Advances in Research

21(4): 44-55, 2020; Article no.AIR.56342
ISSN: 2348-0394, NLM ID: 101666096

Heavy Metal Bioaccumulation Pattern in Edible Tissues of Different Farmed Fishes of Mymensingh Area, Bangladesh and Health Risk Assessment

Mhafuza Akter[1], H. M. Zakir[1*], Shaila Sharmin[2], Q. F. Quadir[1] and Sadia Mehrin[1]

[1]Department of Agricultural Chemistry, Faculty of Agriculture, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh.
[2]College of Agricultural Sciences, International University of Business Agriculture and Technology, Uttara Model Town, Dhaka-1230, Bangladesh.

Authors' contributions

This work was carried out in collaboration among all authors. Author MA performed the sample collection, processing, analysis, data recording and wrote the first draft of the manuscript. Author HMZ designed the study, managed the literatures and supervised the work. Author SS corrected the first draft and helped in manuscript preparation. Author QFQ co-supervised the work and author SM helped in sample processing and analysis. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AIR/2020/v21i430200
Editor(s):
(1) Dr. Martin Kröger, Swiss Federal Institute of Technology (ETH Zürich), Switzerland.
Reviewers:
(1) Forcep Rio Indaryanto, University of Sultan Ageng Tirtayasa, Indonesia.
(2) Mohamed El. Sayed Megahed, National Institute of Oceanography and Fisheries (NIOF), Egypt.
Complete Peer review History: http://www.sdiarticle4.com/review-history/56342

Original Research Article

Received 10 February 2020
Accepted 16 April 2020
Published 23 April 2020

ABSTRACT

An experiment was conducted to study heavy metals bioaccumulation pattern in edible tissues of different farmed fishes and to assess human health risk through their dietary intake. Total 3 different species viz. grass carp (*Ctenopharyngodon idella*), silver carp (*Hypophthalmichthys molitrix*) and mrigel (*Cirrhinus cirrhosis*), and 3 dissimilar sizes of fish samples were collected from Muktagacha and Trishal area of Mymensingh district, Bangladesh during January 2018 and analysed for this study. Among the fish species, mean concentrations of Ca, Na and K were higher in mrigel; Mg and S contents were higher in silver carp and P content was higher in grass carp. As regards to heavy metals, mean concentrations of Pb (18.98 µg g^{-1}), Ni (0.688 µg g^{-1}) and Cu (15.197 µg g^{-1}) were higher in mrigel; Cd (1.127 µg g^{-1}), Cr (15.097 µg g^{-1}) and Zn (36.023 µg g^{-1}) contents were higher in grass carp, while contents of all metals were lower in silver carp. In context of size, both mineral nutrients and heavy metals bioaccumulation pattern in all species were higher

Corresponding author: E-mail: zakirhm.ac.bau@gmail.com;

in large size fishes. Similarly, metal pollution index values for all species of fish samples showed a sequence- large size> medium size> small size, which indicates that heavy metal bioaccumulation pattern was directly related to the size and age of fishes. The study results revealed that the daily intakes of Pb and Cd for all species and sizes of fish samples were higher than that of upper tolerable intake level. Target hazard quotients (THQ) values for Pb and Cr surpassed 1.0 for both male and female, which indicate that the exposed populations are in a level of concern interval. But in context of other heavy metals, these farmed fishes can assume as safe for human consumption.

Keywords: Metal bioaccumulation; Ctenopharyngodon idella; Hypophthalmichthys molitrix; Cirrhinus cirrhosus; target hazard quotients.

1. INTRODUCTION

In Bangladesh, fisheries and aquaculture sector is one among the major component of agriculture, which plays a crucial role in economic development by ensuring food security and stimulating the growth of a number of subsidiary industries. About 10% of the local population directly and indirectly depends on fisheries for their livelihood [1]. Bangladesh has established milestone in aquaculture development and in 2014, the country was ranked 6^{th} in global farmed fish production [2]. Aquaculture depends mainly on formulated feeds, but some of the commercial feed producers failed to meet up with standards for the requirement of fish and in many ways, the source of raw material for the production of the feeds tends to be contaminated with heavy metals. Such metallic contamination comprises significant portion of the problem as these metals known for their bioaccumulation and bio-magnification, which cause various health hazards to human. Polluted fish could be a dangerous dietary source of certain toxic heavy metals to human [3,4].

Essential metals are important for the normal metabolism of fish, and non-essential metals may accumulate in their organs [5]. Essential metals include Fe, Cu, Zn and Mn, whereas non-essential metals are Hg, Pb, Ni and Cd [6]. Evidently, fish form the link for the transfer of toxic heavy metals from water to humans [4]. A number of serious health problems can develop as a result of excessive uptake of different metals. As a result, the increasing demand of food safety has accelerated research regarding the risk associated with food consumption contaminated by heavy metals [7]. Excess amounts of heavy metals from anthropogenic sources that enter into the ecosystem may lead to geo-accumulation [8-14] and bio accumulation [4], which in turn pollute the environment and also affect the food chain and ultimately pose serious human health risks [15-19].

In Bangladesh, Mymensingh district is well known for commercial fish cultivation. Geographically, Mymensingh has been identified as the most important and promising area for fish culture because of favorable resources and climatic conditions, including the availability of ponds [20]. Hydrological conditions are also favorable for fish farming in ponds, in as much as the area is located within the monsoon tropics with an average annual rainfall of 2,500 mm [21]. Among the Upazila's of Mymensingh, Trishal, Mymensingh sadar, Fulpur and Muktagacha are important for fish farming and fishes produced in these areas are distributed throughout the country.

