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Detection of heavy metals in fish muscles of selected local fish varieties of the Shitalakshya River and probabilistic health risk assessment

G. M. M. Anwarul Hasan [a,*], Mohammed A. Satter [a], Anuj Kumer Das [b], Md. Asif [a]

[a] Institute of Food Science and Technology (IFST), Bangladesh Council of Scientific and Industrial Research (BCSIR), Dr. Qudrat-E-Khuda Road, Dhaka 1205, Bangladesh
[b] Hi-Tech Health Care Ltd. Banani, Dhaka 1213, Bangladesh

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ABSTRACT

The Shitalakshya River, located in Dhaka, Bangladesh, is under threat of heavy metal pollution due to the numerous industrial pollutants that flow through its streams. As a result, the heavy metal content and the possible human health risk of ingesting three common fish, *Systomus sarana* (Olive barb), *Pethia ticto* (Ticto barb) and *Mastacembelus armatus* (Tire-track Spiny eel), captured from the industrially contaminated Shitalakya River in Bangladesh were assessed in this study. This research evaluates the possible health risks imposed by five heavy metals copper (Cu), zinc (Zn), lead (Pb), cadmium (Cd), nickel (Ni), As) and chromium (Cr) detected in three of the most common fish species utilizing atomic absorption spectroscopy (AAS). Such toxic metals are poisonous in nature and can enter the human diet via fish ingestion. To quantify the hazard to public health from heavy metal pollution by consuming aquatic species, particularly fish, the estimated daily intake (EDI), targeted hazard quotient (THQ), and carcinogenic risk (TCR) were computed. The results of this investigation revealed the concentrations of heavy metals (As, Pb, Zn, Cd, and Cr) in the three local fish species from the three locations that exceeded the permitted limits established by the international standard references (FAO/WHO, USFDA, MOFL, EC). The THQ values are within the limiting value of 1 for all heavy metals in *Pethia ticto* (Ticto barb), *Mastacembelus armatus* (Tire-track Spiny eel) and *Systomus sarana* (Olive barb). The cumulative impacts of all metals in this study surpassed the allowable limit of 1 for HI (hazard index) in all three species. The presence of Pb, Cd, Ni, and As in the three fish species raises the risk of cancer from the ingestion of selected fish. As a consequence, this study suggests that heavy metal surveillance of fish in contaminated rivers be carried out on a frequent basis through government environmental health management authorities to enforce regulatory criteria.

1. Introduction

Global environmental pollution is considered a multifaceted international human health concern, where environmental pollution is regarded as the disruption of normal environmental functions [1,2]. This is presumably because individuals unconsciously experience pollution on a regular basis or because we have grown accustomed to it in our fast-paced lifestyles [3]. There are various sorts of pollution, but one of the most prevalent to be examined here is water pollution, particularly in developing countries. In recent decades, industrialization and urbanization development, like various anthropogenic origins, have become major sources of water quality degradation. Pesticides [4], food processing wastes [5], toxins from livestock operations [6], volatile organic compounds (VOCs) [2], heavy metals [7], chemical waste [8], and others are all examples of water pollutants. This sort of anthropogenic origin is the key source of massive amounts of pollutants, particularly heavy metals, which are exceedingly detrimental to living creatures [9–13]. In particular, anthropogenic effluents contain significant concentrations of metals, which are eventually delivered into freshwater environments [14].Primarily, groundwater streams may contain naturally occurring materials rich in hazardous metals, which flow into waterways and result in subsequent contamination [15]. Since the rate of decomposition of heavy metals is very slow and their half-life is very long, their impact on water contamination is a major threat to their long-term stability, non biodegradability, bioaccumulation and bio magnification in the food web and chain [16–18]. Heavy metals can penetrate biological components via acute and chronic exposure and aggregate in essential organs of aquatic species, particularly fish species [19–21]. Because of their toxic effects and bioaccumulation tendency, heavy metals dumped into water bodies can harm both aquatic organisms and ecological processes [22–24]. As a consequence, heavy metals reported in freshwater fish ingested by people can cause a significant threat to public health [25]. The potential hazard to human health from

* Corresponding author.
E-mail address: pd-cbirmdp@bcsir.gov.bd (G. M. M. Anwarul Hasan).

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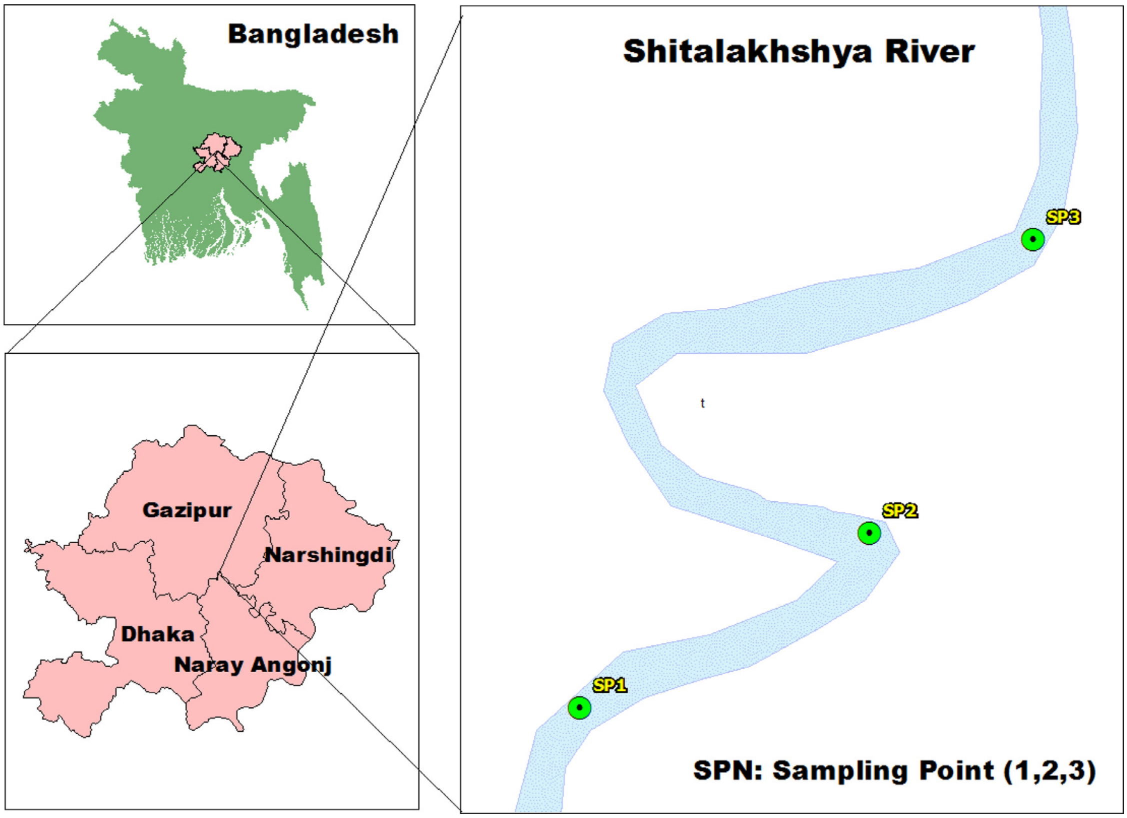

