ASSESSMENT OF HEAVY METAL CONTAMINATION AND POTENTIAL HEALTH RISK OF SELECTED FISH SPECIES IN DHAKA DISTRICT

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Sumaiya Mamun[1*], Naznin Nahar[1], Mohammad Ata Ullah[3], Mohammad Abduz Zaher[1] and Trisha Paul[2]

[1]Institute of Nutrition and Food Science, University of Dhaka, Dhaka-1000, Bangladesh.
[2]Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka-1205, Bangladesh.
[3]Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka-1205, Bangladesh.

ABSTRACT

Fish is a rich source of quality protein and fatty acids. Bangladesh's average daily fish consumption is 67.8 grams per people. Fish species are also prone to heavy metal contamination from their surrounding environment. The main objective of this research was to assess the degree of risk associated with the consumption of various fish species in Dhaka, Bangladesh. Three fish species—Tilapia (*Oreochromis mossambicus*), Shorputi (*Systomus sarana*), and Mola (*Amblypharyngodon mola*)—from three local markets in Savar Union, Dhaka, Bangladesh, were selected for analysis. The Kjeldahl technique, Folch method, and several formulae were used to determine the protein, fat, ash, and moisture content for the proximate analysis. The concentration of heavy metals was determined using Atomic Absorption Spectrophotometry (AAS). The estimated daily intake (EDI), target hazard quotient (THQ), total target hazard quotient (TTHQ), hazard index (HI), and cancer risk (CR) were used to evaluate the danger to human health. Tilapia had the highest moisture and lipid content, whereas Shorputi and Mola had the highest protein and ash contents, ranging from 20.77% to 18.16%, respectively. The mean concentration of heavy metals in fish was determined to be Pb>Ni>Cr>Cd in this study. Every fish species had extremely high levels of lead (Pb), with the Shorputi fish having the highest levels. Fish from the Shorputi species had the highest EDI value. Pb>Ni>Cr>Cd was the trace element EDI for adults. Among all species, only Pd had a THQ value higher than 1. The CR value across all species were within E-3 and E-6 range, while the HI value was >1. In conclusion, the highest average Pb concentrations were detected in Shorputi, while the highest amounts of Cd, Cr, and Ni were observed in Tilapia. The findings of this study recommended that the Bangladeshi government regularly assess the levels of dangerous heavy metal and metalloid contamination in the daily meals of its citizens in order to enforce regulatory limits and determine the likelihood of long-term exposure.

KEYWORDS: Heavy metal, Pollution, Toxicology, Health hazard, Food contamination.

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***CORRESPONDING AUTHOR: Dr. Sumaiya Mamun, Institute of Nutrition and Food Science, University of Dhaka, Dhaka-1000, Bangladesh.**
Email: sumaiya.mamun@du.ac.bd

Introduction

Bangladesh is the world's top producer of inland fish and ranks third in the world for freshwater fish, only behind China and India. [1]. Forty six lac twenty one thousand Metric Tonnes (MT) of fish were produced overall in the 2020–21 fiscal year [2]. Majority of the population in Bangladesh get more than 60% of animal protein by various fish species. [3]. The Household Income and Expenditure Survey (HIES 2022) reports that Bangladesh's average daily fish intake is 67.8 gm/capita [5]. The minimum recommended intake of fish is 18 kg/person/year but an average person in Bangladesh consumes approximately 14 kg of fish per year [6]. Fish is a nutrient-dense food. Fish is high in protein and low in calories and fat. Fish also contains omega-3 fatty acids, which may reduce the risk of coronary heart disease [7]. Fish is an excellent food source of both macronutrients (such proteins, fats, and ash) and micronutrients (like vitamins and minerals). Only 140gm of fish can provide an adult human's daily protein needs of 50-60%. Fish are the most affordable source of animal protein [8].