Heavy metal accumulates by fish in aquatic environment are varies due to the ecological conditions, metabolisms and contamination level of water, sediments and foods. However, fish feed in aquaculture system might be a source of heavy metal contamination in fish body, which may ultimately deposit in human being through consumption of those fishes and create health hazard. Furthermore, as we know, fish is contributing more than 50% of animal protein source of our diets. Considering the above fact, this work was carried out to determine the heavy metal concentrations in different sizes of some selected farmed fish species collected from Muktagacha and Trishal areas of Mymensingh district and to assess potential metallic health risk for adult male and female through consumption of those fishes.

2. MATERIALS AND METHODS

2.1 Collection of Fish Sample

A total 9 farm fish samples of 3 species and 3 different sizes were collected from Muktagacha and Trishal Upazilla's of Mymensingh district during January 2018. A particular fish species of dissimilar sizes were collected from the same pond. Details about the fish species and their features are presented in Table 1. A reasonable amount of fish samples were purchased from the aforementioned locations, and requisite amount of samples were brought to the laboratory of the Department of Agricultural Chemistry, BAU, Mymensingh and processed for subsequent chemical analysis.

2.2 Processing of Fish Sample

After collection fish samples were cleaned first and then the samples were separated for flesh (edible) and bone (non-edible). Then fleshy parts were dried in an electric oven (Model: ED 56, Binder, Germany) at 60-80°C temperature until a constant weight was obtained. After drying the samples were ground well using a mechanical grinder and stored in plastic zip lock bag with proper labeling.

2.3 Digestion of Fish Sample

Oven dried and well ground fleshy part of fish samples were used to prepare extract for the determination of different mineral nutrients and heavy metals. Extract was prepared by wet oxidation method using di-acid mixture [22]. In this method, exactly 0.50 g of finely ground samples were taken into a 250 mL conical flask and 10 mL of di-acid mixture (HNO_3:$HClO_4$ = 2:1) was added to it. Then the flask was placed on an electric hot plate for heating at 180-200ºC temperature until the solid particles disappeared and white fumes were evolved from the flask. Then, it was cooled at room temperature, washed with distilled water and filtered into 100 mL volumetric flask through filter paper (Whatman No. 1). For quality control purpose, a blank extract was also prepared by taking all reagents except sample. Finally, the volume was made up to the mark with distilled water and preserved for the determination of total major mineral nutrients and heavy metals content in the collected fish samples.

2.4 Determination of Major Mineral Elements

Fish is a good source of different mineral nutrient elements. Among the major nutrient elements, Ca and Mg were determined by titrimetrically against Na_2-EDTA standard solution, P and S were measured by spectrophotometrically (660 and 425 nm absorbance wavelength, respectively; T60 UV-Visible Spectrophotometer, PG Instrument, UK), and Na and K were estimated by flame photometrically (589 and 766 nm emission wavelength, respectively; 0.2 ppm limit of detection; Jenway PFP7, Flame Photometer, UK) [22]. The instrumental parameters were adjusted according to the manufacturer's recommendations. All chemicals and reagents were of analytical reagent grade quality.

2.5 Determination of Heavy Metals

Determination of different heavy metals (Cu, Pb, Cr, Cd, Zn, Ni and Mn) in aqueous extracts of different sizes and species of fish samples were done by an atomic absorption spectrophotometer (AAS) (SHIMADZU, AA-7000; Japan). At first the AAS was calibrated followed by the manufacturer's recommendation. Then each extract was run directly in AAS for the determination of each heavy metal in the samples mentioned above. Hollow cathode lamp of Cu, Pb, Cr, Cd, Zn, Ni and Mn was employed as light source at wavelengths of 324.8, 283.3, 357.9, 228.8, 213.9, 232.0 and 279.5 nm, respectively for the determination of each metal. All chemicals and reagents were of analytical reagent grade quality. Before use, all glass and plastic ware were soaked in 14% HNO_3 for 24 hrs. The washing was completed with distilled water rinse.

Table 1. Details of fish samples along with their sizes collected from Trishal and Muktagacha Upazila's of Mymensingh district, Bangladesh

Fish sample with scientific name	Location	Sample size		
		Small (0.8 ≤ 1) kg	Medium (2.0-3.0) kg	Large (4.0-5.0) kg
Grass carp (*Ctenopharyngodon idella*)	Trishal	1.20	2.40	5.00
Silver carp (*Hypophthalmichthys molitrix*)	Trishal	0.85	2.90	5.00
Mrigel (*Cirrhinus cirrhosis*)	Muktagacha	0.80	2.20	4.30

2.6 Estimation of Daily Metal Intakes (DMI)

To assess the health risk associated with heavy metal contamination in different sizes and species of fish samples, the daily intake of metal was calculated with the following formula-

$$DMI = (IR \times C)/BW$$

Where, IR is the fish ingestion rate (mg person^{-1} day^{-1}), C is the individual metal concentration in fish samples (mg kg^{-1}, fresh weight), BW is the body weight assuming 70 kg for adult male and 50 kg for adult female in the present study [23].

