Table 6. Human health risk of Indian Major Carp (*Labeo rohita)* consumption for male and female population in Bangladesh

Regions	Metal	EDI Female	EDI Male	RfD	HQ Female	HQ Male
Cumilla	As	0.158	0.150	1	0.158	0.150
	Cd	0.042	0.040	0.3	0.140	0.133
	Cr	0.740	0.703	5	0.148	0.141
	Cu	0.514	0.488	40	0.013	0.012
Mymensingh	As	0.101	0.096	1	0.101	0.096
	Cd	0.067	0.064	0.3	0.225	0.213
	Cr	1.632	1.550	5	0.326	0.310
	Cu	1.516	1.440	40	0.038	0.036

Discussion

Heavy metals concentration in water

In recent years, there has been considerable documentation of heavy metal and metalloid pollution in Bangladesh's water sources. The concentrations of these elements were compared to the permissible limits set by the USEPA (1999). Arsenic (As) and Chromium (Cr) were within acceptable levels at both locations, while Lead (Pb) and Cadmium (Cd) were within acceptable limits in Mymensingh but not in Cumilla. Copper (Cu) exceeded the maximum allowable concentrations. The run-off and waste materials from land and agriculture might be a potential source for Cd concentration. In addition of fertilization can increase the concentration of Cd in the pond (environment) (Sultana et al., 2017; Rzetala, 2016). Cadmium is carcinogenic, disrupts bone metabolism, causes various toxic effects, impacts kidney function, and affects reproductive and endocrine systems. Exposure to cadmium can lead to skeletal demineralization, increasing the risk of bone fragility and fractures (Wu et al., 2001). In pregnant women, cadmium exposure may result in lower birth weight and a higher risk of premature death (Henson et al., 2004). Copper (Cu) primarily originates from agricultural activities, agrochemical companies, and urban sewage (Islam et al., 2015). Excessive copper intake can lead to organ dysfunction, vomiting, nausea, kidney failure, hemolytic jaundice, and depression of the central nervous system (Hashem et al., 2011). Lead (Pb) sources include automobile emissions, metal plating, wastewater discharge, and fertilizers (Karrari et al., 2012).

Heavy metals concentration in sediment

The concentration of these metals was compared to the permissible limits set by the USEPA (1999). Arsenic (As), cadmium (Cd), chromium (Cr), and lead (Pb) were within acceptable levels, while copper (Cu) exceeded the maximum permissible limits in sediment. Copper, which is released into the environment through activities like mining, metal processing, agriculture, and chemical industries, is widely used in both industrial and agricultural sectors (Yunus et al., 2020).

Heavy metals concentration in fish

Worldwide, anthropogenic activities are causing the natural environment and aquaculture systems to become heavily contaminated with heavy metals, which can lead to consumer's health problems (Habib et al., 2023). The present study was conducted to assess the comparative analysis of heavy metals levels in different organs of farmed *Labeo rohita*, water, and sediment of the fish pond. The concentrations of As and Cd in fish tissues from Cumilla were within the limits set by MOFL (2014), although their levels varied across different organs and in response to changes in the habitat. Additionally, the average chromium levels in this study exceeded the recommended limits outlined by MOFL (2014). Chromium in the diet plays a significant role in fat and glucose absorption (Ali et al., 2018). A deficiency in chromium can hinder growth and disrupt the absorption of lipids, proteins, and glucose (Calabrese et al., 1985). Excessive chromium intake can cause acute respiratory problems and damage vital organs such as the liver, lungs, and kidneys (Ali et al., 2020). Copper

(Cu) is a vital element that supports health by aiding in hemoglobin formation alongside iron (Hart et al., 2002). However, excessive copper intake can impair liver and kidney function (Baki et al., 2018). Lead (Pb) affects heme biosynthesis and erythropoiesis, with chronic exposure leading to cancer, anemia, reproductive issues in males, hormonal imbalances, and a decrease in IQ in young children (Vagnoni et al., 2014; Siddiqui et al., 2002). Concentrations of Cd, Cr, Cu and Pb in the *Labeo rohita* fish muscle and liver (µg/g) was (0.05, 0.03, 1.54, 2.46) and (1.16, 0.51, 13.28, 9.17), respectively in commonly consumed fish species (*Labeo rohita*) of farmed selling in the local market of district Mianwali, Pakistan (Habib et al., 2024). Concentrations of Cd, Cr and Pb in the *Labeo rohita* fish (µg/g) was (0.03, below detection limit, below detection limit), respectively cultured in commercial fish farm of Natore, Bangladesh (Alam et al., 2023).

