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Ecological Assessment of Heavy Metal Concentrations in Fish Species and Aquatic Environments in the Vicinity of the Baropukuria Coal Mine Industry of Bangladesh: A Seasonal Perspective

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Abstract

Heavy-metal pollution of surface water, sediment and fish is recognized as a significant global issue, particularly affecting developing countries like Bangladesh. Water quality is drastically diminished due to industrial discharge of heavy metals. The present study aimed to explore different physico-chemical water quality parameters and the level of heavy metal concentration in sediment, water and muscle of fish species near a coal mine industry. Water and sediment samples were taken from three separate locations over two distinct seasons (wet and dry) to compare the seasonal variations of five heavy metals (Cr, Co, Cd, As, and Pb) using inductively coupled plasma mass spectrometry (ICPMS). The average concentrations of the heavy metals under investigation showed a downward sequence of Cr > Pb > Co > As > Cd in both wet and dry seasons. Furthermore, the mean concentration of heavy metals was higher in the Gangetic leaffish (*Nandus nandus*) than in the striped dwarf catfish (*Mystus vittatus*) and the ticto barb (*Puntius ticto*). Additionally, the enrichment factor values of the heavy metals in the sediments were in the following sequence: Cd > Co > Cr > As. The wetland sediment under investigation was not designated as significantly polluted by the pollution load index (PLI < 1). Moreover, the water from these rivers is not fit for human consumption or cooking as the levels of metals tested were higher than what is considered safe. This study highlights the importance of thoroughly evaluating the risks associated with heavy metals in the river. However, the research recommends that relevant authorities implement necessary measures to prevent further contamination, thereby preserving aquatic life in freshwater ecosystems.

Keywords: Ashura wetland, pollution load, enrichment factor, freshwater fish

Introduction

The environment is intimately influenced by heavy metals, as they substantially affect the air, water, sediment and biota, among other environmental compartments (Meena et al., 2018; Ore and Adeola, 2021). Most of the source of heavy metals in the environment is human activity combined with natural processes. These processes include industrial activities (Silva and Shimizu, 2004), weathering of rocks, agricultural practices (Khan et al., 2008; Sankhla et al., 2016) and discharge of effluents (Zynudheen et al., 2009). However, a metallic element with a relatively high density and toxicity in small amounts is referred to as a heavy metal (Lenntech, 2004; Chouhan et al., 2016; Ali et al., 2020). The main environmental concern, particularly during the last decade, has been the contamination of water and sediments with heavy metals (Fernandes et al., 2008). Heavy metal poisoning of aquatic environments has garnered global attention due to its ubiquity, durability, and toxicity to the environment. Its prevalence, especially in developing countries, has further heightened concerns (Wang et al., 2016; Kabir et al., 2020; Khalid et al., 2021). Metal toxicity and mobility are influenced by several factors, including overall metal concentration, metal-binding state, and pH (Naidu et al., 2008). Other key factors include specific chemical forms, organic matter content, and soil texture (Muhammad et al., 2011). Unplanned industrialisation and urbanisation have detrimental effects on the sediment, water quality and other aquatic fauna (Chung et al., 2018; Sarker et al., 2021). Industry, atmosphere, soil, water, foods, fish, and humans are the main cyclical links in the heavy metals pollution cycle (Matta and Gjyli, 2016).

Heavy metal pollution of water and sediments has become a major water quality issue in emerging countries. This is because hygienic structures and water quality maintenance do not keep pace with population growth and urbanisation (Ahmad et al., 2010). The disposal of agricultural inputs, untreated wastewater from various enterprises and municipal trash into water bodies in Bangladesh has resulted in a concerning situation (Kibria et al., 2016). Keeping these negative impacts in mind over the last decade, several types of research have been carried out in lakes, estuaries, rivers and marine water, emphasising the aquatic environment (Pote et al., 2008; Bhuyan et al., 2017; Gammanpila, 2021).

Moreover, this wetland is located adjacent to the coal mining region of Barapukuria. It is heavily polluted by household and industrial sewage, which adds to the massive heavy metal load (Halim et al., 2015; Haque et al., 2020). The Ashura wetland of Bangladesh is exposed to discharges that have higher levels of many heavy metals due to its industrialised surroundings which significantly pollute the sediments and water. Ultimately, they are recognised as being harmful to both human health and aquatic life. Currently, there is no scientific research on the heavy metal pollution of fish, water, and sediment in the Ashura wetland of Bangladesh. In light of the foregoing, the goal of this investigation is to assess the water quality and concentration of five heavy metals (Cr, Co, Pb, As and Cd) in sediment, water as well as in the fish muscles of three IUCN (2015) listed fish species: the Gangetic leaffish (*Nandus nandus*), the striped dwarf catfish (*Mystus vittatus*) and the ticto barb (*Puntius ticto*).