2.7 Metal Pollution Index (MPI)

To examine the overall heavy metal concentrations in different species and sizes of fish samples, the metal pollution index (MPI) was computed. This index was obtained by calculating the geometrical mean of concentrations of all the metals present in the fish samples [24].

$$MPI\ (mg\ kg^{-1}) = (Cf_1 \times Cf_2 \times \ldots\ldots \times Cf_n)^{1/n}$$

Where, Cf_n = Concentration of metal n in the sample

2.8 Target Hazard Quotients (THQ)

THQ was calculated by the general formula established by the US EPA as follows-

$$THQ = (E_F \times F_D \times DMI) / (RfD \times W \times T)$$

Where, E_F is exposure frequency; F_D is the exposure duration; DMI is the daily metal ingestion (mg person^{-1} day^{-1}) and RfD is the oral reference dose (mg kg^{-1} day^{-1}); W is the average body weight (kg) and T is the average exposure time for noncarcinogens (365 days year^{-1} × number of exposure years).

3. RESULTS AND DISCUSSION

3.1 Major Mineral Nutrient Status in Fish Samples

Calcium (Ca) is an essential macronutrient element. Calcium is important for bone formation and fish is known to be a good source of this mineral. The maximum concentration of Ca in fish samples was 1.23%, which is obtained from large size mrigel, while the minimum content of Ca (0.56%) was obtained from medium size silver carp (Table 2). The mean Ca concentrations for grass carp, silver carp and mrigel were 0.78, 0.71 and 1.21%, respectively. So, it can be inferred that among the fish species, mrigel is a good source of Ca for human nutrition compared to other two species. As regards to size, large size contained comparatively higher amount of Ca (Table 2). The recommended daily intake (RDI) of Ca for adult human being is 1000-1300 mg [25]. According to Islam [26] cereals contributed 27.3% of the total Ca intake followed by fish (21.8%), vegetables (14.0%), and milk and dairy products (10.6%) for the poor households in Bangladesh. In case of non-poor households, the contribution of cereals, fish, vegetables, and milk and dairy products was 27.3%, 21.7%, 14.9%, and 10.6% of the total Ca intake, respectively.

Magnesium (Mg) content in different sizes and species of fish samples collected from Trishal and Muktagacha Upazila's of Mymensingh district ranged from 0.080-0.180% with a mean value of 0.118%. The highest amount of Mg was obtained from the large size silver carp and the lowest amount of Mg was obtained from the small size mrigel (Table 2). The mean Mg concentrations for grass carp, silver carp and mrigel were 0.089, 0.148 and 0.118%, respectively. So, it can be inferred that among the fish species, silver carp is a good source of Mg for human nutrition compared to other two species, and large size silver carp and mrigel contained comparatively higher amount of Mg (Table 2). The recommended daily intake of Mg for adults human is 220-260 mg [25]. So, it can be inferred from the study results that 100 g fish flesh portion can contribute about 50% of Mg requirement.

Sodium (Na) content in different sizes and species of fish samples varied from 0.011 to 0.050% with a mean value of 0.028%, which was within the recommended value of FAO (30-134 mg 100 g^{-1}). The highest amount of Na was obtained from large size grass carp. On the other hand, the lowest amount of Na was obtained from large size silver carp fish. The mean Na concentrations for grass carp, silver carp and mrigel were 0.030, 0.016 and 0.039%, respectively (Table 2). On the other hand, the highest concentration of potassium (K) was obtained from large size mrigel (0.148%) among the different species and sizes of fish samples, while the lowest was in large size silver carp fish (0.048%). The mean K concentrations for grass carp, silver carp and mrigel were 0.091, 0.066 and 0.133%, respectively (Table 2). So, it can be said that mrigel is a good source of K nutrition

Table 2. Concentrations of major nutrient elements in different species and sizes of farm fish samples collected from Trishal and Muktagacha Upazila's of Mymensingh district, Bangladesh

Sl. no.	Type and size of fish	Major nutrients concentration (%)					
		Ca	Mg	Na	K	P	S
1.	Grass carp (SS)	0.73	0.089	0.019	0.083	0.012	0.052
2.	Grass carp (MS)	0.89	0.090	0.021	0.076	0.016	0.038
3.	Grass carp (LS)	0.71	0.088	0.050	0.115	0.016	0.067
4.	Silver carp (SS)	0.68	0.096	0.018	0.080	0.013	0.053
5.	Silver carp (MS)	0.56	0.168	0.018	0.069	0.009	0.047
6.	Silver carp (LS)	0.88	0.180	0.011	0.048	0.007	0.125
7.	Mrigel (SS)	1.19	0.080	0.039	0.132	0.010	0.081
8.	Mrigel (MS)	1.22	0.100	0.038	0.119	0.011	0.076
9.	Mrigel (LS)	1.23	0.174	0.040	0.148	0.012	0.061
Average	Grass carp	0.78	0.089	0.030	0.091	0.015	0.052
	Silver carp	0.71	0.148	0.016	0.066	0.010	0.075
	Mrigel	1.21	0.118	0.039	0.133	0.011	0.073
Maximum		1.23	0.180	0.050	0.148	0.016	0.125
Minimum		0.56	0.080	0.011	0.048	0.007	0.038
Standard deviation		0.26	0.042	0.014	0.033	0.003	0.026

Note: SS=Small size; MS=Medium size; LS=Large size

followed by grass carp and silver carp. However, these results were much lower compared to some studies carried out in freshwater fishes in Turkey (321-441 mg 100 g^{-1}) [27], China (301-402 mg 100 g^{-1}) [28] and Spain (286-446 mg 100 g^{-1}) [29]. The recommended daily allowance (RDA) of K for males aged between 25-50 years is 800 mg [25]. So, the consumption of 100 g of these farmed fish flesh can meet up only a small portion of daily K requirement.