Rapid industrialisation and unplanned waste water management pose a threat to the aquatic life. It has become a global problem. Fish gather pollutants from aquatic environments. Twenty-three of the seventy metals and metalloids found in the environment are classified as heavy or trace metals; several of these are thought to be potent biological toxins. Concentrated heavy metals can be lethal at distances from the source of contamination in the food chain due to their long persistence periods, inability to biodegrade, and propensity to accumulate over time [9]. Because heavy metals are stable, non-biodegradable, have a propensity to build up in sediments, and have a lengthy half-life in the environment, managing them can be challenging [10]. Fish absorb food, adsorb metals to the surfaces of their tissues and membranes, exchange ions across lipophilic membranes (such as the gills), and consume particles floating in the water. As a result, fish may absorb massive amounts of metals from the water; the rate at which this occurs is determined by both the rate of absorption and excretion [11]. Excess amount of these heavy metals adversely affects normal body metabolism. The maximum allowable residual levels of lead, barium, cadmium, mercury, arsenic, and chromium for humans have been established. Based on the maximum allowable level these heavy metals are classified as toxic [12]. Heavy metal toxicity can affect multiple organs. Chronic exposure can lead to kidney failure, cardiovascular diseases, cancer and even death. Chronic cadmium poisoning damages the kidneys and causes symptoms such as liver dysfunction, hypertension, decreased fertility, kidney function, and altered renal function [13]. While respiratory diseases are known to be caused by Cr and Ni, excessive consumption of Cu can have a negative impact on the kidneys and liver. Overdosing on zinc has a detrimental effect on the immune system (reducing lymphocyte activation response) and cholesterol metabolism [12].

Methodology

A total of three different kinds of locally consumed fish samples were selected for the analysis of proximate composition and Heavy metal content. This study included Tilapia Fish, Shorputi Fish, and Mola Fish. Selected samples were collected from three points: Jhawchar Bazaar, Rajphulbaria Bazaar, and Basa Bazaar adjacent to Dhaleshwari River in Savar Union as fresh as possible. Samples were collected from the local market near the industrial area in Savar, Dhaka (Figure 1). Fish were collected during the months of March 2022.

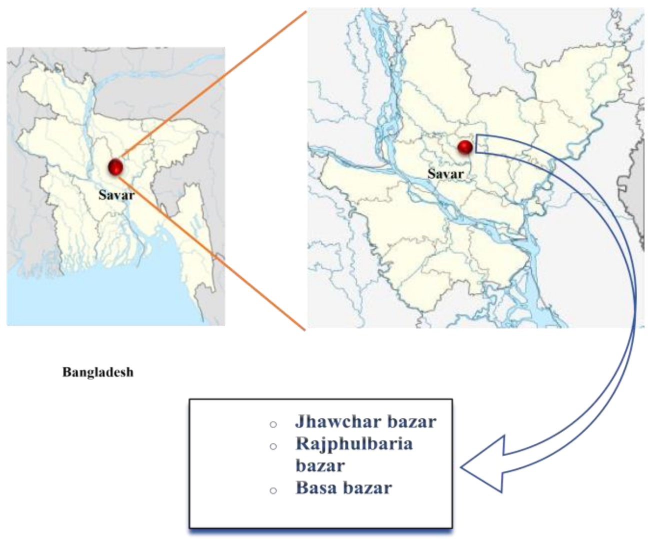


Figure 1. Sampling sites of Dhaka city

After being bought from the market, fish were promptly cleaned with distilled water and their surface water drained. The fish's purchase weight was recorded. After that, they were handled in accordance with protocol. The viscera, fins, and scales were cut off and divided. After that, the fish was filleted on both sides. After processing, deionized water was used to rinse the fish. The edible portion was finely chopped using a sharp knife and a composite sample of a homogeneous mixture of units of the same kind and variety was used for the analysis. The proximate analysis was done by Kjeldal method and heavy metal analysis were done by AAS method. For Bangladeshi nationals, the values of metal accumulation in fish were used to individually compute the Target Hazard Quotients (THQ), Carcinogenic Risk (CR), and Estimated Daily Intake (EDI) of metals.

ESTIMATED DAILY INTAKE (EDI)

The weight of the food items ingested by an individual (body weight 60 kg for an adult in Bangladesh) was multiplied by the average concentrations of the heavy metals in the food samples [13], information came from a study of household income and expenditure survey [5]. The daily intake rate was determined by the following equation (1) [15]:

$$\mathrm{EDI} = \frac{(\mathrm{Efr} \times \mathrm{ED} \times \mathrm{FIR} \times \mathrm{C})}{(\mathrm{BW} \times \mathrm{AT})} \; x\, 10 - 3$$

Efr Denotes the exposure frequency (365 days/year), ED is the exposure duration (72.3 years), FIR is the food ingestion rate (g/person/day), C denotes the metal concentration in foods (mg/kg), and AT is the averaging time for non-carcinogens (365 days/ year _ number of exposure years) [17,18], C denotes the trace element concentration in food samples (mg/kg), and BW depicts the body weight.