Materials and Methods

Ethical approval

The research methods were certified by the Institute of Research and Training (IRT), Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh, to ensure compliance with ethical standards for the study titled 'Ecological Risk Assessment Through Analyzing Heavy Metal Contamination in Ashura Beel of Dinajpur District, Bangladesh: An Approach Towards Wetland Conservation'. The methodology underwent a thorough review and verification process (Ref. No. HSTU/IRT/4213).

Study region and sample collection

The selection of sampling sites inside the study area was based on human activities occurring near and within the wetland, such as agricultural and household, as well as the geographical proximity of industrial discharges of Barapukuria coal mine effluents. Wetland water levels rise during the rainy season as a result of significant rainfall; during the dry season, water levels fall because of no rainfall. Two different seasons, namely wet (August–September 2022) and dry (January–February 2023) were chosen considering high and low water levels to compare variations (Rakib et al., 2021). Three different wetland locations (S1, S2, and S3) were taken to collect samples of water, sediment and fish samples (Fig. 1). Field tests were performed to determine water temperature (°C), transparency (cm), dissolved oxygen (mg.L^{-1}), pH, total alkalinity (mg.L^{-1}), total dissolved solids (mg.L^{-1}), ammonia (mg.L^{-1}), phosphate (mg.L^{-1}), nitrate (mg.L^{-1}) and iron (mg.L^{-1}) of different sampling sites with three replications. A portable Ekman grab sampler (12-B42-E10, Wildco, USA) was used to gather 12 sediment samples (6 samples for each season) from the

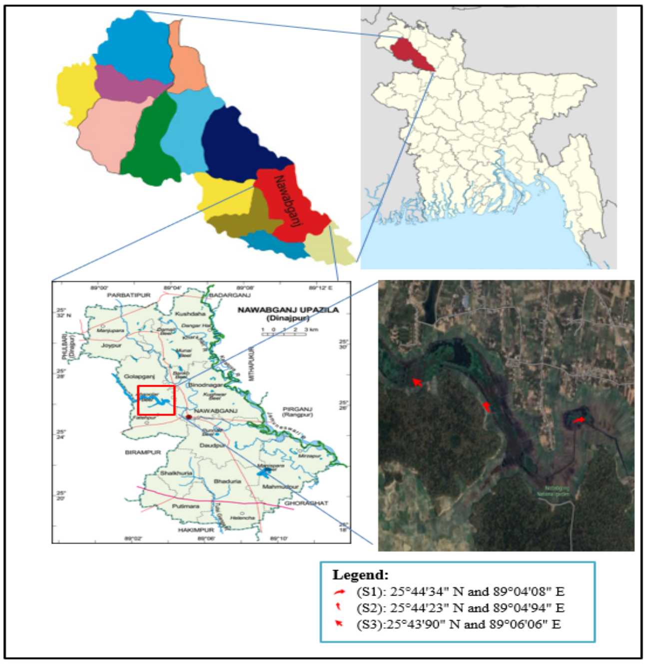

Fig. 1. Map displaying the Ashura wetland research area of Bangladesh, where heavy metals were sampled in the water, sediments, and tissue of three fish species.

riverbed, with a depth range of 0–5 cm. Twelve water samples (6 samples for each season) were obtained from 10 to 15 cm below the surface and stored in acid-cleaned polypropylene bottles. About 36 fish samples (18 samples for each season and 6 fish samples for a single fish species) from three different species (*Puntius ticto*, *Mystus vittatus* and *Nandus nandus*) were collected. The samples were gathered, put in containers that had already been cleaned, sealed, labelled and transported to the laboratory for further investigation, where they were kept at 4 °C.

Preparation of samples for heavy metals evaluation

Deionised water was used to produce the solution, and analytical-grade chemicals were used throughout the investigation. Merck, Germany, provided the target element with standard solutions with the greatest purity level (99.98 %). Before being cleaned and dried, the polypropylene and Teflon containers were first soaked in 5 % HNO_3 for more than 24 h. Before being homogenised using an ultrasonic homogeniser (Scientz-IIDN, China), the fish muscle samples were blended in a laboratory blender. The sediment and fish muscle samples used for metal analysis were 5 mg, whereas the water sample was 5 mL. Drying was performed in an oven (Nuve, Turkey) set at 120 °C for 1 h until a consistent weight was reached, after which the homogenised sample was precisely weighed in a crucible. Ash was produced by subjecting the dehydrated samples to a temperature of 450 °C for 10 h in a muffle furnace (Witeg, Germany). Then, in an automated microwave digestion system, the sample was treated with 8 mL of 0.01 M HNO_3 acid (Merck, Germany) and 1 mL of 8.5 M H_2O_2. Then, 5 mL of 5 M HCl (Merck, Germany) was added to the Teflon vessel and heated till the fume disappeared. A 100 mL solution of a semisolid digesting byproduct sinks to the bottom of the tube after being diluted with deionised water. Syringe filters (Toyota Roshi Kaisha, Japan) were used to transport the digested solution into polypropylene tubes (Nalgene, USA).