Phosphorus (P) as phosphate is an essential nutrient involved in many physiological processes, such as the cell's energy cycle, regulation of the whole body acid-base balance, as a component of the cell structure (as phospholipids), in cell regulation and signaling, and as a major constituents of bones and teeth [30]. The maximum concentration of P in different sizes and species of fish samples was 0.016% and the minimum was 0.007%. The mean P concentrations for grass carp, silver carp and mrigel were 0.015, 0.010 and 0.011%, respectively (Table 2). The P concentration range obtained by this study was much lower than some other studies carried out in freshwater fishes in Turkey (232-426 mg 100 g^{-1}) [27] and China (198-240 mg 100 g^{-1}) [28]. However, this variation of P content in different fish species might be due to lower content of P in fish feeds. Sulphur (S) content in different sizes and species of fish samples collected from Trishal and Muktagacha Upazila's of Mymensingh district ranged from 0.038-0.125% with a mean value of 0.067%. The average S concentrations for grass carp, silver carp and mrigel were 0.052, 0.075 and 0.073%, respectively (Table 2). S content in some important fish species of Bangladesh ranged from 160 to 300 mg 100 g^{-1} sample [31], and this findings are almost at par with the present study results.

3.2 Heavy Metal Status in Fish Samples

3.2.1 Lead (Pb)

There are some common sources of Pb such as paints, batteries, insecticides and gasoline. Thus, it is very common metal in our everyday life. It is rapidly absorbed into the bloodstream of human body through inhalation, ingestion, or by skin contact [32]. In fact, there are no any known health benefits or biological role of lead for the human body. On the contrary, lead has adverse effects that deleterious the human body. It can affect almost every organ and system in the human body. Although there is no safe level of exposure to lead has been found, chronic toxicity of it is much more common and occurs at blood levels of about 40-60 µg dL^{-1} [32]. The maximum concentration of Pb was obtained from the large size mrigel fish (21.94 µg g^{-1}; dry wt. basis) and the minimum concentration (13.57 µg g^{-1}) was obtained in small size silver carp fish. The mean Pb concentrations for grass carp, silver carp and mrigel were 15.86, 16.02 and 18.98 µg g^{-1}, respectively (Table 3). The maximum Pb concentrations in fish samples allowed by the WHO, the FAO, and the European Community (EC) are 2.0, 0.5, and 0.2 µg g^{-1}, respectively [33]. The result obtained from the present study was much higher than these permissible limits.

Table 3. Concentration of different heavy metals in different species and sizes of farm fish samples collected from Trishal and Muktagacha Upazila's of Mymensingh district, Bangladesh

Sl. no.	Type and size of fish	Heavy metals concentration (µg g^{-1})						
		Pb	Cd	Cr	Zn	Ni	Cu	Mn
1.	Grass carp (SS)	14.33	0.927	13.23	28.98	trace	9.86	trace
2.	Grass carp (MS)	16.46	1.172	15.60	28.98	trace	12.07	trace
3.	Grass carp (LS)	16.78	1.283	16.46	50.11	trace	13.03	trace
4.	Silver carp (SS)	13.57	0.727	13.57	18.09	trace	9.96	trace
5.	Silver carp (MS)	17.27	0.969	14.06	18.08	trace	10.40	trace
6.	Silver carp (LS)	17.23	0.955	16.08	23.63	trace	12.89	trace
7.	Mrigel (SS)	15.60	0.820	13.27	22.96	2.06	12.15	trace
8.	Mrigel (MS)	19.40	0.870	14.70	28.28	trace	12.50	trace
9.	Mrigel (LS)	21.94	1.008	16.86	30.39	trace	20.94	trace
Average	Grass carp	15.86	1.13	15.10	36.02	-	11.65	-
	Silver carp	16.02	0.88	14.57	19.93	-	11.08	-
	Mrigel	18.98	0.90	14.94	27.21	0.69	15.20	-
Maximum		21.94	1.283	16.86	50.11	2.06	20.94	-
Minimum		13.57	0.727	13.23	18.08	-	9.86	-
Standard deviation		2.54	0.17	1.42	9.60	0.69	3.35	-

Note: SS=Small size; MS=Medium size; LS=Large size

3.2.2 Cadmium (Cd)

Cadmium is highly toxic even at very low exposure levels and has acute and chronic effects on health and environment. Cadmium accumulates in the human body and according to the current knowledge kidney damage (renal tubular damage) is probably the critical health effect of Cd [34]. Cd concentration in different species and sizes of fish samples ranged between 0.727 to 1.283 µg g^{-1}. The highest amount of Cd was recorded in large size grass carp while the lowest content was found in small size silver carp. The average Cd concentrations for grass carp, silver carp and mrigel were 1.13, 0.88 and 0.90 µg g^{-1}, respectively (Table 3). However, the World Health Organization has established a provisional tolerable weekly intake of Cd 7 µg kg^{-1} body weight [35]. Cadmium concentrations measured in liver of Kerguelen brook trout (1.13±0.11 µg g^{-1}) were in between FAO limits of 0.05-5.50 µg g^{-1} [36]. The Cd concentration obtained by the present study was also within this range.