Fig. 1. A map showing the sampling sites of Shitalaksya River.

heavy metal migration is assessed based on the amount of fish consumed [26].

Fish is a source of nutrients, lipids, proteins, vitamins, and minerals. Therefore, ingesting it can assist in preventing malnutrition and boosting public health [27–29]. Fish is a major source of animal protein in developing countries such as Bangladesh, accounting for more than 60% of the total animal protein demand [30]. Rivers in Bangladesh are polluted in a variety of ways, most notably from industrial and municipal discharges. Increased anthropogenic activities have accelerated the pace of river pollution, particularly heavy metal pollutants that can be hazardous to humans and aquatic life [31,32]. According to these viewpoints, fish are a positive indication of metal contamination in aquatic ecosystems because fish are at a higher trophic level in these environments. Fish can be contaminated by heavy metals from the surrounding environment, either directly or indirectly. Metal deposition in the gills suggests *in situ* metal concentration in water, but metal accumulation in the liver implies deposition of metals for a long time [33]. The accumulation of heavy metals including Cr, Cd, Hg, Pb, Fe, Cu, Zn and As in 11 fish species were studied İznik Lake Basin (Turkey). Among the analyzed heavy metals, Cr, Zn, As and Pb were accumulated in higher concentration in Capoeta tinca and Pb, Cu and Zn exceeded the recommended guidelines [34]. The presence of potentially toxic elements was studied in various fruit samples of Iran where apple and mango were detected with highest and lowest pollution index respectively. However, Total target hazard quotients were in the safe range for all of the samples but, some apple and peach fruits showed cumulative cancer risks [35].

Metals bind with proteins, enzymes, and DNA molecules form harmful toxins that induce oxidative stress, DNA damage, and cell death processes while also impeding biochemical reactions and posing carcinogenic risks [36,37].

The Shitalakshya River is the major river in Narayanganj district. It is a distributary of the Brahmaputra River and combines with the Dhaleswari River at Kalagachhiya [38]. The Shitalakhya River serves as the primary source of industrial and drinking water in Narayanganj, Bangladesh. According to the Department of Environment (DoE), 118 knitting and dyeing mills, printing and chemical enterprises that do not have an ETP are largely responsible for the district's canals and rivers becoming polluted [39]. According to sources, over 2000 industries along the river's banks from Kanchpur to Narayanganj discharge various types of harmful chemicals into the river, producing massive pollution. Fish populations also experience massive decline from the river as a result of ongoing water contamination. Since the Shitalakshya River is one of the most important resources of the district as well as the country, research on its water pollution with living organisms is crucial. This river is also known as Narayanganj's lifeline as well as the important riverport of Narayanganj. Further, many industries, particularly dyeing and textile, have been established in this area. Over 80% of industries do not have an effluent treatment plant (ETP) and discharge their waste material directly or indirectly into the Shitalakshya River. Additionally, the Shitalakshya River is used as a waste dump, and agricultural chemicals containing heavy metals, toxins, germs, and nitrogenous toxins contaminate the water. Therefore, this river water has been significantly polluted by the massive amounts of untreated wastewater with other effluents from anthropogenic sources [40].

The aim of the current research was to measure the level of heavy metals in local fish samples and assess the possible health risks to fish consumers. The intention of this study is to ensure public health safety by increasing awareness of potential health risks associated with fish consumption.

2. Material and methods

2.1. Study area

This investigation was performed on the fishes of the Shitalakshya River, which is situated adjacent to Narayanganj district, Bangladesh. Three local fish species were collected from three different sampling sites. Fish samples were collected from Kanchpur Bridge (23°42′11.17"N and 90°31′01.92"E), Nabiganj (23°37′58"N and 90°31′6"E) and Atlapur (23°87′58.98"N and 90°57′91.90"E) respectively. The map of the sampling site is presented in Fig. 1.

2.2. Sample collection and preparation

Samples were collected just after the end of rainy season and beginning of winter. Sampling was performed between October, 2021 to February, 2022. About ten (10) samples of each fish species were collected from each sampling site. In total, ninety (90) fish samples were collected from three (3) sampling sites for this analysis. While sampling, samples were carefully handled to avoid any contamination. To confirm that no particles, such as sediment or other external particles were included, fish samples were thoroughly washed with clean water as soon as possible after sampling. Fish of almost the same size and weight were considered for sampling. The collected samples were washed several times with distilled water, followed by drying for 24 h at 105°C. Later, the dried samples were ground using a mortar and pestle and stored in a polybag pack in plastic bottles at -20°C until further analysis. The working procedure started within 24 hours of the samples being stored.