Fulton's condition factor (K) and metal pollution index (MPI)

The calculated condition factor (CF) ranged from 2.51 to 2.90 among the Indian Major Carp fish sampled. A CF greater than 1.0 indicates that all the Indian Major Carp were from a healthier population. The length-weight relationship in Indian Major Carp depends on factors such as food availability, seasonal changes, health, habitat conditions, and sex. The correlation between heavy metals and fish size is influenced by various factors. These include the habitat, feeding habits, swimming behavior, seasonal fluctuations, metabolic rates, and the physical and chemical properties of water, in addition to the fish's size and weight (Yi et al., 2012). Pelagic fish, which feed on phytoplankton and zooplankton, generally accumulate fewer heavy metals compared to carnivorous or omnivorous bottom feeders (Niri et al., 2018). Furthermore, fish like Indian Major Carp, which occupy a lower trophic level, tend to absorb fewer heavy metals than those higher up in the food chain. Seasonal changes also affect the levels of heavy metals. These metals were most concentrated in the gills and liver, with much lower accumulation in the muscles, likely due to the gills' direct exposure to external water (Ali et al., 2020).

Bioconcentration factor (BCF) and biota-sediment accumulation factor (BSAF)

The bioconcentration factor (BCF) for cadmium was greater than 1.0 in all tissues of Indian Major Carp, indicating that cadmium accumulates from water. BCF values for copper (Cu) and chromium (Cr) in all tilapia tissues also exceeded 1.0, suggesting that water is the main source of bioaccumulated Cu and Cr in the tissues. The biota-sediment accumulation factor (BSAF) results showed that the BSAF values for cadmium were above 1.0 in both the muscle and kidney, indicating that cadmium was bioaccumulated in Indian Major Carp from sediment. Except for cadmium, the BCF values were higher than the BSAF for all other metals. A BCF or BSAF value greater than 1 indicates the potential accumulation of metals or metalloids in fish muscle, while a value below 1 suggests that the substances are not directly deposited in fish tissue from water but are associated with sediment (Salam et al., 2020). Additionally, an organism's tissue with a BSAF greater than 2, between 1 and 2, and less than 1 can be classified as a macro-concentrator, micro-concentrator, and de-concentrator, respectively (Dallinger, 1993).

Human health risk assessment

The present study found that the hazard quotient (HQ) values for all fish species were below 1 for both males and females. However, females exhibited higher non-carcinogenic health risks than males. According to the USEPA (2011), the standard threshold for HQ is 1. None of the fish samples exceeded the recommended levels for any metal. The calculated HQ values remained below the threshold, indicating that consumers, regardless of gender, would not experience non-carcinogenic health effects from consuming these fish species. Humans can be vulnerable to the negative impacts of combined exposure to multiple contaminants (Li et al., 2013). The health risks associated with HQ arise from consuming fish that have accumulated heavy metals from their environment. Our biota accumulation factor (BAF) data suggests that heavy metals are transferred from water into Indian Major Carp tissues, primarily through the gills, then accumulate in the liver and are evenly distributed throughout the muscle tissues (Sarker et al., 2021).

Conclusion

The findings indicate that Cd, Cu, and Pb levels in water; Cu in sediment; and Cr, Cu, and Pb in fish exceeded recommended standards, suggesting that the pond ecosystem in Bangladesh is contaminated with trace elements, which could have harmful effects on the environment. For THQ, the standard threshold limit is 1, recommended by USEPA. The present study described that the THQ means of all fish species were below 1, both for male and female. None of these exceeded the guideline limit for every metal in all specimens. However, the examined HI did not exceed the recommended limit, indicating that consumers (male and female) would not suffer non-carcinogenic health effects from consuming selective fish species. Here are policy recommendations to mitigate heavy metal contamination in aquaculture, designed to help protect human health, aquatic ecosystems, and sustainable food production: set strict regulatory limits for heavy metals in water and feed, mandate regular monitoring and testing, ban or regulate high-risk inputs, promote eco-friendly aquaculture practices, control industrial pollution near aquaculture sites, educate and train stakeholders and strengthen enforcement and penalties.