TARGET HAZARD QUOTIENTS (THQ)

The target hazard quotient (THQ) and total target hazard quotient (TTHQ) was determined by the following equation (2): [14,15]

$$\mathrm{THQ} = \frac{EDI}{Rfd}$$

TTHQ (in individual food) =THQ metal 1+ THQ metal 2+……..+THQ metal n

Based on the USEPA Guidelines for Health Risk Assessment of Chemical Mixtures, the following hazard index (HI) has been created to evaluate the overall potential for non-carcinogenic effects from various heavy metals [16, 17]:

HI = ∑TTHQ

= TTHQ 1+ TTHQ 2+……...+TTHQ n

Where THQ is the target hazard quotient, RfD denotes the oral reference dose (mg/kg/day) for Cd, Cr, Ni and Pb is, 0.001, 0.003, 0.02 and 0.004 (mg/kg BW/day) [17, 18].

A person's lifetime risk of getting cancer as a result of being exposed to a substantial carcinogen is referred to as their carcinogenic risk. [15].

$$TCR = EDIxSFL$$

Where TCR denotes the target cancer risk or lifetime cancer risk, SFL denotes the oral carcinogenic slope factor obtained from the USEPA database, which was 0.0085 $(mg/kg/day)^{-1}$ for Pb, 0.38 $(mg/kg/day)^{-1}$ for Cd, 0.5 $(mg/kg/day)^{-1}$ for Cr and 1.7 $(mg/kg/day)^{-1}$ for Ni [14, 17, 20].

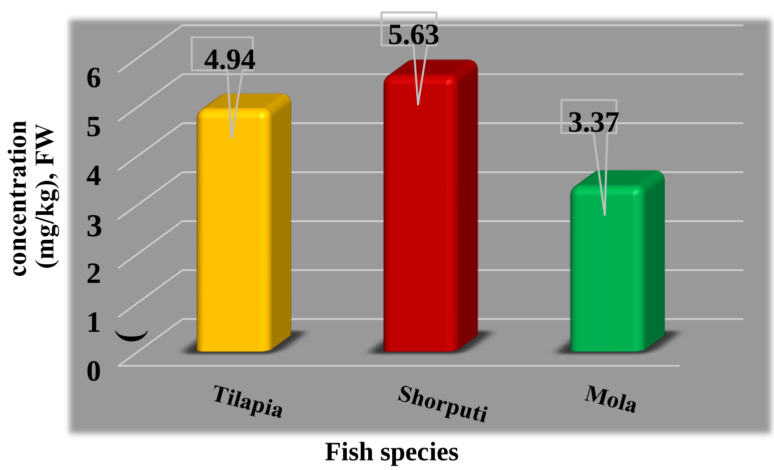
Results

Table 1 stated the physical parameters of different fish species (composite sample). It was found that protein content was highest in Shorputi (*Systomus sarana*). For fat content and moisture content Tilapia *(Oreochromis mossambicus)* had the highest value. Mola (*Amblypharyngodon mola*) had the highest ash content among the fishes.

Table 1. Physical parameters of different fish species (composite)

Fish Sample		Physical parameter (%)			
		Protein	**Fat**	**Moisture**	**Ash**
Tilapia	Mean ±SE	17.47 ± 0.341	3.69±0.216	78.20 ± 0.583	1.13± 0.000
	SD	0.59	0.375	1.01	0.00
Shorputi	Mean ±SE	18.16 ± 0.287	1.18±0.125	74.16 ± 0.331	1.14 ± 0.028
	SD	0.49	0.217	0.57	0.05
Mola	Mean ±SE	17.77 ± 0.139	0.82±0.200	73.36 ± 0.098	4.10 ± 0.017
	SD	0.24	0.346	0.17	0.03