2.3. Sample digestion

Metal elements were separated in this analysis using a microwave digestion device (Berghof, Germany). An optimized three-step program for fish samples was developed that was performed with a maximum temperature of 200°C, maximum pressure of 35 bar, and a maximum power of 90%. Then, for the digestive process, we employed 5 mL HNO_3 acid (65% pure, Merck, Germany) and 2 mL H_2O_2 (30% pure, Merck, Germany). Digestion reagent was mixed with a 0.3 g sample in a Teflon vessel for processing. When the digestion was completed, the samples were transferred to a beaker. Milli-Q water was added to a total volume of 25 mL. (Millipore, USA). Finally, the mixture was filtered with a syringe filter (PTFE, 0.45 μm). The whole mixture was preserved in a screw-capped plastic tube.

2.4. Sample analysis

In this analysis, an atomic absorption spectrophotometer (iCE -3000 series, Thermo Scientific, USA) was used to calibrate and quantify heavy metal elements. The standard solution for this methodology was procured from Sigma in the United States. The spectral responses of Cd, Cr, Cu, Mn, Pb, and Zn as lines were 228.67, 357.65, 324.57, 217.35, and 248.30 nm, respectively. Four standard solutions of each metal at 0.01, 0.1, 1.0, and 5.0 parts per million (ppm) concentrations were employed. The concentration ranges as detection limits for Cr and Zn were 0.005 mg/kg and 0.002 mg/kg for Pb and 0.001 mg/kg for Cd and Cu respectively.

2.5. Quality assurance and control

During this study, distilled water was extensively used from initial to final cleaning and dilution. Blank samples with reagent additions were analyzed to further clarify the analysis and prevent instrumental error in the readings. To clarify the analysis to determine the amount perfectly and to prevent instrumental errors in the readings, blank samples with reagents were analyzed. Standard calibration solutions were prepared by serially diluting the stock solution. Through using the standard stock solution, based on the preparative method working standard solutions of zinc (Zn), copper (Cu), chromium (Cr), cadmium (Cd), Arsenic (As) and lead (Pb) were prepared. The repeatability test and verification of the analytical samples were performed by spiking the fish samples with known concentrations of heavy metals. In every run, the samples were analyzed in triplicate. Fish samples that were spiked with heavy metals were digested and analyzed using the same method used for the original samples. The following equation was used to determine the percent recovery from the spiked samples:

Recovery (%) = [(x–y)/z] × 100, where 'x' indicates the average concentration of heavy metals after spiking, 'y' indicates the average concentration of heavy metals before spiking, and 'z' indicates the concentration of spiked heavy metals.

In this analysis, the recovery percentages of Cr, Cd, Cu, Pb, Zn, Ni and As were 69.04%-87.34%, 73.83%-92.29%, 67.45%-88.65%, 82.23%-90.29%, 70.32%-87.23%, 69.38%-90.28% and 74.78%-86.37%, respectively. Then, the selected metals accumulated in fish species in which samples were collected to determine the concentrations in this case.

2.6. Transfer factor (TF) (bioaccumulation factor)

The TF of any heavy metals was determined by identifying the metal concentration in both the surrounding water and fish muscle samples collected from the same water.

The following equation was used to determine the TF:

$$TF = M_{tissue}/M_{water}$$

When the TF value is >1, heavy metal bioaccumulation by the fish samples is considered.

2.7. Methodology for computation of risk evaluation on human health for intake of fish

The EDI, THQ and TCR of metals were all determined by detecting the concentrations of heavy metal accumulation in the organs of fish species.

2.7.1. EDI of heavy metals from fishes

EDIs are used to estimate the potential consequences resulting from metal intake through food [41]. The EDI of heavy metals is analyzed in milligrams per kilogram of body weight per day [42]. The EDI of the selected heavy metals was determined using the following expression:

$$\mathrm{EDI} = \frac{\mathrm{D_i} \times \mathrm{M_c}}{\mathrm{BW}}$$

where D_i is the fish intake rate (g/person/day), M_c is the heavy metal concentration in freshwater fish species (mg/kg), and BW is the adult person's body weight (presuming 60 kg). Statistics for the average fish intake rate were documented from the Preliminary Report on Household Income and Expenditure Survey 2016 to perform the evaluation of health risks [43].

2.7.2. Assessment noncarcinogenic risks using the THQ

The THQ is an indication of the level of noncarcinogenic risk from exposure to contaminants. THQ was utilized to analyze the non carcinogenic risk of each selective metal from fish intake [44]. The carcinogenic risks have allowable tolerance limits ranging from 10^{-4} to 10^{-6}.

The mathematical expression of THQ is shown below:

$$\mathrm{THQ} = \frac{\mathrm{EDI}}{\mathrm{RfD}} \times 10^{-3}$$

Where, THQ is mentioned as the non carcinogenic risk and dimensionless quantity. RfD (reference dose of individual metal) is a daily basis exposure by human assessment that is implausible to cause significant harm throughout life. The EDI is measured in milligrams per day, and the standard oral reference values for Cu, Zn, Pb, Cd, Ni, As and Cr are 0.04, 0.05, 0.004, 0.001, 0.02 0.0003 and 0.0003 mg/Kg BW/Day respectively. When the THQ value is higher than or equal to 1, it indicates a significant health risk [45].

2.7.3. Hazard index (HI)

To measure and evaluate the risk to human health induced by multiple metals, the sum of THQ of each metal is indicated as HI, which is established according to the USEPA guideline [46]. The HI values identified the non carcinogenic risk from heavy metal accumulation in [47]. The hazard index equation is given below [48]:

$$TTHQ(HI) = THQ(Metal\ 1) + THQ(Metal\ 2) + \ldots\ldots + THQ(Metal\ n)$$

2.7.4. Target cancer risk (TCR)

TCR refers to carcinogenicity. The method for calculating TCR is represented in the USEPA (USEPA Regional Screening Level Summary Table: November 2011).