3.2.3 Chromium (Cr)

Trace amounts of trivalent Cr is non-toxic and necessary for human beings but the hexavalent form of Cr is very toxic. In 2001, Dietary Reference Intakes for chromium were established. Adequate intakes of chromium is 35 mg day^{-1} for adult males and 25 mg day^{-1} for adult females [37]. The highest concentration of Cr (16.86 µg g^{-1}) was found in large size mrigel while the lowest concentration (13.21 µg g^{-1}) was obtained from small size grass carp among the sizes and types of collected farmed fish samples. The average Cr concentrations for grass carp, silver carp and mrigel were 15.10, 14.57 and 14.94 µg g^{-1}, respectively (Table 3). According to Shakeri et al. [38], WHO set the maximum allowable concentration of Cr 0.15 µg g^{-1} for human. The present study results revealed that all species and sizes of fish samples contained higher amount of Cr than this limit of WHO.

3.2.4 Zinc (Zn)

Zinc is the second metal present in the human body (about 2.5 g), after Fe (about 4.0 g) but before copper (Cu) (about 0.2 g). It is found throughout the entire body system, with half in the muscle tissue. It is a component of many metallo-enzymes, important for gene expression and cellular growth. The concentration of Zn in different sizes and species of farmed fish samples ranged between 18.08 to 50.11 µg g^{-1} (dry wt.). The mean Zn concentrations for grass carp, silver carp and mrigel were 36.02, 19.93 and 27.21 µg g^{-1}, respectively (Table 3). The established RDA for Zn is 8.0 mg day^{-1} for women and 11.0 mg day^{-1} for men [39]. However, The Zn concentration range obtained by this study was higher than some other studies carried out in freshwater fishes in Turkey (0.57-1.30 mg 100 g^{-1}) [27] and China (0.64-0.81 mg 100 g^{-1}) [28].

3.2.5 Nickel (Ni)

Nickel is one of the ubiquitous elements. Nickel is relatively toxic and widespread in the environment. The effects of nickel exposure vary from skin irritation to damage to lungs, the nervous system, and mucous membranes [40]. However, present study results detected Ni in only small size mrigel and the concentration was 2.064 µg g^{-1} (dry wt.), while other species and sizes of collected fish samples contained trace amount of Ni (Table 3). Thus, it can be inferred from this study results that different types of farmed fishes seem to be safe as regards to Ni content.

3.2.6 Copper (Cu)

Copper is an essential part of several enzymes and is necessary for the synthesis of hemoglobin. The established RDA for Cu in normal healthy adults is 2.0 mg day^{-1} [41]. However, studies have shown that Cu is highly toxic in aquatic environments and has effects on fish, invertebrates, and amphibians, with all three groups equally sensitive to chronic toxicity [42]. Copper may accumulate in many different organs of fish. The highest concentrations of Cu (20.94 µg g^{-1}) was found in the large size mrigel and the lowest concentration (9.86 µg g^{-1}) was obtained from the small size grass carp among the sizes and types of collected farmed fish samples. The mean Cu concentrations for grass carp, silver carp and mrigel were 11.65, 11.08 and 15.20 µg g^{-1}, respectively (Table 3).

3.2.7 Manganese (Mn)

Manganese is a trace metal, which is present in very small amounts in human body. But it is one of the most important nutrients for our health. The average human body contains about 12.00 mg of Mn. About 43% of it is found in the skeletal system, with the rest occurring in soft tissues including liver, pancreas, kidneys, brain, and central nervous system [43]. The RDA for Mn is 2.3 mg day^{-1} for adult males and 1.8 mg day^{-1} for adult females [37]. But in the present study, Mn content in different sizes and types of farmed fish samples were trace i.e. below detectable level (Table 3).

3.3 Assessment of Metal Pollution Index (MPI)

The MPI was used to compare the total metals accumulation level in different species and sizes of farm fish samples collected from Mymensingh area. In spite of indisputable importance of established chemical, biochemical and biological methods, MPI might be included in complex freshwater monitoring programmes since it could produce some additional information on metal bioavailability, bio-concentration and metal input into the environment [44]. The MPI is a reliable and precise method for monitoring metal pollution in food samples. The MPIs of individual fish samples are presented in Fig. 1. Among the fish species used in the present study, large size mrigel and grass carp showed the highest MPIs (2.97 and 2.96, respectively). It is evident from the Fig. 1 that MPI values for all 3 species of collected farmed fishes followed a sequence-large size > medium size > small size, which indicates heavy metal accumulation pattern was directly related to the size and age of fishes. It is also apparent from the Fig. 1 that among the fish species, silver carp showed comparatively lower MPI values for all sizes than that of grass carp and mrigel.

3.4 Estimation of Daily Metal Intake (DMI)

To evaluate the health risk associated with heavy metal through consumption of different species and sizes of farmed fishes collected from Trishal and Muktagacha area, the daily intake of metals were calculated. Among the possible pathways of exposure of heavy metals to humans, food chain contamination is the most important. The daily intake of metals was calculated according to the average fish consumption for both adults male and female. According to HIES [45], fish ingestion rate in Bangladesh is 62.58 g $person^{-1}$ day^{-1}, which is used to calculate DMI. The DMI estimate of Mn, Zn, Cu, Cr, Cd, Ni and Pb from edible part of fish samples were calculated by multiplying the daily intake and heavy metal concentrations measured by this study. The calculated DMI values are presented in Table 4, and it can be seen from the table that DMI for female > male and among the metals, DMI followed the sequence as Zn >Pb> Cr > Cu > Cd > Ni = Mn. So, it can be assumed adverse effects on human health if daily intake is exceeded the recommended daily allowance for a particular metal. According to FDA [37], upper tolerable intake levels (UTIL) for Zn and Cu are 40.0 and 10.0 mg day^{-1} $person^{-1}$, respectively. The UTIL value for Cr is not established yet. On the other hand, UTIL for Pb and Cd are 0.24 and 0.064 mg day^{-1} $person^{-1}$, respectively [46]. So, it can be inferred from this study that daily intake of Pb and Cd were higher than that of UTIL, which indicate serious adverse effects have been associated with intake of different species and sizes of farmed fishes.