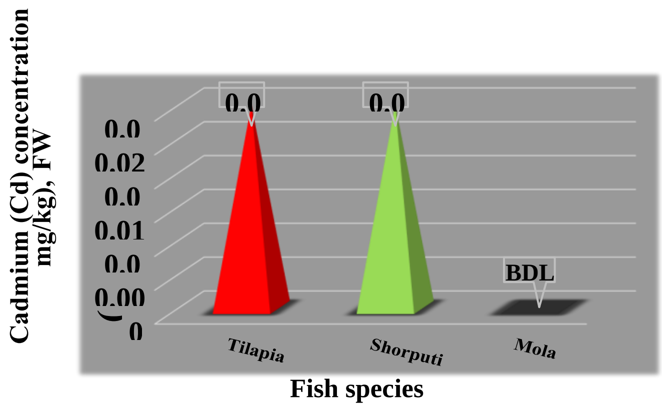
*****_SEM=Standard Error of Mean, SD=Standard Deviation._



**FW= Fresh weight*

Figure 1. Lead (Pb) concentration (mean) in different fish species

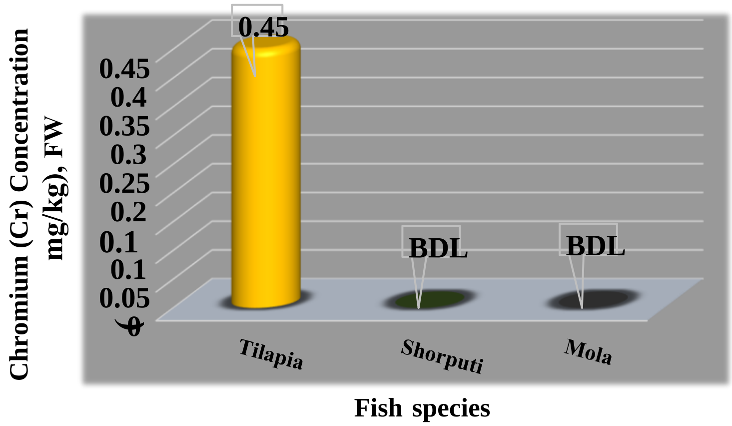
Figure 1 showed a bar diagram presenting the mean concentration of lead (Pb) in different composite fish species based on fresh weight. It was depicted that Shorputi fish had highest lead concentration than other fishes. Mola fish had lower lead concentration than others.



**BDL= Below Detection Limit. FW= Fresh weight*

Figure 2. Cadmium (Cd) concentration (mean) in different fish species

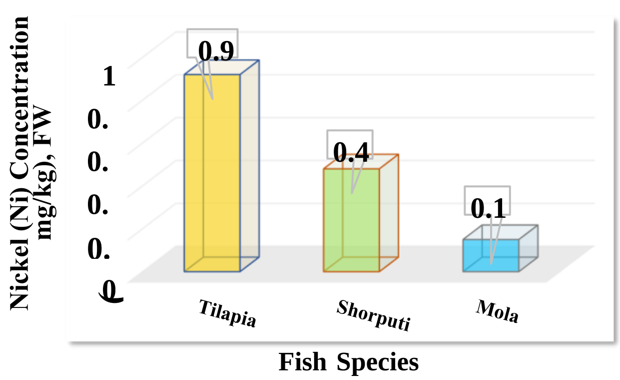
Figure 2 showed a bar diagram presenting the mean concentration of cadmium (Cd) in different composite fish species based on fresh weight. It was depicted that Tilapia and Shorputi both fishes had highest mean lead concentration than other fishes. Mola fish had cadmium concentration below detection limit.



**BDL= Below Detection Limit, FW= Fresh weight*

Figure 3. Chromium (Cr) concentration (mean) in different fish species

A bar diagram representing the mean concentration of chromium (Cr) in different composite fish species based on fresh weight (Figure 3). It was depicted that only Tilapia fish had detected for chromium concentration. Shorputi and Mola both fishes had chromium concentration below detection limit.



**FW= Fresh weight*

Figure 4. Nickel (Ni) concentration (mean) in different fish species

Figure 4 showed a bar diagram presenting the mean concentration of Nickel (Ni) in different composite fish species based on fresh weight. It was depicted that Tilapia fish had highest nickel concentration than other fishes. Mola fish had lower nickel concentration comparative to others.

Table 2 stated that Pb concentration in all fish species was higher than the FAO recommended limit but Cd, Cr, and Ni had concentration below the permissible limit.