The equation used to compute TCR is given below:

$$\mathrm{TCR} = \frac{\mathrm{EFr} \times \mathrm{ED} \times \mathrm{EDI} \times \mathrm{CSF}}{\mathrm{BW} \times \mathrm{AT}}$$

where EFr is the exposure frequency of metal elements (365 days/year), ED is the duration of exposure (67 years) (adult life expectancy in Bangladesh is approximately 70 years),

BW relates to the average body weight of 60 kg. AT represents the average time for carcinogenic risk in adults (365 days per year, 70 years). CSF° is the oral carcinogenic slope factor obtained from the combined Risk Information database provided by the USEPA [49], where arsenic is 1.5 mg kg^{-1} day^{-1}, lead is 0.0085 mg kg^{-1} day^{-1}, nickel (nickel subsulfide) is 1.7 and cadmium is 15 mg kg^{-1} day^{-1}.

2.7.5. The Monte Carlo simulation (MCS)

MCS is a probabilistic and statistical-mathematical theory that quantifies both the uncertainty in the risk assessment and the degree of influence of the exposure pathways and parameters on the risk. In this study, MCS has been used to minimize uncertainty. The MCS and sensitivity analysis was performed with Oracle Crystal v11.1.2.3.0 software with 10,000 repetitions.

2.8. Statistical analysis

The one-way ANOVA test was used in this analysis to demonstrate the main statistical parameters and statistically significant differences and to properly assess the results of the experiment. To analyze the outcome data, we preferred Microsoft Office Excel 2016. Finally, using Pearson's correlation coefficients, the concentrations of heavy metals in *Systomus sarana* (Olive barb), *Pethia ticto* (Ticto barb) and *Mastacembelus armatus* (Tire-track Spiny eel) fish species were measured.

3. Results and discussion

3.1. Heavy metal concentration in fish samples

Since fish is a major food item consumed daily by the Bangladeshi people, it is a preferred source for analyzing the health impact assessment of heavy metals. The levels of heavy metals, Cu, Zn, Pb, Cd, Ni, As and Cr in muscle tissues of three local freshwater fish are presented in Table 1. The recommended maximum permissible limit (MPL) of metal element deposition in fish organs is also presented in Table 1. The average concentrations of the analyzed trace heavy metals in fish samples were listed in ascending order, which was Cd > As > Ni > Cr >Pb> Cu > Zn. Cr concentrations in fish varied from 0.53 to 3.86 depending on the sampling site. The maximum mean concentration of Cr was found in *Systomus sarana* (Olive barb) (3.26 µg/g), and the lowest was found in *Mastacembelus armatus* (Tire-track Spiny eel) (0.61 µg/g). The reported Cr metal may have entered fish species as a result of wastewater entering the Shitalakshya River from anthropological activities, especially in industries located around the Shitalakshya River.

The nutritional and medicinal aspects of human health of fish have resulted in a rise in global demand in recent decades. Fish also provide high levels of essential minerals, vitamins, protein (fish fulfill 60% of protein demand) and unsaturated fatty acids [50]. For example, contamination of metals, such as chromium, accumulating in fish causes anuria, nephritis, extensive lesions, and kidney lesions [51]. Another factor, such as cadmium pollution in fish, causes poor reproductive potential, kidney abnormalities, tumors, hypertension, and hepatic dysfunction. Additionally, the intake of several other toxic metal-contaminated fish resulted in a variety of severe complications. Heavy metal accumulation in fish occurs not only through the air/water exchange but also through the intake of food substances and aquatic organism ingestion [52]. Metal accumulation varies significantly among fish organs due to the incorporation of metal-binding proteins such as metallothioneins in metabolic organs [53–55]. Bangladesh is a prominent nation in South Asia, where fisheries commodities are used to feed the underprivileged since it has a large area of rivers and streams as well as a skilled workforce with a rich tradition of fish farming [56].

The European Union Commission recommended a daily acceptable Cr concentration of 1 µg/g, while the FEPA and WHO both recommended 0.15 µg/g. Chromium (Cr) is potentially very dangerous to human health and has been listed as a critical pollutant and carcinogen, triggering a wide range of pulmonary health complications, such as lung inflammation, fibrosis, emphysema, and tumors [57,58].

Cadmium (Cd) is a major pollutant and a highly poisonous metal that is present in a variety of sources and is carried in water and air. Cd concentrations in selected fish tissues varied from 0.03 to 0.43. The highest mean concentration of Cd (0.43) was found in *Systomus sarana* (Olive barb). The current study significantly demonstrated that the Cd levels in the examined fish species in the Shitalakshya River were greater than those in FAO/WHO (1989) and that long-term deposition of Cd in fish could cause serious human health complications.

Copper (Cu) is required for the synthesis of hemoglobin and several enzymes in humans; however, overconsumption can cause liver and kidney damage [59]. The maximum mean concentration of Cu was found (8.8 µg/g) in *Pethia ticto* (Ticto barb), while the minimum mean concentration was found (5.36 µg/g) in *Systomus sarana* (Olive barb). This indicates that the Cu concentration did not exceed the acceptable limits established by international organizations, including the Food and Agriculture Organization (FAO) and the World Health Organization (WHO). Overconsumption of copper (Cu) can result in health threats such as liver and kidney damage.

The concentration of lead (Pb) in the fish collected from the three sampling sites ranged from 1.07 to 5.78 µg/g. The maximum Pb concentration was 4.57 µg/g in *Mastacembelus armatus* (Tire-track Spiny eel), and 9.14 µg/g was the minimum mean concentration for Systomus sarana (Olive barb). The FAO and WHO both recommended a 0.5 µg/g limit for Pb in food. Lead can interrupt children's cognitive development and function, as well as raise blood pressure and cause cardiovascular disease in adults [60].

Zinc (Zn) is a very essential element of all living organisms [61]. At all three sampling sites, Zn was found at high concentrations of all heavy metals in all three species of fish. *Pethia ticto* (Ticto barb) and *Systomus sarana* (Olive barb) had the minimum (180.29 µg/g) and maximum (144.47 µg/g) Zn concentrations, respectively. A high Zn concentration can be detrimental to the pancreas, interrupt protein metabolism, and cause arteriosclerosis [62].