The samples were analysed at the Bangladesh Livestock Research Institute (BLRI) in Bangladesh using inductively coupled plasma mass spectrometry (iCAP RQ, Thermo Fisher Scientific, USA). The standard solutions for many elements were used to build the calibration curve. An internal quality approach was used to analyse and verify all tests, ensuring they matched the defined internal quality controls (IQCs). Blank and certified reference materials (CRM) were used in each experiment run, and samples were double-checked to ensure that there were no mistakes particular to different batches.

Pollution load index (PLI)

The pollutant load index of the studied metals was established to assess the sediment quality using an integrated method. The mth root of the metal contamination factor's (CF) multiplications is known as the pollution load index. The pollutant load index of the metals under consideration was determined following Suresh et al. (2012).

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \ldots \times CFn)^{1/m}$$

Where, CF_{metals} display the ratio of each metal's concentration to sediment background values and $CF_{metals} = C_{metal}/C_{background}$. The PLI estimated the sample's general toxicity status and determined the metals contributed to that evaluation. Accordingly, perfect PLI performance is represented by a value of zero, whereas baseline pollution levels are represented by a value of one and values higher than one suggest a continual quality decline of the site.

Enrichment factor (EF)

The assessment of the enrichment factor, which entails normalising the sediments with regard to reference elements like Pb, was done to distinguish between metal sources coming from anthropogenic and natural sources (Salati and Moore, 2010). Metal concentrations in Ashura wetland sediments from each site were normalised using the method proposed by Loska et al. (1997). The equation below was used to find the enrichment factor of the average concentration of metals in shale (Turekian and Wedepohl, 1961).

$$EF = \frac{\left(\frac{Cn}{CPb}\right)sample}{\left(\frac{Cn}{CPb}\right)shale}$$

Where, (Cn/CPb) is the ratio of the potentially dangerous elements (Cn) to the amount of lead (CPb) in the sediment sample (mg.kg^{-1}), and (Cn/CPb) is the same ratio in comparison to reference samples that have not been exposed to pollution.

Cluster analysis

Multivariate data analysis using cluster analysis (CA) includes putting samples into groups based on what they have in common. It was used in this study to find different geological groups. To show the CA results, a dendrogram was used which showed the concentration correlations at different levels of similarity between the factors. The amalgamation rule utilised in constructing the clusters was Ward's technique (Ferati er al., 2015).

Statistical analysis

The variations of the heavy metal concentration and physico-chemical parameters were analysed by one-way analyses of variance (ANOVA) to test the differences in each season using the statistical package, SPSS 25.0. Physico-chemical parameters and heavy metal concentrations were computed using

SPSS 25.0 to determine their mean, standard deviation and Pearson correlation coefficient. The physico-chemical characteristics of water over the wet and dry seasons were displayed by means of contour graphs created using Surfer 16.0.

Results

Water quality parameters

During the wet and dry seasons, the water quality parameters are summarised in Figures 2 and 3, respectively. The difference between the two seasons in the water temperature, dissolved oxygen, transparency, total dissolved solids and total alkalinity exhibited statistical significance ($P < 0.01$). The pH of wetland water fluctuated between slightly acidic to alkaline (6.7 to 7.48). The ammonia, phosphate, nitrate and iron content of the study area water varied from 0.25–1.00 mg.L^{-1}, 1.00–3.00 mg.L^{-1}, 0.50–1.00 mg.L^{-1}and 1.00–4.00 mg.L^{-1}, respectively.

Heavy metal concentration

Table 1 displays the content of heavy metals in sediment, surface water and fish samples of the Ashura wetland, Bangladesh. The investigated heavy metals' average concentrations followed the decreasing sequence of Cr > Pb > Co > As > Cd for both seasons (Table 1). In both seasons, relatively high level of heavy metal content was observed in sediment compared with water. Fish from bottom waters often have greater levels of heavy metal toxicity than fish from surface waters and compared to wet season, dry season had a higher concentration level. Nevertheless, overall mean values of the heavy metal concentrations in fish species were greatest in *Nandus nandus*, then *Mystus vittatus* and then *Puntius ticto*.

Table 2 shows the concentration of heavy metals in sediment and water from the Ashura wetland compared to different rivers and wetlands around the world. In sediment concentrations of Pb, Cd, and Cr in the Ashura wetland were significantly lower than in highly polluted rivers such as Buriganga, Bangshi, and Kortoya. Furthermore, the concentration of heavy metals in the water of Ashura wetland remained mostly within and slightly above USEPA's freshwater quality criteria, with Pb and Cd levels exceeding chronic limits during the dry season.