Table 4. Calculated daily metal intakes (DMI) for different species and sizes of farm fish samples collected from Trishal and Muktagacha Upazila's of Mymensingh district, Bangladesh with the upper tolerable intake level (UTIL) and oral reference doses (RfD)

			Cu	Zn	Cr	Pb	Ni	Cd	Mn
UTIL (mg day^{-1} person^{-1})			10.0[a]	40.0[a]	-	0.24[b]	1.0[a]	0.064[b]	11.0[a]
RfD (mg kg^{-1} day^{-1})			0.04[c]	0.30[c]	0.003[d]	0.0035[e]	0.02[c]	0.001[e]	0.014[c]
Daily Metal Intake (mg day^{-1} person^{-1})	Grass carp (SS)	Male	2.20	6.48	2.96	3.20	0.00	0.21	0.00
		Female	3.09	9.07	4.14	4.48	0.00	0.29	0.00
	Grass carp (MS)	Male	2.70	6.48	3.49	3.68	0.00	0.26	0.00
		Female	3.78	9.07	4.88	5.15	0.00	0.37	0.00
	Grass carp (LS)	Male	2.91	11.20	3.68	3.75	0.00	0.29	0.00
		Female	4.08	15.68	5.15	5.25	0.00	0.40	0.00
	Silver carp (SS)	Male	2.23	4.04	3.03	3.03	0.00	0.16	0.00
		Female	3.12	5.66	4.25	4.25	0.00	0.23	0.00
	Silver carp (MS)	Male	2.32	4.04	3.14	3.86	0.00	0.22	0.00
		Female	3.25	5.66	4.40	5.40	0.00	0.30	0.00
	Silver carp (LS)	Male	2.88	5.28	3.59	3.85	0.00	0.21	0.00
		Female	4.03	7.39	5.03	5.39	0.00	0.30	0.00
	Mrigel (SS)	Male	2.72	5.13	2.97	3.49	0.46	0.18	0.00
		Female	3.80	7.18	4.15	4.88	0.65	0.26	0.00
	Mrigel (SS)	Male	2.79	6.32	3.29	4.34	0.00	0.19	0.00
		Female	3.91	8.85	4.60	6.07	0.00	0.27	0.00
	Mrigel (SS)	Male	4.68	6.79	3.77	4.90	0.00	0.23	0.00
		Female	6.55	9.51	5.28	6.87	0.00	0.32	0.00

[a] = FDA [37]; [b] = Garcia-Rico et al. [46]; [c] = US EPA [47]; [d] = IRIS [48] and [e] = Khan et al. [49]

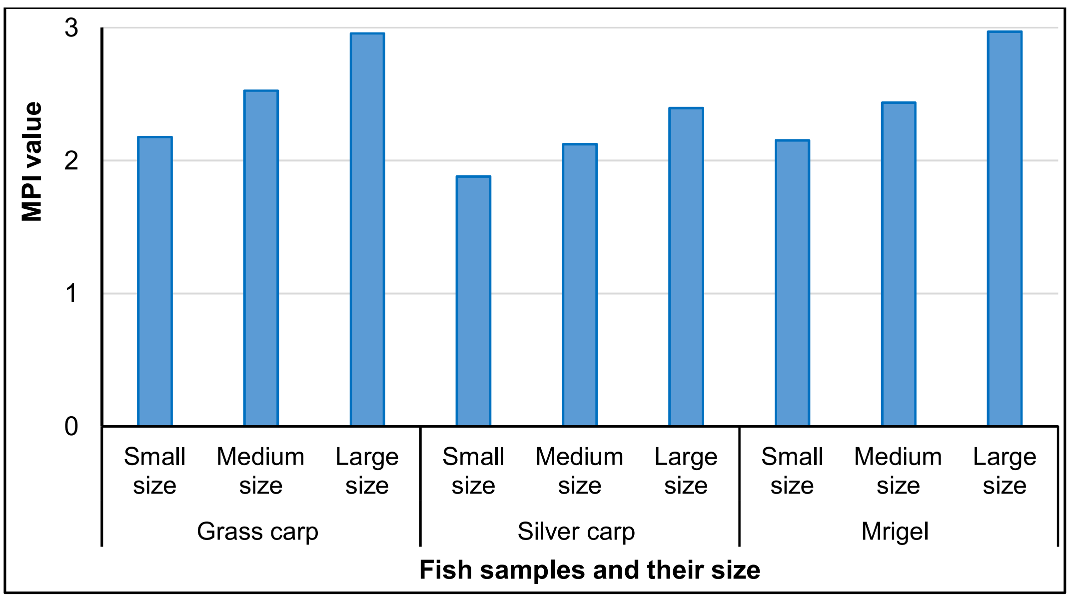

Fig. 1. Metal pollution index (MPI) for edible part of different species and sizes of farm fish samples collected from the Muktagacha and Trishal Upazila's of Mymensingh district