Table 2. Concentration of heavy metals compared to the Permissible References concentration this study limit (mg/kg, FW)

Heavy Metal	Fish	Concentration of heavy metal mg/kg FW Mean±SD)	recommended (mg/kg) FW by FAO (mg/kg)	Reference
Pb	Tilapia Shorputi Mola	4.94±0.0001 5.63±0.0023 3.37±0.0001	0.3	[26]
Cd	Tilapia Shorputi Mola	0.03±0.0001 0.03±0.0006 BDL	0.1	[26]
Cr	Tilapia Shorputi Mola	0.45±0.0050 BDL BDL	1.00	[27]
Ni	Tilapia Shorputi Mola	0.92±0.0017 0.48±0.0015 0.15±0.0015	0.80	[27, 28]

**BDL=Below Detection Limit, FW=Fresh Weight, SD= Standard Deviation.*

The table 3 showed EDI of different heavy metals in different fishes. The value of EDI was highest in Shorputi fish. Compared with the maximum tolerable daily intake, the table showed that all the samples EDI value for Pb was higher. EDI value for Cd, Cr, and Ni were lower than the MTDI value.

Table 3. Estimated Daily Intake (EDI) of heavy metals (mg/day)

Fish samples	**Estimated Daily Intake (EDI) of heavy metals (mg/day)**			
	Pb	Cd	Cr	Ni
Tilapia	5.58E-3	0.034E-3	0.51E-3	1.04E-3
Shorputi	6.36E-3	0.034E-3	ND	0.542E-3
Mola	3.81E-3	ND	ND	0.169E-3
MTDI	0.21[22]	0.05[23]	0.2[24]	0.3[25]

**MTDI=Maximum Tolerable Daily Intake*

The calculation of THQ in fish species based on the duration of human exposure (72.3 years) found that only THQ for Pd had value higher than 1 for Tilapia and Shorputi. THQ value for other metals for fishes were lower than 1.

In table 4, the non-carcinogenic effects of several different elements are expressed by the HI value. In the calculation of Hazard index (HI) of all fish species were >1 which indicates consumption of these fishes had adverse health effect on consumers.

Table 4. Target Hazard Quotient (THQ) and Hazard Index (HI) of fish species

Fish samples	Target hazard quotient (THQ)				HI =(∑TTHQ)
	Pb	**Cd**	**Cr**	**Ni**	
Tilapia	1.59	0.03	0.004	0.052	1.676
Shorputi	1.82	0.03	ND	0.027	1.877
Mola	1.10	ND	ND	0.0085	1.109
TTHQ from fish	4.51	0.06	0.004	0.087	

**TTHQ=Total Hazard Quotient, HI=Hazard Index.*

The Total Carcinogenic Risk (CR) for Pb, Cd, Cr, and Ni consumption were computed since, depending on the exposure level, these elements may induce both non-carcinogenic and carcinogenic effects. Table 5 depicted that CR value for every species was within acceptable range (E4 – E6).

Table 5. Carcinogenic risk (CR) of heavy metals for consuming different fish species

Fish sample	Heavy metals			
	Pb	**Cd**	**Cr**	**Ni**
Tilapia	4.7E-5	1.29E-5	2.5E-4	1.76E-3
Shorputi	1.5E-5	1.29E-5	ND	4.6E-5
Mola	9.4E-6	ND	ND	1.4E-5

Discussion

The nutritional values of the various fish samples varied. Mola (*Amblypharyngodon mola*) had the lowest mean moisture content, whereas Tilapia (*Oreochromis mossambicus*) had the highest. The study's findings on the moisture content of tilapia and mola were 78.10% and 73.36%, respectively. These results were also comparable with the values recorded in the Food Composition Table (FCT) for Bangladesh [26] and Hasan et al [27]. Fish moisture content for Shorputi (*Systomus sarana*) was determined to be between 74.16% and 75.53%, which was comparable to FCT values [26]. Compared to other fish species, the ash percentage of Mola fish (*Amblypharyngodon mola*) was found to be greater. *Systomus sarana*, or shorputi, had the least amount of ash. Mola and Shorputi have mean ash contents of (4.10%-3.16%) and (1.09% - 1.14%), respectively which was similar with the study of Hasan et al [27] and FCT [26].