Heavy metals correlation coefficient matrix in sediment

A very strong negative linear relationship was seen in the heavy metal correlations during the rainy season in the sediments between Co and Cr (-0.980), Pb and Cr (-0.943), As and Co (-0.930). In contrast, Cd and As (0.993) showed a highly significant positive linear relationship during the wet season at the 0.01 % significance level (Table 3). A very strong positive linear relationship

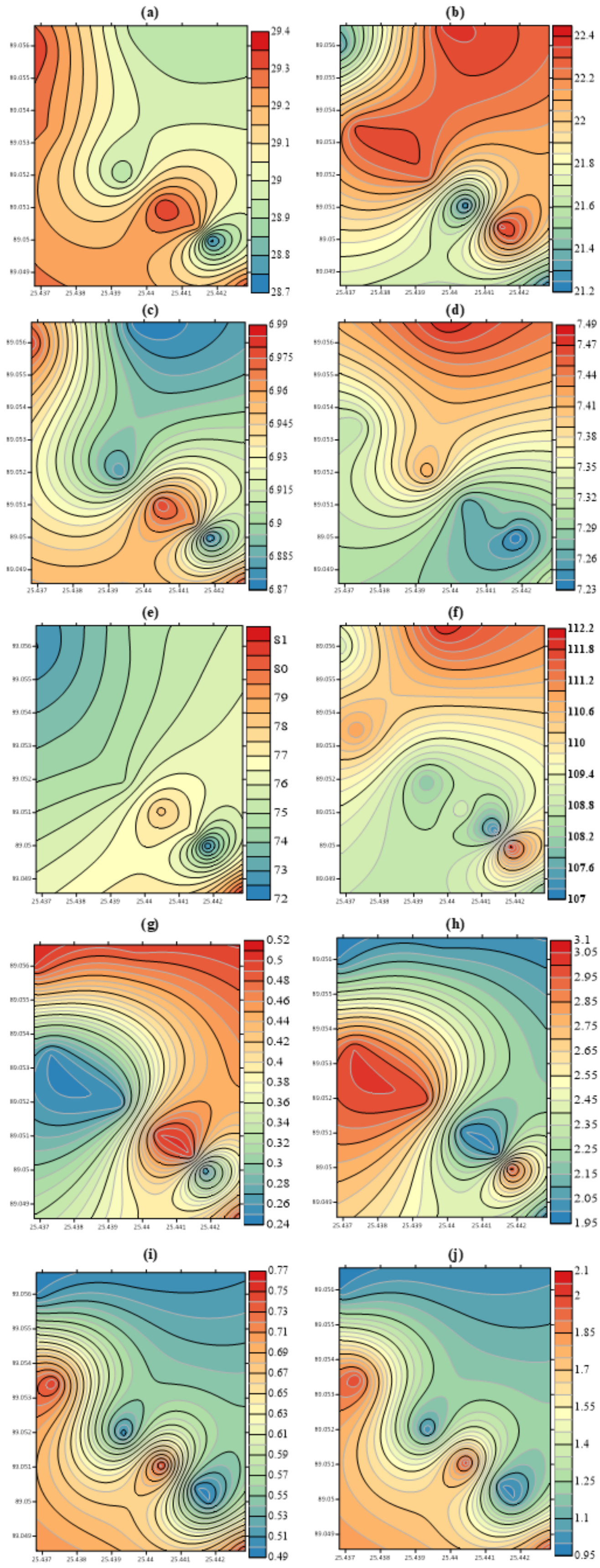

Fig. 2. Spatial distribution of water temperature (a), transparency (b), DO (c), pH (d), total alkalinity (e), TDS (f), NH_3 (g), PO_4 (h), NO_3 (i) and Fe (j) during the wet season in the Ashura wetland, Bangladesh. Warmer colours (ranging from orange to red) indicate higher concentrations, while cooler colours (green to blue) represent lower concentrations in the colour gradients contour maps.