The fish with the maximum mean Ni concentrations ranged from 0.87 to 2.98 µg/g. All three fish species tested for Ni concentrations were below the acceptable limits recommended by the USFDA. However, humans have been associated with potential health risks from chronic exposure to Ni and Ni compounds.

According to the US Food and Drug Administration (USFDA) in 1993, 90% of shellfish and fish species are linked to arsenic, making it a potentially hazardous metal. In this study, the range of arsenic concentrations was 0.11 to 3.98 µg/g at different sampling sites. Since arsenic is poisonous, it poses a range of threats to human health, such as those related to skin cancer, major circulatory system abnormalities, and skin damage.

Table 1
Mean ± SD concentrations of heavy metals (μg/kg dry weight) in fish muscles caught from Shitalakshya River and Recommended Maximum permissible limit (MPL) of metal elements depositing in fish organs (mg/kg wet weight) in accordance with internationally accepted standards [64].

	Fish Species	Trace elements						
		Cr	Cd	Cu	Pb	Zn	Ni	As
Sampling site-1	*Systomus sarana* (Olive barb)	3.76 ± 0.29	0.35 ± 0.006	4.23 ± 0.76	3.09 ± 0.09	178.34 ± 10.62	1.05 ± 0.53	0.14 ± 0.04
	Pethia ticto (Ticto barb)	2.78 ± 0.069	0.43 ± 0.031	8.98 ± 1.45	4.32 ± 1.02	98.95 ± 4.37	1.39 ± 0.74	0.21 ± 0.07
	Mastacembelus armatus (Tire-track Spinyeel)	0.67 ± 0.06	0.03 ± 0.006	9.45 ± 1.19	5.78 ± 1.16	169.41 ± 7.37	2.89 ± 0.69	3.87 ± 1.03
Sampling site-2	*Systomus sarana* (Olive barb)	2.17 ± 0.28	0.31 ± 0.005	6.43 ± 0.07	1.98 ± 0.08	197.23 ± 9.32	0.87 ± 0.21	0.11 ± 0.04
	Pethia ticto (Ticto barb)	1.97 ± 0.07	0.28 ± 0.061	9.96 ± 1.18	4.44 ± 1.45	166.19± 9.39	1.17 ± 0.62	0.19 ± 0.09
	Mastacembelus armatus (Tire-track Spinyeel)	0.63 ± 0.08	0.03 ± 0.001	7.62 ± 1.67	3.21 ± 0.97	174.21 ± 9.73	2.13 ± 0.72	3.23 ± 0.69
Sampling site-3	*Systomus sarana* (Olive barb)	3.86 ± 1.19	0.41 ± 0.02	5.42 ± 0.86	1.07 ± 0.57	165.29 ± 7.38	1.87 ± 0.59	0.17 ± 0.08
	Pethia ticto (Ticto barb)	3.11 ± 1.09	0.28 ± 0.042	7.46 ± 1.06	2.89 ± 0.75	168.29 ± 8.98	1.38 ± 0.32	0.27 ± 0.06
	Mastacembelus armatus (Tire-track Spinyeel)	0.53 ± 0.06	0.08 ± 0.019	6.32 ± 1.08	4.73 ± 1.04	177.68 ± 10.43	2.98 ± 0.98	3.98 ± 1.03
MPL		1	0.05	30	0.3	30	80	1
Reference		MOFL (2014)	EC (2006)	FAO/WHO (1989)	MOFL (2014), EC (2006)	FAO (1983)	USFDA (1993)	FAO/WHO (2002)

Table 2
Results of Pearson's correlation analysis.

	Cr	Cd	Cu	Pb	Zn	Ni	As
Cr	1.000						
Cd	0.905**	1.000					
Cu	-0.470	-0.269	1.000				
Pb	-0.647	-0.548	0.649**	1.000			
Zn	-0.200	-0.397	-0.428	-0.276	1.000		
Ni	-0.690	-0.755	0.155*	0.519**	0.050*	1.000	
As	-0.876	-0.929	0.195*	0.596**	0.198*	0.918**	1.000

** Correlation is significant at $P < 0.01$ level (two-tailed).
* Correlation is significant at $P < 0.05$ level (two-tailed).

The Pearson correlation analysis was employed is this study to identify the sources and transport of detected heavy metals. The results of Pearson correlation analysis in fish samples are displayed in Table 2. The positive correlation between the heavy metals indicates similar behavior and source while negative correlation indicates different features. In this study, Pearson correlation analysis showed strong correlation between Zn and Cu, Pb and Ni indicating similar geochemical behavior or input sources.*3.2 Bioaccumulation factor of heavy metals in fishes*

The bioaccumulation factors of heavy metals are presented in Fig. 2. The BAFs in *Systomus sarana (*Olive barb*), Pethia ticto (*Ticto barb*) and Mastacembelus armatus (*Tire-track Spinyeel*)* were in the range of 0.278073-1.487616 for Cr, 0.20771-1.602334 for Cd, 1.23386-2.02575 for Cu, 0.673123-1.504111 for Pb, 0.7034858-0.8778518 for Zn, 0.622312-1.263577 for Ni and 0.13049-3.44242 for As respectively. The lowest BAF was found for As in Systomus sarana (Olive barb) while highest BAF for same metal was found in Mastacembelus armatus (Tire-track Spinyeel). In addition, the BAFs were found in the order of Cd>Cr>Cu>Zn>Pb>Ni>As; Cu>Cd>Pb>Cr>Zn>Ni>As; As>Cu>Pb>Ni>Zn>Cr>Cd in *Systomus sarana (Olive barb), Pethia ticto (Ticto barb) and Mastacembelus armatus (*Tire-track Spinyeel*)* respectively.