Shorputi (*Systomus sarana*) had the highest protein content, while Tilapia (*Oreochromis mossambicus*) had the lowest. The protein content of tilapia and shorputia was 17.47% and 18.16%, respectively, which was in line with findings from studies by Mansur et al. [28] and FCT [26], which revealed that the protein content of tilapia and shorputia was between 17.4% and 19.95%. Mola's protein content value (17.77–17.59) is comparable to that of Mazumder et al.'s (18.47%) finding [29]. The fat content of tilapia was 3.69%, which is comparable to the FCT values [26]. Shorputi and Mola contained fat contents of 1.18% and (0.82%-0.77%), respectively; according to literature, their respective values were 2.5% and 2.8% [29,30].

Tilapia (*Oreochromis mossambicus*) has the lowest protein content and shorputi (*Systomus sarana*) the highest. According to research by Mansur et al. [28] and FCT [26], the protein content of tilapia and shorputia was 17.47% and 18.16%, respectively. These results were consistent with the findings of those studies, which showed that the protein content ranged from 17.4% to 19.95%. The protein content values of Mola (17.77–17.59) and Mazumder et al. (18.47%) are similar [29]. The fat percentage of tilapia was found to be 3.69%, in agreement with the FCT values [26]. According to literature, the fat contents of Shorputi and Mola were 1.18% and (0.82%-0.77%), respectively; their respective values were 2.5% and 2.8% [29, 30].

For both Tilapia and Shorputi, the mean Cd concentration was determined to be 0.03 mg/kg fresh weight, which is close to the value found. Cd level for Shorputi was found in study 0.31 µg/kg, dry weight in Shitalakshya River by Hasan et al. [27]. Every fish detected in this study had a cd concentration below the FAO-permissible limit [31,32]. Every fish detected in this investigation had a Cr content below the FAO-permissible limit [32]. The species of Tilapia (*Oreochromis mossambicus*) had the greatest average Ni concentration, whereas Mola (*Amblypharyngodon mola*) had the lowest. The fresh weight of tilapia and mola was 0.92 mg/kg and 0.15 mg/kg, respectively. Ni concentrations in two separate studies were determined to be 0.96 mg/kg in dry weight and 0.012 mg/kg in fresh weight in tilapia and mola, respectively [33, 34]. In this investigation, Shorputi had a mean concentration of 0.48 mg/kg of fresh weight for Ni. Another study discovered that the dry weight of the Shitalakshya River had a 0.87 µg/kg Ni concentration at Shorputi [28].

The FAO concluded that the concentration of Ni in all fish was within the allowable limit [32]. The mean concentration of heavy metals in fish was determined to be Pb>Ni>Cr>Cd in this study. Every fish species had extremely high levels of lead, with the Shorputi fish having the highest levels—above the FAO's allowable limit. Other heavy metals were discovered to be below the allowable limit.

Fish from the Shorputi species had the highest EDI value. Pb>Ni>Cr>Cd was the trace element EDI for adults who consumed fish. When compared to the maximum allowable daily consumption, the study showed that the EDI values for Pb in all of the samples were higher. The EDI values of Cd, Cr, and Ni were all less than the MTDI values [22-25]. Only Pd had a THQ value greater than 1 in all fish species, according to the calculation of THQ in fish species over the course of human exposure. Fish with THQ readings of less than 1 are associated with other metals. All fish could be harmful to health because their THQ levels were higher than the permissible limit of 1 for Pb [37]. The non-carcinogenicity of certain elements is indicated by their HI value. The Hazard Index (HI) value of all fish species were >1, suggesting that eating these fish may have a detrimental effect on consumers' health [37]. The CR value for all species were within the safe range (E-4 to E-6), suggesting that consuming these fish may not have carcinogenic health impacts on consumers.

It is vital to consider any possible health problems as a result of fish consumption. This study does not address all possible methods of metal exposure, including dust inhalation and the consumption of foodstuffs (including meat, vegetables, and grains) that contain additional metals. In order to determine whether there may be a health danger to consumers, it is advised that both hazardous and necessary substances in all food items be continuously monitored.

Conclusion

According to the estimation, the carcinogenic risk of heavy metals was below the allowed limit, but the high HI index in all fish species pose risk for non-carcinogenic impact on health. According to this study, elemental pollution exposes consumers to both carcinogenic and non-carcinogenic effects on a regular basis. The findings of this study recommended that the Bangladeshi government regularly assess the levels of dangerous heavy metal and metalloid contamination in the daily meals of its citizens in order to enforce regulatory limits and determine the likelihood of long-term exposure.

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Conflict of interest

The authors declare no conflict of interest which may have inappropriately influenced them in writing this article.

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