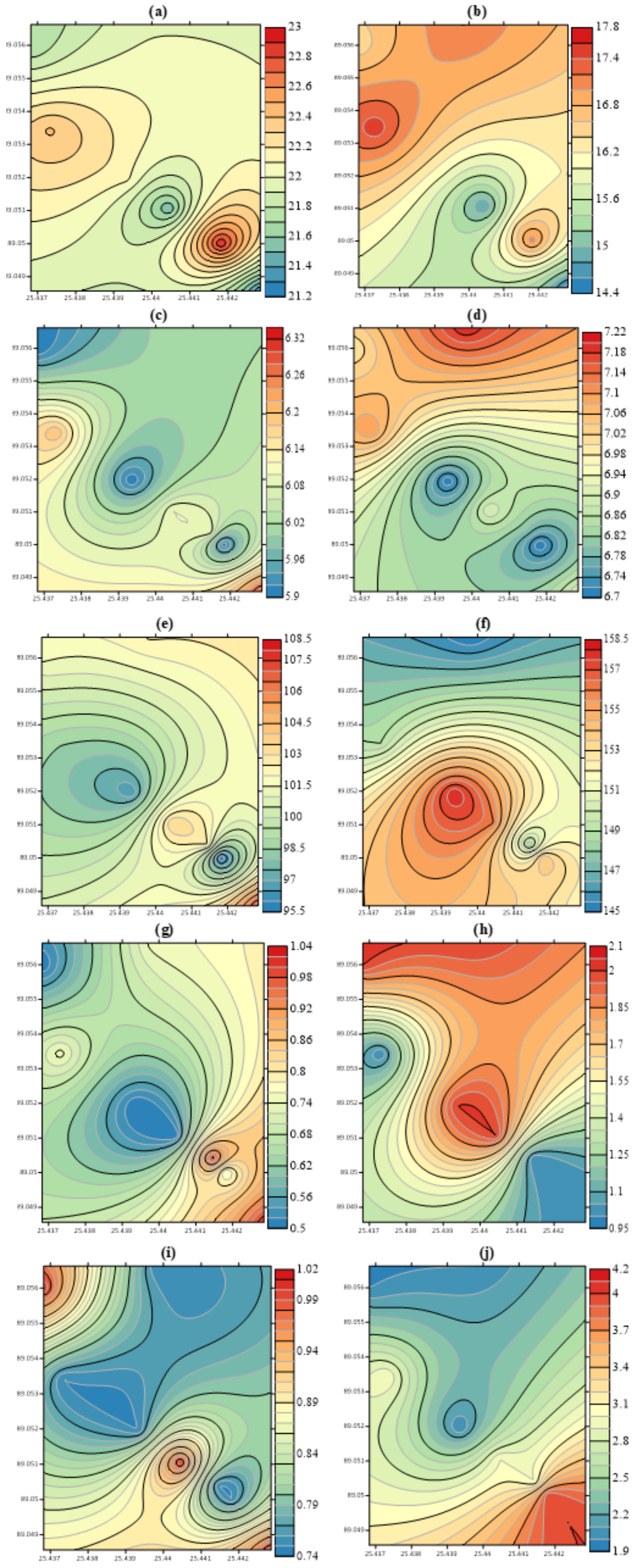

Fig. 3. Spatial distribution of water temperature (a), transparency (b), DO (c), pH (d), total alkalinity (e), TDS (f), NH_3 (g), PO_4 (h), NO_3 (i) and Fe (j) during the dry season in the Ashura wetland, Bangladesh. Warmer colours (ranging from orange to red) indicate higher concentrations, while cooler colours (green to blue) represent lower concentrations in the color gradients contour maps.

between Cd and Co (0.939) was observed during the dry season, with a significance level of 0.05 % (Table 3).

Heavy metals correlations in the water

The correlation matrix of heavy metals in water showed a very strong linear relationship during wet season for Cd and Cr (0.978) and Cd and Pb (0.983) (Table 4) at the 0.05 % significance level (Table 4). During the dry season, a very strong linear relationship was found between Cr and Cd (0.972) and Co and Cd (0.999) at the 0.05 % significance level (Table 4).

Pollution load index (PLI)

Table 5 summarises the estimated pollution load index (PLI) for metals in sediment, which ranged from 0.092 to 0.117 through the wet and dry seasons, demonstrating that sediment of the investigated wetland was not highly polluted (PLI < 1). In addition, the PLI findings also indicate Pb and Cd are the main causes of sediment contamination.

Enrichment factor (EF)

The enrichment factors of the experimental area were compiled in Figure 4. Among the heavy metals that were studied, the EF values were reported in the subsequent sequence: Cd > Co > Cr > As. It was discovered that the investigated area was enriched with all of the studied heavy metals.

Cluster analysis

Figure 5 illustrates the dendrogram created by Ward's method and cluster analysis (CA) used to separate the heavy metals into different groups. During the wet season, Cr, Pb, Co and As formed one cluster, to which Cd was connected by a long linkage distance. However, in the dry season Cr, Pb, Co and As formed one cluster during the dry season, and Cd was connected to this cluster by a long linkage distance (Fig. 6).

Discussion

The water temperature at the research sites was discovered to be within the prescribed range (20 to 30 °C) established by the DoE (2016). On the contrary, the transparency of the wetland was lower due to low water depth (Sayeed et al., 2015). In addition, the dissolved oxygen levels revealed slightly acidic in nature which has similarities to the findings of Gondwe et al. (2011) in Lake Malawi. Nutrient surface runoff and agricultural slurry were the causes of this acidic character which indicates a higher level of organic pollutants. However, this study's nitrate concentration and alkalinity coincide with what Karikari et al. (2013) found at Volta Lake and Tamot et al. (2008) at the Halali reservoir, respectively. The water of Ashura wetland retains more alkalinity during the dry season because most of the crops are harvested and the wetland sides are heavily used for agricultural purposes (Islam et al.,

Table 1. Mean (± SE) heavy metal concentrations (mg.kg^{-1}) in sediment, surface water and fish collected from Ashura wetland, Bangladesh.