3.2. Health risk assessment

Utilizing the entire analysis, we calculated the daily intake of five heavy metals for potential health complications related to the consumption of particular fish. The mean concentration of each hazardous metal element and each person's rate of consumption of that element can be used to evaluate the estimated daily intake [63]. EDI is defined as the ratio of the product of mean metal concentrations and daily fish species consumption rates to the average adult body weight. The EDI levels of the specified metals that were found in three different species of fish in the Shitalakshya River are shown in Table 3. For each fish species, an ingestion rate of 62.58 g fish per day on a dry weight basis was employed to determine the daily intake of heavy metals [43]. In this investigation, three fish species' EDI values for Zn and Cd were determined to be the maximum and minimum, respectively (mg/day). *Systomus sarana* (Olive barb) had the highest daily Zn intake (187.00 mg/day), whereas *Mastacembelus armatus* (Tire-track Spiny eel) had the lowest daily Cd intake (0.05 mg/day).

3.3. Noncarcinogenic health risk

The Environmental Protection Agency (EPA) developed THQ, which can manage possible environmental health risks associated with prolonged exposure to harmful toxic substances. This includes not just daily metal ingestion but also the frequency and duration of contact, body weight, and the oral reference dose (RfD). Table displays the THQ as noncarcinogenic values of Cu, Zn, Pb, Cd, Ni, As and Cr, which were determined for individual heavy metals via ingestion of various fish species. THQ has an acceptable guideline value of 1. THQ levels were less than one for all individual heavy metals except Zn in *Systomus sarana* (Olive barb), whereas *Pethia ticto* (Ticto barb) (Pb and Zn) and *Mastacembelus armatus* (Tire-track Spiny eel) (Pb, As, and Zn) indicated a considerable noncarcinogenic health risk from intake of the aforementioned heavy metals through consumption of these fishes.

In this investigation, Table 4 presents the TTHQ values of the *Systomus sarana* (Olive barb), *Pethia ticto* (Ticto barb) and *Mastacembelus armatus* (Tire-track Spiny eel) fish samples for the noncarcinogenic health risks of adults. TTHQ in consumers due to heavy metals content of Systomus sarana (Olive barb), Pethia ticto (Ticto barb) and *Mastacembelus armatus* (Tire-track Spinyeel) obtained from Shitalakshya River is presented through Monte carlo simulation (Fig. 3). In every species, the cumulative impacts of all metals under investigation exceeded the permissible limit of 1 for TTHQ. Excessive and prolonged ingestion of all of these species, particularly Mastacembelus armatus (Tire-track Spiny eel), might come with a variety of noncarcinogenic threats in the Shitalakshya River area of Bangladesh.Heavy metals including Hg, Pb, Cd and Sn were measured in canned tuna fish in Iran and identified heavy metal concentrations were in the safe range except Pb concentration was detected higher than the allowable limit. However, THQ and TTHQ were lower than one for all of the tested samples and identified safe for the consumers [65].

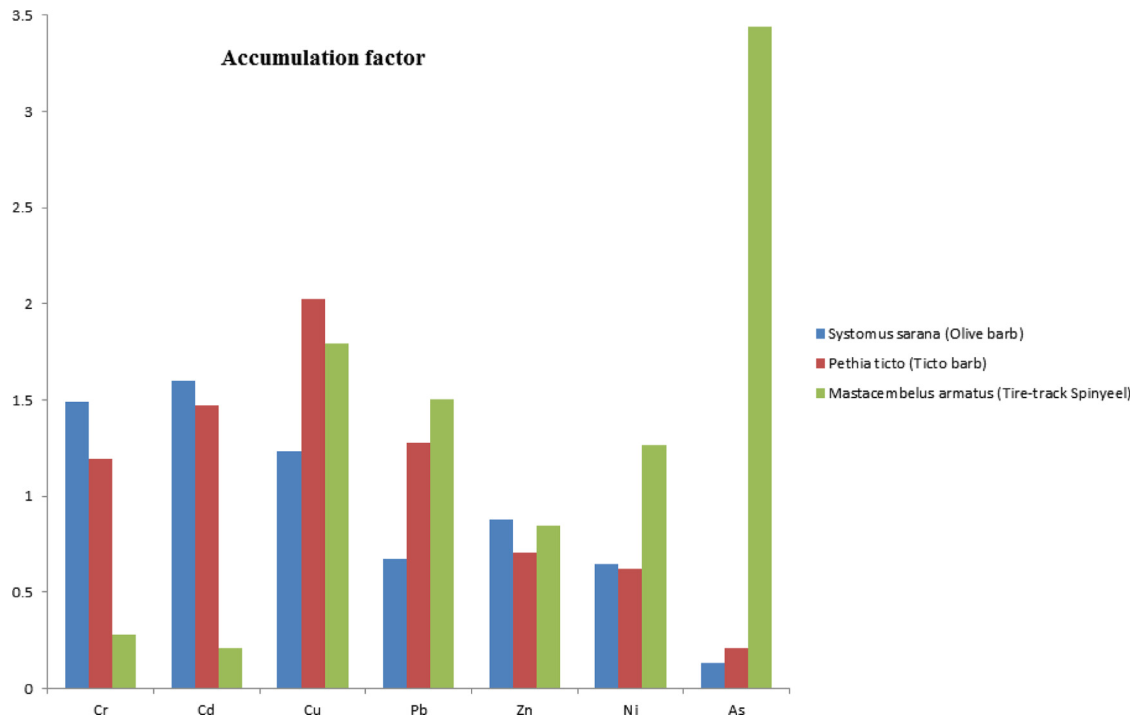

Fig. 2. Accumulation factor of heavy metals in fishes.

Table 3
Estimated Daily Intake (EDI) consumption of metals found in organs of three fish species sampled from the Shitalakshya River.

Fish Species	Expected Daily Intake (mg/kg/dw)						
	Cr	Cd	Cu	Pb	Zn	Ni	As
Systomus sarana (Olive barb)	0.0034	0.00038	0.00559	0.00213	0.188	0.00132	0.00015
Pethia ticto (Ticto barb)	0.00273	0.00034	0.00918	0.00405	0.15069	0.00137	0.00023
Mastacembelus armatus (Tire-track Spinyeel)	0.00064	0.00005	0.00813	0.00477	0.18124	0.00278	0.00385

Table 4
Target Hazard Quotient (THQ) and Total target hazard quotient (TTHQ) results of metals found in organs of three fish species sampled from the Shitalakshya River.