Funding statement

Research Management Wing (RMW) at GAU, Bangladesh, funded the work of Md. Emranul Ahsan.

Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no conflict of interest.

References

Abidi, S.F. and Khan, M.A. 2010. Growth, protein retention and body composition of fingerling Indian major Carp, rohu, *Labeo rohita* (Hamilton) fed diets with various levels of lysine. *Journal of the World Aquaculture Society*, 41: 791-799. https://doi.org/10.1111/j.1749-7345.2010.00421.x

Ahmed, M.K., Baki, M.A., Islam, M.S., Kundu, G.K., Habibullah-Al-Mamun, M. and Sarkar, S.K. 2015. Human health risk assessment of heavy metals in tropical fish and shellfish collected from the river Buriganga, Bangladesh. *Environ. Sci. Pollut. Res.* 22: 15880–15890.

Ahsan, M.E., Islam, S.R., Razzak, M.A., Ali, M.L., Haque, M.M. 2022. Assessment of heavy metals from pangasius and tilapia aquaculture in Bangladesh and human consumption risk. *Aquaculture International.* https://doi.org/10.1007/s10499-022-00903-w

Alam, M., Rohani, M. F. and Hossain, M. S. 2023. Heavy metals accumulation in some important fish species cultured in commercial fish farm of Natore, Bangladesh and possible health risk evaluation. *Emerging Contaminants*, 9(4): 100254.

Ali, H., Haque, M.M. and Belton, B. 2013. Striped catfish (*Pangasianodon hypophthalmus*, Sauvage, 1878) aquaculture in Bangladesh: an overview. *Aquaculture research*, 44(6): 950-965. https://doi.org/10.1111/j.1365-2109.2012.03101.x

Ali, M.M., Ali, M.L., Islam, M.S. and Rahman, M.Z. 2018. Assessment of toxic metals in water and sediment of Pasur River in Bangladesh. *Water Sci. Technol.,* 77 (5): 1418–1430. https://doi.org/10.2166/wst.2018.016.

Ali, M.M., Ali, M.L., Proshad, R., Islam, S., Rahman, Z. and Kormoker, T. 2020. Assessment of trace elements in the demersal fishes of a coastal River in Bangladesh: A public health concern. Thalassas: Int. *J. Mar. Sci.,* 36 (2): 641–655. https://doi.org/10.1007/s41208-020-00227-7

Ali, M.M., Ali, M.L., Proshad, R., Islam, S., Rahman, Z., Tusher, T.R., Kormoker, T. and Al, M.A. 2020. Heavy Metal Concentrations in Commercially Valuable Fishes with Health Hazard Inference from Karnaphuli River, Bangladesh. Hum. *Ecol. Risk Assess.,* 26: 2646–2662. https://doi.org/10.1080/10807039.2019.1676635

Asaolu, S.S., Ipinmoroti, K.O., Adeyinowo, C.E. and Olaofe, O. 1997. Interrelationship of heavy metals concentration in water, sediment as fish samples from Ondo State Coastal Area, Nigeria. *African Journal of Science*, 1: 55-61. https://doi.org/10.9734/BJAST/2014/1965

Baki, M.A., Hossain, M.M., Akter, J., Quraishi, S.B., Shojib, M.F.H., Ullah, A.A. and Khan, M.F. 2018. Concentration of heavy metals in seafood (fishes, shrimp, lobster and crabs) and human health assessment in Saint Martin island, Bangladesh. *Ecotoxicol Environ Saf,* 159: 153–163. https://doi.org/10.1016/j.ecoenv.2018.04.035

Calabrese, E.J., Canada, A.T. and Sacco, C. 1985. Trace elements and public health. Annu. Rev. *Public Health,* 6 (1): 131–146.