Heavy metals	Sediment		Water		*Puntius ticto*		*Mystus vittatus*		*Nandus nandus*	
	WS	DS	WS	DS	WS	DS	WS	DS	WS	DS
Chromium (Cr)	4.945 ± 0.23	5.840 ± 0.33	0.078 ± 0.01	0.090 ± 0.01	0.329 ± 0.05	0.389 ± 0.06	0.301 ± 0.02	0.392 ± 0.08	0.788 ± 0.15	0.908 ± 0.12
Cobalt (Co)	1.958 ± 0.06	1.774 ± 0.32	0.045 ± 0.01	0.056 ± 0.02	0.075 ± 0.01	0.088 ± 0.01	0.057 ± 0.01	0.067 ± 0.01	0.088 ± 0.01	0.095 ± 0.01
Arsenic (As)	0.465 ± 0.01	0.757 ± 0.03	0.008 ± 0.00	0.009 ± 0.01	0.062 ± 0.00	0.080 ± 0.01	0.068 ± 0.01	0.082 ± 0.01	0.332 ± 0.02	0.341 ± 0.02
Lead (Pb)	2.772 ± 0.46	4.596 ± 0.03	0.074 ± 0.01	0.128 ± 0.01	0.062 ± 0.01	0.065 ± 0.01	0.079 ± 0.01	0.132 ± 0.02	0.073 ± 0.01	0.080 ± 0.01
Cadmium (Cd)	0.073 ± 0.01	0.085 ± 0.01	0.043 ± 0.00	0.058 ± 0.00	0.005 ± 0.01	0.007 ± 0.01	0.033 ± 0.01	0.040 ± 0.01	0.031 ± 0.01	0.049 ± 0.01

WS = wet season, DS = dry season.

Table 2. Comparison of mean heavy metals values (mg.kg^{-1}) in sediments and water of the Ashura wetland with different waterbodies in Bangladesh, Nigeria and China. Standards of acute and chronic concentrations used by the United States EPA are also shown.

Locations	Cr	Co	As	Cd	Pb	References
Sediments						
Ashura wetland (Wet season)	4.945	1.958	0.465	0.073	2.772	Current study
Ashura wetland (Dry season)	5.840	1.774	0.757	0.085	4.596	Current study
Chalan wetland, Bangladesh	NS	NS	NS	6.22	51.39	Salam et al., 2021
Dhalai wetland, Bangladesh	NS	NS	NS	0.61	59.99	Rahman et al., 2014
Karnafuly River, Bangladesh	20.3	NS	81.09	2.01	43.69	Ali et al, 2016
Bangshi River, Bangladesh	98	NS	1.93	0.61	60	Rahman et al., 2014
Paira River, Bangladesh	45	NS	12	0.72	25	Islam et al., 2015a
Kortoya River, Bangladesh	109	NS	25	1.2	58	Islam et al., 2015b
Buriganga River, Bangladesh	178	NS	NS	3.3	70	Ahmad et al., 2010
Louhajang River, Bangladesh	9.205	NS	8.999	0.083	4.597	Kormoker et al., 2019
Okumeshi River, Nigeria	0.87	NS	NS	1.32	0.45	Ekeanyanwu et. al, 2010
Water						
Ashura wetland (Wet season)	0.078	0.045	0.008	0.043	0.074	Present study
Ashura wetland (Dry season)	0.090	0.056	0.009	0.058	0.128	Present study
Halda River, Bangladesh (Wet)	0.004	0.010	1.34	0.032	0.030	Rakib et al., 2021
Halda River, Bangladesh (Dry)	0.060	0.049	1.07	0.04	0.104	Rakib et al., 2021
Shitalakhya River, Bangladesh	0.08	NS	NS	0.003	0.05	Islam et al., 2014a
Turag River, Bangladesh	NS	NS	NS	0.01	0.002	Mokaddes et al., 2012
Meghna River, Bangladesh	0.01	0.2	NS	0.001	0.11	Bhuyan et al., 2017
Buriganga River, Bangladesh	0.114	NS	NS	0.059	0.112	Mokaddes et al., 2012
Karnafully River, Bangladesh	0.25	NS	0.0111	0.01	0.14	Islam et al., 2013
Danjiangkou Reservoir, China	0.0063	0.00108	0.0111	0.0117	0.0106	Li et al., 2008
Standards for freshwater to safeguard aquatic life						
USEPA (CMC, acute)	0.016	NS	0.34	0.0018	0.082	USEPA, 2020
USEPA (CCC, chronic)	0.011	NS	0.15	0.00072	0.0032	USEPA, 2020

NS = not studied, CMC = criterion maximum concentration, CCC = criterion continuous concentration.