Fish Species	Target Hazard Quotient (THQ)							THQ
	Cr	Cd	Cu	Pb	Zn	Ni	As	
Systomus sarana (Olive barb)	2.27E^{-06}	3.80E^{-04}	1.40E^{-04}	5.33E^{-04}	3.76E^{-03}	6.60E^{-05}	5.00E^{-04}	5.38E^{-03}
Pethia ticto (Ticto barb)	1.82E^{-06}	3.40E^{-04}	2.30E^{-04}	1.01E^{-03}	3.01E^{-03}	6.85E^{-05}	7.67E^{-04}	5.43E^{-03}
Mastacembelus armatus (Tire-track Spinyeel)	4.27E^{-07}	5.00E^{-05}	2.03E^{-04}	1.19E^{-03}	3.62E^{-03}	1.39E^{-04}	1.28E^{-02}	1.80E^{-02}

Table 5
Target carcinogenic risk (TCR) of heavy metals (Cd, Pb, Ni and As) results from the intake by three sample fish species from Shitalakshya river.

Fish Species	Target carcinogenic risk (TCR)			
	Cd	Pb	Ni	As
Systomus sarana (Olive barb)	9.50E^{-08}	3.02E^{-10}	3.74E^{-08}	3.75E^{-09}
Pethia ticto (Ticto barb)	8.50E^{-08}	5.74E^{-10}	3.88E^{-08}	5.75E^{-09}
Mastacembelus armatus Tire-track Spinyeel	1.25E^{-08}	6.76E^{-10}	7.88E^{-08}	9.63E^{-08}

3.4. Carcinogenic health risk

To analyze the possible risk associated with carcinogenic agent ingestion throughout the lifetime, target cancer risk (TCR) has been utilized as an indication of cancer risk [66]. Table 5 depicts the cancer risk of Cd, As, Ni and Pb through ingesting the selected fish species from the Shitalakshya River. TCR values were determined for metals with known carcinogenic effects. Since it was initially assumed that the Cd, As, Ni and Pb metal elements were carcinogenic, the US EPA devised an oral cancer slope, which was investigated in this study. Generally, TCR values less than 10^{-6} are regarded as minimal for carcinogenic risk, but cancer risks greater than 10^{-4} are considered unacceptable [67–69]. As shown in the TCR values from Table 5, Pb, Cd, Ni and As contents in the three fish species pose a carcinogenic effect from any carcinogenic heavy metal ingestion. Overconsumption of currently studied fish species is anticipated to reveal lifetime cancer risk.

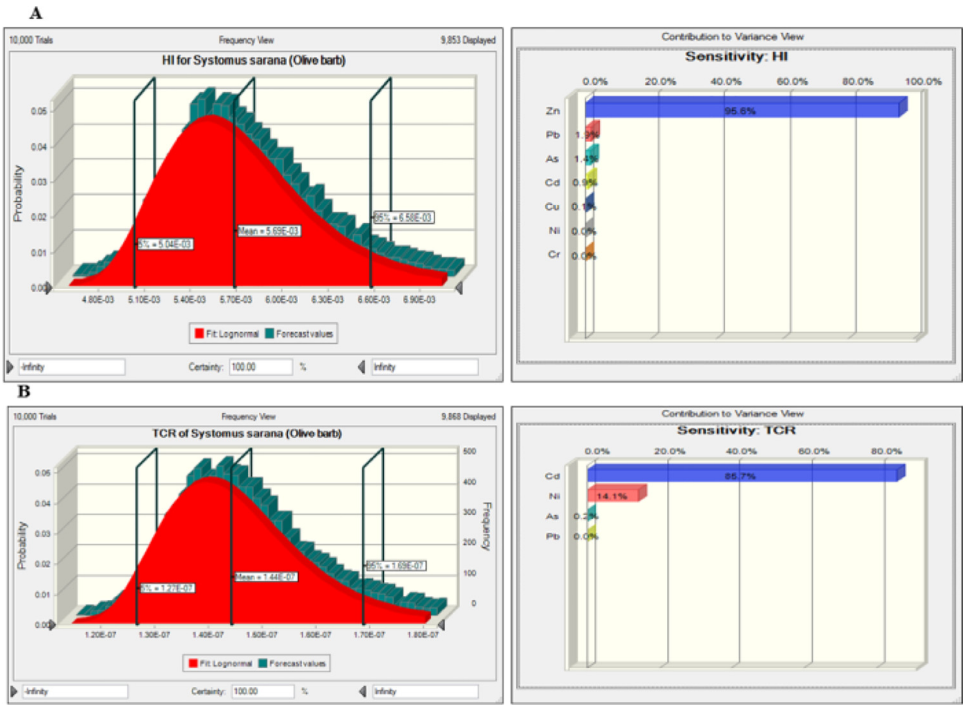

Fig. 3. Histograms of the heavy metals (HI and CR) uncertainty analysis, as well as the role of the input parameter to the uncertainty of approximate HI and CR and Sensitivity analysis of Systomus sarana (Olive barb) (A&B).