Dallinger, R. 1993. Strategies of metal detoxification in terrestrial invertebrates. In: Dallinger R, Rainbow PS, eds. Ecotoxicology of Metals in Invertebrates. *Lewis Publisher*, 291-313.

DoF. 2023. Yearbook of fisheries statistics of Bangladesh, 2022-23. Fisheries resources survey system, Department of fisheries, Ministry of fisheries and livestock, 2023, 40, 138p.

Debels, P., Figueroa, R., Urrutia, R., Barra, R. and Niell, X. 2005. Evaluation of water quality in the Chillán River (Central Chile) using physicochemical parameters and a modified water quality index. *Environmental monitoring and assessment,* 110: 301-322. https://doi.org/10.1007/s10661-005-8064-1

Froese, R. 2006. Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. *Journal of applied ichthyology*, 22(4): 241-253. https://doi.org/10.1111/j.1439-0426.2006.00805.x

Gilbert, B.M. and Oldewage, A.A. 2014. Arsenic, chromium, copper, iron, manganese, lead, selenium and zinc in the tissues of the largemouth yellowfish, Labeo barbus kimberleyensis (Gilchrist and Thompson, 1913), from the Vaal Dam, South Africa, and associated consumption risks. *Water SA,* 40 (4): 739-748. https://doi.org/10.4314/wsa.v40i4.19.

Gu, Y.G.; Lin, Q.; Huang, H.H.; Wang, L.G.; Ning, J.J.; Du, F.Y. 2017. Heavy metals in fish tissues/stomach contents in four marine wild commercially valuable fish species from the western continental shelf of South China Sea. *Mar. Pollut. Bull.* 114: 1125–1129.

Hart, E.B., Steenbock, H., Waddell, J. and Elvehjem, C.A. 2002. Iron in nutrition: VII. Copper as a supplement to iron for hemoglobin building in the rat. *J Biol Chem*, 277(34): e22. https://doi.org/10.1016/S0021-9258(20)74028-7

Hasan, J., Lima, R.A. and Shaha, D.C. 2021. Fisheries resources of Bangladesh: A review. *Int. J. Fish. Aquat. Stud,* 9 (4): 131-138. https://doi.org/10.22271/fish.2021.v9.i4b.2532

Hashem, E.Y., Seleim, M.M. and El-Zohry, A.M. 2011. Environmental method for spectrophotometric determination of copper (II), Green Chem. *Lett. Rev.,* 4: 241–248. https://doi.org/10.1080/17518253.2010.546370.

Habib, S. S., Naz, S., Fazio, F., Cravana, C., Ullah, M., Rind, K. H. and Khayyam, K. 2024. Assessment and bioaccumulation of heavy metals in water, fish (wild and farmed) and associated human health risk. *Biological Trace Element Research*, 202(2): 725-735.

Henson, M.C. and Chedrese, P.J. 2004. Endocrine disruption by cadmium, a common environmental toxicant with paradoxical effects on reproduction. *Exp. Biol. Med.,* 229: 383–392. https://doi.org/10.1177/153537020422900506.

Hossain, A.M., Monir, T., Ul-Haque, A.R., Kazi, M.A.I., Islam, M.S. and Elahi, S.F. 2007. Heavy metal concentration in tannery solid wastes used as poultry feed and the ecotoxicological consequences. *Bangladesh Journal of Scientific and industrial research,* 42(4): 397-416. https://doi.org/10.3329/bjsir.v42i4.748

Islam, G.R., Khan, F.E., Hoque, M.M. and Jolly, Y.N. 2014. Consumption of unsafe food in the adjacent area of Hazaribag tannery campus and Buriganga River embankments of Bangladesh: heavy metal contamination. *Environmental monitoring and assessment,* 186: 7233-7244. https://doi.org/10.1007/s10661-014-3923-2

Islam, M.S., Ahmed, M.K., Raknuzzaman, M., Habibullah-Al-Mamun, M. and Islam, M.K. 2015. Heavy metal pollution in surface water and sediment: a preliminary assessment of an urban river in a developing country. *Ecol. Indicat.,* 48: 282–291. https://doi.org/10.1016/j.ecolind.2014.08.016