Table 3. Correlation matrix between different heavy metals in sediments during the wet and dry season in the Ashura wetland, Bangladesh.

		Dry season				
	Heavy metals	Cr	Co	As	Pb	Cd
Wet season	Cr	1	0.640	-0.402	0.770	0.865
	Co	-0.980*	1	0.446	0.003	0.939*
	As	0.838	-0.930	1	-0.894	0.110
	Pb	-0.943	0.859	-0.609	1	0.347
	Cd	0.770	-0.881	0.993**	-0.514	1

n = 12 for each correlation. ** $P < 0.01$ and * $P < 0.05$.

Table 4. Correlation matrix between different heavy metals in the water during the wet and dry season of the Ashura wetland, Bangladesh.

		Dry season				
Wet season	Heavy metals	Cr	Co	As	Pb	Cd
	Cr	1	0.886	0.792	-0.071	0.972*
	Co	0.513	1	0.418	-0.526	0.970*
	As	0.187	-0.748	1	0.552	0.626
	Pb	0.924	0.801	-0.202	1	-0.305
	Cd	0.978*	0.68	-0.021	0.983*	1

n = 12 for each correlation. * $P < 0.05$.

Table 5. Heavy metal pollution load index value in sediment and water of Ashura wetland, Bangladesh during the wet and dry seasons.

Sample	Season	Contamination factors (C_f)					Pollution load index (PLI)
		Cr	Co	As	Pb	Cd	
Sediment	Wet	0.055	0.103	0.036	0.139	0.243	0.092
	Dry	0.065	0.094	0.058	0.230	0.282	0.117
Water	Wet	0.001	0.003	0.001	0.004	0.144	0.004
	Dry	0.001	0.003	0.001	0.005	0.179	0.005

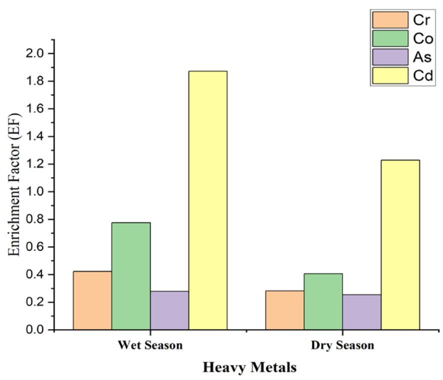

Fig. 4. Enrichment factor of heavy metals for sediment samples of Ashura wetland Bangladesh in the wet and dry seasons.

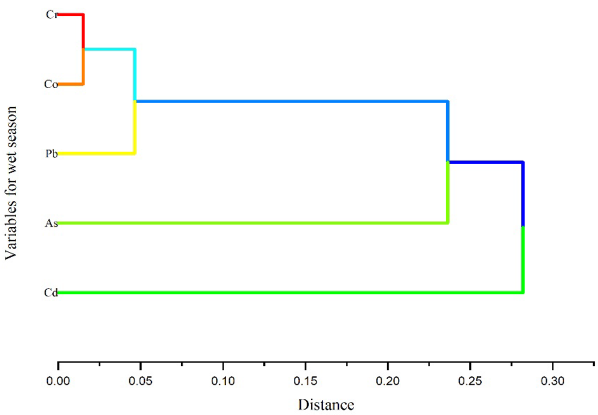

Fig. 5. Cluster analysis of heavy metal concentrations in the Ashura wetland Bangladesh during the wet season.

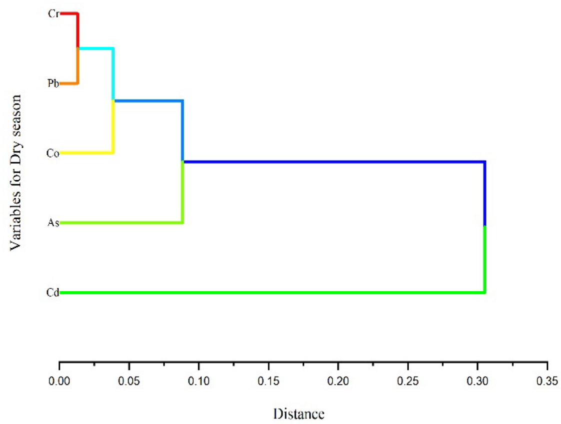

Fig. 6. Cluster analysis of heavy metal concentrations in the Ashura wetland Bangladesh during the dry season.

2014a). In addition, the phosphate concentrations in this investigation were greater than the range found in the Volta Lake by Clottey et al. (2016).