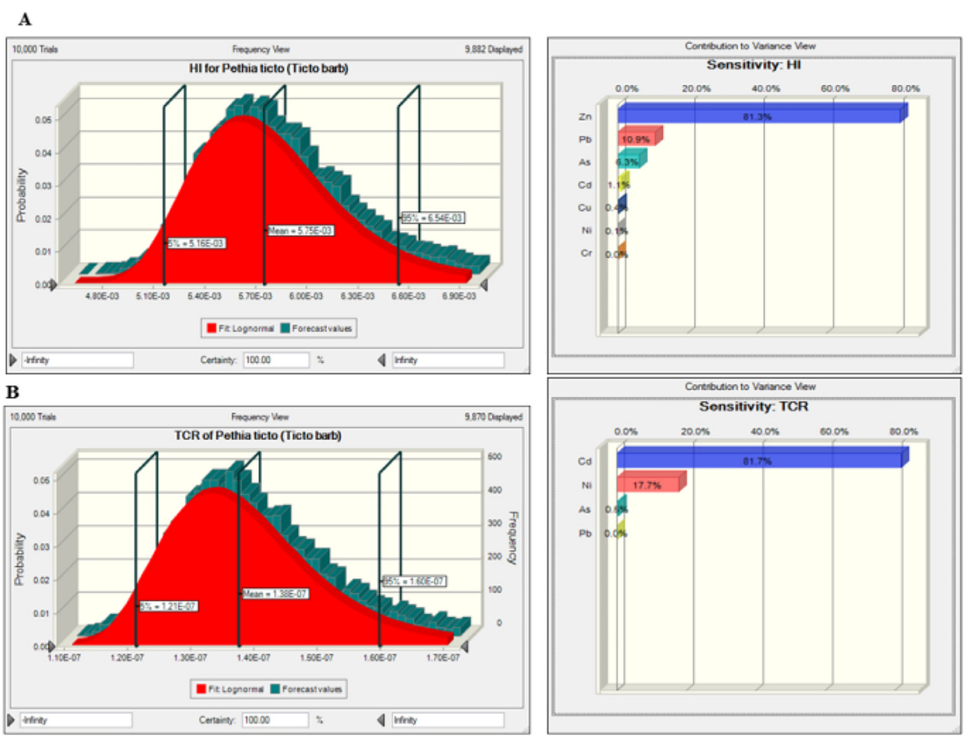

Fig. 4. Histograms of the heavy metals (HI and CR) uncertainty analysis, as well as the role of the input parameter to the uncertainty of approximate HI and CR and Sensitivity analysis of *Pethia ticto* (Ticto barb) (A&B).

During the risk assessment three factors including exposure parameters, concentrations of heavy metals and model selection for health risk assessment contributes to the uncertainty analysis of risk assessment. It is difficult to obtain accurate results because of uncertainty of parameters which can be overcome by applying MCS in health risk assessment. MCS has been widely used in health risks occurred through toxic and harmful elements in several sample parameters. The cumulative distributions of carcinogenic and non-carcinogenic risks of peoples who consumed these fishes in Sitalaksya river are shown in Figs. 3–5 respectively. In comparison with the deterministic risk assessment more information is obtained from MCS. The findings demonstrated that HI values in consumers were far less than one. According to the MCS plot, prolonged exposure to heavy metals (Pb, Cd, Ni and As) via fish consumption may not raise the risk of non carcinogenic anxiety and potential implications of consumption of analyzed fishes. Sensitivity analysis was also employed to figure out the possible aspect in raising the health hazard in treated people. According to the findings, non carcinogenic risk may greatly increase by the consumption of three fish species due to the presence of Zn and As contents. Following the research results, the level of Cd and As were the major effect on CR. The simulation results

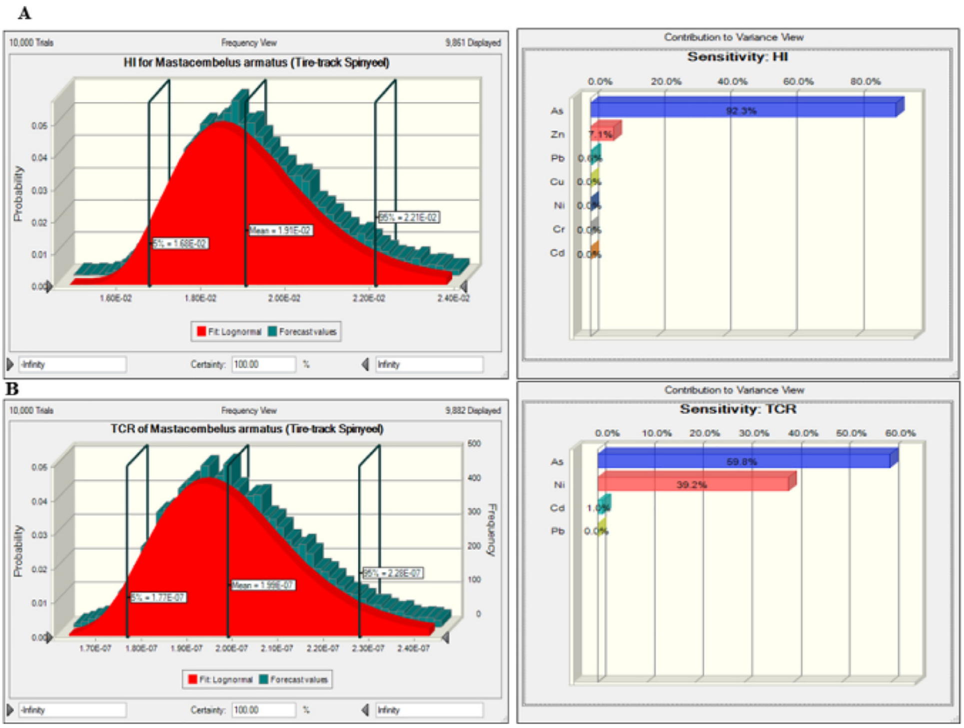

Fig. 5. Histograms of the heavy metals (HI and CR) uncertainty analysis, as well as the role of the input parameter to the uncertainty of approximate HI and CR and Sensitivity analysis of *Mastacembelus armatus* (Tire-track Spinyeel) (A&B).

showed that, the non-carcinogenic health risks for the fish consumers of Sitalakshya river are negligible but carcinogenic risks associated with Cd, Pb and As are relatively higher

4. Conclusion

The findings of this study clearly demonstrated that As, Pb, Zn, Cd, and Cr contents in three fish species from three different locations were above the maximum permissible limit (MPL). The combined effect of all metals under research exceeded the allowed limit of 1 for the TTHI. According to the target carcinogenic risk (TCR) evaluation, the concentrations of Pb, Cd and As in the three fish species increased the risk of cancer from consuming selected fish species. In conclusion, sufficient awareness must be raised in people, and government environmental health management organizations must apply appropriate legislation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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