Kabir, M.H., Islam, M.S., Hoq, M.E., Tusher, T.R. and Islam, M.S. 2020. Appraisal of heavy metal contamination in sediments of the Shitalakhya River in Bangladesh using pollution indices, geospatial, and multivariate statistical analysis. *Arabian journal of geosciences*, 13: 1-13. https://doi.org/10.1007/s12517-020-06072-5

Karrari, P., Mehrpour, O. and Abdollahi, M.A. 2012. Systematic review on status of lead pollution and toxicity in Iran; Guidance for preventive measures, *DARUJ. Pharm. Sci.* 20: 2. https://doi.org/10.1186/1560-8115-20-2

Lawson, E.O. 2011. Physico-chemical parameters and heavy metal contents of water from the Mangrove Swamps of Lagos Lagoon, Lagos, Nigeria. *Advances in biological research,* 5(1): 8-21.

Li, J., Huang, Z.Y., Hu, Y. and Yang, H. 2013. Potential risk assessment of heavy metals by consuming shellfish collected from Xiamen, China. *Environ. Sci. Pollut. Res.,* 20 (5): 2937–2947. https://doi.org/10.1007/s11356-012-1207-3

Malik, N., Biswas, A.K., Qureshi, T.A., Borana, K. and Virha, R. 2010. Bioaccumulation of heavy metals in fish tissues of a freshwater lake of Bhopal. *Environmental monitoring and assessment,* 160: 267-276. https://doi.org/10.1007/s10661-008-0693-8

Markert, B.A. 1993. Plants as biomonitors: Indicators for heavy metals in the terrestrial environment.

MOFL. 2014. Bangladesh Gazette, Bangladesh Ministry of Fisheries and Livestock, SRO no. 233/Ayen.

Mansur, M. A., Haider, M. N., Hossain, M. M., Mia, M. M., & Karmakar, M. 2021. Heavy metal concentration in some freshwater fishes during autumn and winter in Mymensingh district of Bangladesh. *Bangladesh Journal of Fisheries*, 33(1): 81-87.

Mohanta, L. C., Niloy, M. N. H., Chowdhury, G. W., Islam, D., & Lipy, E. P. 2019. Heavy metals in water, sediment and three fish species of Dhaleshwari river, Savar. *Bangladesh Journal of Zoology*, 47(2): 263-272.

Niri, A.S., Sharifian, S. and Ahmadi, R. 2015. Assessment of Metal Accumulation in Two Fish Species (*Tenualosa ilisha* and *Otolithes ruber*), Captured from the North of Persian Gulf. Bull. *Environ. Contam. Toxicol.,* 94: 71–76. https://doi.org/10.1007/s00128-014-1429-9

Papafilippaki, A.K., Kotti, M.E. and Stavroulakis, G.G. 2008. Seasonal Variations in Dissolved Heavy Metals in The Keritis River, Chania, Greece. *Global NEST J.,* 10(3): 320. https://doi.org/10.30955/gnj.000528

Rajkowska, M. and Protasowicki, M. 2013. Distribution of metals (Fe, Mn, Zn, Cu) in fish tissues in two lakes of different trophy in Northwestern Poland. *Environmental monitoring and assessment*, 185: 3493-3502. https://doi.org/10.1007/s10661-012-2805-8

Rzętała, M.A. 2016. Cadmium contamination of sediments in the water reservoirs in Silesian Upland (southern Poland). *J. Soils Sediments*, 16: 2458–2470. https://doi.org/10.1007/s11368-016-1477-3

Salam, M.A., Paul, S.C., Zain, R.A.M.M., Bhowmik, S., Nath, M.R., Siddiqua, S.A., Aka, T.D., Iqbal, M.A., Kadir, W.R., Ahamad, R.B., Khaleque, M.A., Rak, A.E. and Amin, M.F.M. 2020. Trace metals contamination potential and health risk assessment of commonly consumed fish of Perak River, Malaysia. *PLoS One*, 15: e0241320. https://doi.org/10.1371/journal.pone.0241320

Sarker, J. M., Kanungo, I., Tanmay, M. H., & Patwary, S. A. 2016. A Study on the Determination of Heavy Metals in Sediment of Fish Farms in Bangladesh. *Fish Aquac J*, 7(159): 2.