On the other hand, the concentration of lead is high in the Ashura wetland sediments which is adjacent to the Barapukuria coal mine in Bangladesh because of coal mining activity (Halim et al., 2015) and agrochemical residues used around the crop field of the wetland (Salam et al., 2021). Earlier, a concerning amount of Pb and Cd was found in the sediments of the Dhalai wetland (Rahman et al., 2014) and Chalan wetland (Salam et al., 2021) of Bangladesh because of pigment complexes and application of various phosphatic fertilisers for crop production (Salam et al., 2021) respectively. The concentration of Cd and Co discovered in Ashura wetland sediment was higher than the concentrations recorded by Balkis et al. (2007) in the Black Sea Rivers and Bhuyan et al. (2017) in the Meghna River. Moreover, industrial wastes associated Cd are dispersed widely into the environment and easily taken up into the food chain, affecting the aquatic environment (Ostrowski et al., 1999). In contrast, the Cr concentration of the Ashura wetland is similar to the concentrations recorded by Bhuyan et al. (2017) in the Meghna River of Bangladesh.

All heavy metals, with the exception of arsenic, had mean concentrations in water samples from the study area that were much higher than WHO (2011) and USEPA (2020) guidelines for safe drinking water. These findings indicate that the water in the Ashura wetlands is not safe for drinking purposes and offers a significant risk to the surrounding ecosystems. The concentration of heavy metals in water samples were lower during the wet season which matches the findings from several other studies in Bangladesh (Ali et al., 2016, Ali et al., 2018, Rakib et al., 2021). This is because of the diluting effect of the water caused by precipitation and strong input flows into wetlands during the wet (Mohiuddin et al., 2012, Islam et al., 2014c). However, both natural and anthropogenic reasons are responsible for heavy metals enrichment of surface water by discharging waste from industrial activities (Facetti et al., 1998, Mohiuddin et al., 2011).

The heavy metal concentrations in the waters of the Ashura wetland were much higher than in some waterbodies in Bangladesh such as the Buriganga River and Turag River (Mokaddes et al., 2012). Furthermore, the concentrations of heavy metals were relatively high compared with some other countries like India, Iran, China, Spain and Malaysia (Li et al., 2008, Carafa et al., 2011, Rajaei et al., 2012, Gao et al., 2016, Wang et al., 2017) indicated that high level of pollution prevails in the water of the wetland. Studies show that crops grown with industrial wastewater contain higher levels of heavy metals than those grown in other locations (Laboni et al., 2022). However, compared to the water column, sediment has a higher concentration of heavy metals (Nobi et al., 2010) as they typically travel to the sediments from the water column by adhering to the surfaces of tiny particles (Saha and Zaman, 2013). Through the food chain, soluble forms of heavy metals can pass from crustaceans, finfish, and shellfish to people (Ahmed et al. 2015). It might subsequently make its way into the human food chain and pose health problems (Baby et al., 2010; Zaynab et al., 2022).

Physico-chemical changes and microbial activity in the aquatic environment increase the mobility of the metals and make them bioavailable to the biota (Sekhar et al., 2004). Heavy metals can also bio-accumulate in fish tissues whose magnitude depends on age, species and trophic transfer (Van der Oost et al., 2003, Qiu et al., 2011). In comparison to pelagic fish, bottom-dwelling fish have much higher levels of heavy metals (Gupta et al., 2009, Islam et al., 2014b). Sediments may be the main cause of metal buildup in bottom-dwelling fish species. *Mystus* sp. and *Puntius* sp. had lower quantities of heavy metals recorded by Islam et al. (2017) in Bangladesh. In contrast, *Nandus nandus* species showed a higher level of metal concentration than found by Begum et al. (2009) in India. The levels of Pb and Cr in this investigation were greater than those in previous studies carried out in the Okumeshi River (Ekeanyanwu et al., 2010), Wadi Hanifah (Abdel-Baki et al., 2011) and Nallihan Bird Paradise (Ayas et al., 2007) designating Cr and Pb toxicity of fish species in the research area. Residents of the study area may therefore face potential health risks, including chronic poisoning, from the long-term consumption of the three fish species in this study.

Conclusion

Heavy metal contamination in the Ashura wetland's sediment, water and fish are examined in detail. The low groundwater quality and drinking water quality in Ashura wetland, Bangladesh pose serious health risks to the residents. These contaminants have surpassed safe drinking water standards and potentially harm freshwater aquatic life. The study suggests strict regulations of industrial emissions, proper waste management, remediation techniques like bioremediation, public awareness campaigns regarding the dangers of heavy metal exposure and the use of personal protective equipment when working with heavy metals in industrial settings as a means of reducing heavy metal contamination. There should be enforcement of environmental rules by relevant authorities to ensure firms establish modern, effective effluent treatment systems that include adsorption and membrane filtering.

Other trace metals including mercury, antimony, zinc and copper were not considered in this study; consequently, future studies should evaluate the overall elemental exposure and the resulting health risks from these metals. Additional research should be conducted separately on unique target organs, including fish gonads, liver, kidney, gut and gills. The source of heavy metal pollution, its ecological impact on neighbouring plants, animals and people, and its magnitude must be studied.

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