Sarker, M.J., Islam, M.A., Rahman, F. and Anisuzzaman, M. 2021. Heavy metals in the fish *Tenualosa ilisha* Hamilton, 1822 in the Padma–Meghna River confluence: potential risks to public health. *Toxics,* 9(12): 341. https://doi.org/10.3390/toxics9120341

Siddiqui, M.K.J., Srivastava, S. and Mehrotra, P.K. 2002. Environmental exposure to lead as a risk for prostate cancer, Biomed. *Environ. Sci.,* 15: 298–305.

Siddique, M.A.M., Mustafa Kamal, A.H., Aktar, M. 2012. Trace metal concentrations in salt marsh sediments from Bakkhali River estuary, Cox's Bazar, Bangladesh. *Zool. Ecol.* 22: 254–259.

Sultana, N., Sarker, M. J., & Palash, M. A. U. 2017. A study on the determination of heavy metals in freshwater aquaculture ponds of Mymensingh. *Bangladesh Med. J*, 3(1): 143-149.

Tao, L., Zhang, C.X., Zhu, J.Q., Zhang, S.Y., Li, X.L. and Li, G. 2012. Improving fishpond sediment by aquatic vegetable rotation. *Advance Journal of Food Science and Technology,* 4(5): 327-331.

Tolkou, A. K., Toubanaki, D. K., & Kyzas, G. Z. 2023. Detection of arsenic, chromium, cadmium, lead, and mercury in fish: Effects on the sustainable and healthy development of aquatic life and human consumers. *Sustainability,* 15(23): 16242.

USDA. (United States Department of Agriculture). 2000. Heavy Metal Soil Contamination. Natural Resources Conservation Service, Soil Quality-Urban Technical Note No. 3, September.

USEPA. 1999. Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities; Appendix E Toxicity Ref Values; USEPA: Washington, DC, USA, Volume 3.

USEPA. 2011. USEPA Regional Screening Level (RSL) Summery Table: November 2011. http://www.epa.gov/regshwmd/risk/human/Index.htm.

Usero, J., Gonzalez-Regalado, E. and Gracia, I. 1997. Trace metals in the bivalve molluscs Ruditapes decussatus and Ruditapes philippinarum from the Atlantic Coast of Southern Spain. *Environment International*, 23(3): 291-298. https://doi.org/10.1016/S0160-4120(97)00030-5

Vajargah, M.F., Sattari, M., Namin, J.I. and Bibak, M. 2020. Length-Weight, Length-Length Relationships and Condition Factor of *Rutilus kutum* (Actinopterygii: Cyprinidae) from the Southern Caspian Sea, Iran. *J. Anim. Divers*., 2: 56–61.

Vagnoni, G., Bortolotti, E., Checchi, S., Saieva, C., Berti, G., Doccioli, C., & Caini, S. 2024. Lead (Pb) in biological samples in association with cancer risk and mortality: A systematic literature review. *Cancer Epidemiology*, 102630.

Wu, X., Jin, T., Wang, Z., Ye, T., Kong, Q. and Nordberg, G. 2001. Urinary calcium as a biomarker of renal dysfunction in a general population exposed to cadmium. *J. Occup. Environ. Med.,* 43: 898–904. https://doi.org/10.1097/00043764-200110000-00009

Yi, Y., Yang, Z. and Zhang, S. 2011. Ecological risk assessment of heavy metals in sediment and human health risk assessment of heavy metals in fishes in the middle and lower reaches of the Yangtze river basin. *Environ. Pollut.,* 159: 2575–2585. https://doi.org/10.1016/j.envpol.2011.06.011

Yunus, K., Zuraidah, M. and John, A. 2020. A review on the accumulation of heavy metals in coastal sediment of Peninsular Malaysia. Ecofeminism Clim. Chang., 1: 21–35. https://doi.org/10.1108/EFCC-03-2020-0003.

Zhang, H., Wang, Z., Zhang, Y., & Hu, Z. (2012). The effects of the Qinghai–Tibet railway on heavy metals enrichment in soils. Science of the Total Environment, 439, 240-248.