3.5 Target Hazard Quotients (THQ)

Target hazard quotients is used widely for the assessment of potential health risks associated with long term exposure to chemical pollutants [15-16,19,49-50]. The THQ <1 means the exposed population is assumed to be safe; 1 < THQ < 5 means that the exposed population is in level of concern interval, and THQ > 5 means exposed population is unsafe. It is a dimension

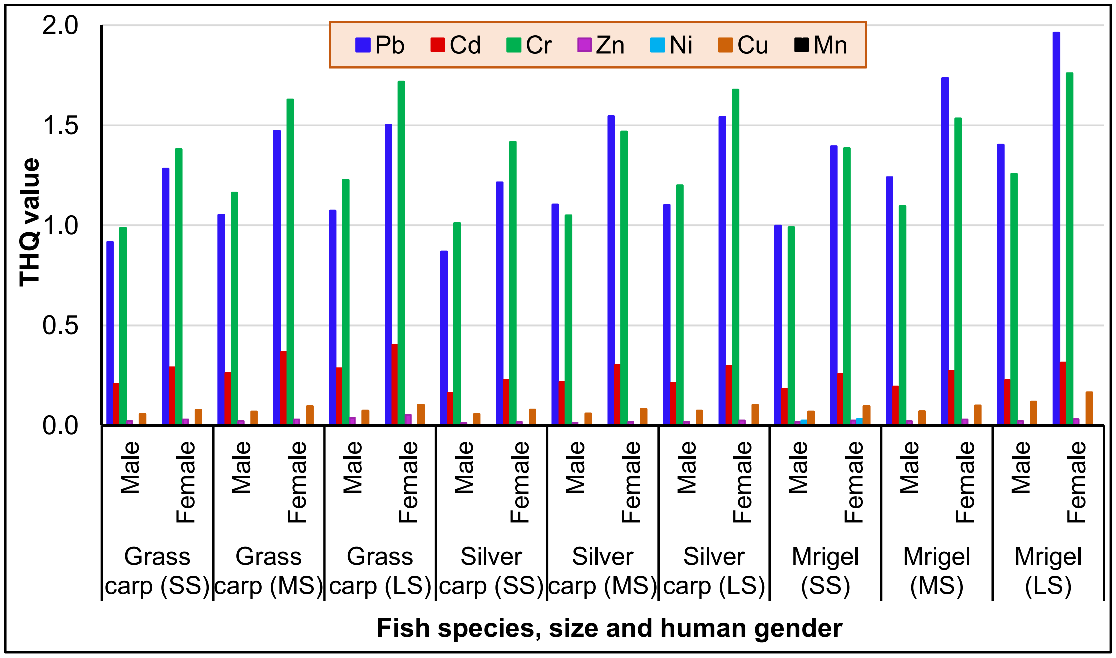

Fig. 2. Target hazard quotient (THQ) for adult male and female due to consumption of different species and sizes of farm fish samples collected from the Muktagacha and Trishal Upazila's of Mymensingh district

less index and THQ values are additive, but not multiplicative. It must be noted that THQ is not a measure of risk but indicates a level of concern. Target hazard quotients was measured considering DMI of people, average body weight (male: 70 kg and female: 50 kg) and average life expectancy (male: 70.6 and female: 73.1) [23] of concern people. Values of this parameter (THQ) due to consumption of edible part of different species and sizes of farmed fishes for investigated metals are presented in Fig. 2. THQ values for Pb and Cr surpassed 1.0 for both male and female in most cases i.e. in context of these two metals populations are in a level of concern interval. So, it can be concluded from the present study results that Cr and Pb concentrations in different species and sizes of farmed fishes are in a level of concern interval for human consumption.

4. CONCLUSION

This study provides baseline data on major mineral elements and heavy metal contents in farmed fishes of greater Mymensingh area, along with their accumulation pattern in different species and sizes of fishes. The information generated from this study could be used as a baseline data for developing food composition database for Bangladesh. The present study results revealed that the concentrations of Pb and Cr were higher than the permissible limit recommended by the WHO. Among the fish species, the mean concentrations of Pb and Cu were higher in mrigel; Cd, Cr and Zn contents were higher grass carp, while the amounts of all metals were lower in silver carp. The metal pollution index (MPI) indicates heavy metal accumulation pattern was directly related to the size and age of fishes. The daily intake of Pb and Cd through consumption of different species and sizes of farmed fishes were higher than that of upper tolerable intake level, which indicates serious adverse effects for human health. THQ values for Pb and Cr surpassed 1.0 for both male and female in most cases i.e. in context of these two metals populations are in a level of concern interval. But as regards to other heavy metals, these farmed fishes can assume as safe for human being. However, before final conclusion, further research is needed by considering more area and large scale of fish species.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest among the authors and producers of the products because we do not

intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by any company/ organization rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. DoF (Department of Fisheries). National Fish Week 2013 Compendium (In Bengali). Ministry of Fisheries and Livestock, Dhaka-1000, Bangladesh; 2013.
2. FAO (Food and Agriculture Organization of the United Nations). Fisheries and Aquaculture topics. The State of World Fisheries and Aquaculture (SOFIA). Topics Fact Sheets. Text by Jean-Francois Pulvenis. In: FAO Fisheries and Aquaculture Department; 2016.
3. Afshan S, Ali S, Ameen US, Farid M, Bharwana SA, Hannan F, Ahmad R. Effect of different heavy metal pollution on fish. Res J Chem Environ Sci. 2014;2(1):74-79. Available:www.aelsindia.com
4. Zakir HM, Eti MSA, Quadir QF, Mallick S. Health risk assessment of heavy metal intake of common fishes available in the Brahmaputra river of Bangladesh. Arch Cur Res Int. 2019;19(2):1-15. DOI: 10.9734/ACRI/2019/v19i230153
5. Canli M, Atli G. The relationships between heavy metal (Cd, Cr, Cu, Fe, Pb, Zn) levels and the size of six Mediterranean fish species. Environ Pollut. 2003;121:129-136. DOI: 10.1016/S0269-7491(02)00194-X
6. Türkmen A, Türkmen M, Tepe Y, Akyurt I. Heavy metals in three commercially valuable fish species from Iskenderun Bay, Northern East Mediterranean Sea, Turkey. Food Chem. 2005;91:167-172. DOI: 10.1016/j.foodchem.2004.08.008
7. Mansour SA, Belal MH, Abou-Arab AAK, Gad MF. Monitoring of pesticides and heavy metals in cucumber fruits produced from different farming systems. Chemosphere. 2009;75(5):601-609. DOI: 10.1016/j.chemosphere.2009.01.058
8. Zakir HM, Arafat MY, Islam MM. Assessment of metallic pollution along with geochemical baseline of soils at Barapukuria open coal mine area in Dinajpur, Bangladesh. Asian J Water Environ Pollut. 2017;14(4):77-88. DOI: 10.3233/AJW-170038
9. Zakir HM, Islam MM, Hossain MS. Heavy metal contents in sediments of an urban industrialized area: A case study of *Tongi* canal, Bangladesh. Asian J Water Environ Pollut. 2017;14(1):59-68. DOI: 10.3233/AJW-170007
10. Zakir HM, Arafat MY. Contamination level of different chemical elements in top soils of Barapukuria coal mine area in Dinajpur, Bangladesh. Asian J Water Environ Pollut. 2020;17(1):59-73. DOI: 10.3233/AJW-200007
11. Zakir HM, Sumi SA, Sharmin S, Mohiuddin KM, Kaysar S. Heavy metal contamination in surface soils of some industrial areas of Gazipur, Bangladesh. J Chem Bio Phy Sci. 2015;5(2):2191-2206.
12. Islam F, Zakir HM, Rahman A, Sharmin S. Impact of industrial wastewater irrigation on heavy metal deposition in farm soils of Bhaluka area, Bangladesh. J Geog Environ Earth Sci Int. 2020;24(3):19-31.
13. Zakir HM, Hasan MN, Quadir QF, Sharmin S, Ahmed I. Cadmium and lead pollution in sediments of midstream of the river Karatoa in Bangladesh. Int J Engg Sci. 2013;2(2):34-42.
14. Zakir HM, Islam MM, Hossain MS. Impact of urbanization and industrialization on irrigation water quality of a canal- a case study of *Tongi* canal, Bangladesh. Adv Environ Res. 2016;5(2):109-123. DOI: 10.12989/AER.2016.5.2.109
15. Aysha MIJ, Zakir HM, Haque R, Quadir QF, Choudhury TR, Quraishi SB, Mollah MZI. Health risk assessment for population via consumption of vegetables grown in soils artificially contaminated with arsenic. Arch Cur Res Int. 2017;10(3):1-12. DOI: 10.9734/ACRI/2017/37612
16. Haque R, Zakir HM, Aysha MIJ, Supti Mallick, Rahman MS. Heavy metal uptake pattern and potential human health risk through consumption of tomato grown in industrial contaminated soils. Asian J Adv Agril Res. 2018;5(4):1-11. DOI: 10.9734/AJAAR/2018/40169
17. Weldegebriel Y., Chandravanshi BS, Wondimu T. Concentration levels of metals in vegetables grown in soils irrigated with river water in Addis Abada, Ethiopia. Ecotoxicol Environ Safety. 2012;77:57-63. DOI: 10.1016/j.ecoenv.2011.10.011.

18. Zakir HM, Aysha MIJ, Mallick S, Sharmin S, Quadir QF, Hossain MA. Heavy metals and major nutrients accumulation pattern in spinach grown in farm and industrial contaminated soils and health risk assessment. Arch Agric Environ Sci. 2018; 3(1):95-102.
DOI: 10.26832/ 24566632.2018.0301015
19. Mehrin S, Zakir HM, Akter M, Seal HP. Nutritional quality and metallic health risk assessment of industrially processed tomato sauces available in the markets of Bangladesh. Euro J Nutr Food Safety; 2020;12(3):67-78.
20. Ahmed N. Revolution in small-scale freshwater rural aquaculture in Mymensingh, Bangladesh. World Aqua. 2009;40(4):31-35.
21. FAO (Food and Agriculture Organization of the United Nations). Forest resources of Bangladesh - country report. Forest Resources Assessment Program, Forestry Department, FAO Working Paper 15, Rome, Italy; 2000.
22. Singh D, Chhonkar PK, Pandey RN. Soil, plant and water analysis: A method manual. IARI, New Delhi. India; 1999.
23. BBS (Bangladesh Bureau of Statistics). Health and Morbidity Status Survey- 2014. Bangladesh Bureau of Statistics, Statistics and Informatics Division, Ministry of Planning, Govt. of the People's Republic of Bangladesh; 2015.
Available:www.bbs.gov.bd
24. Usero J, Gonzalez-Regalado E, Gracia L. Trace metals in the bivalve mollusks *Ruditapes decussates* and *Ruditapes phillippinarum* from the Atlantic coast of Southern Spain. Environ Int. 1997; 23(3):291-298.
DOI: 10.1016/S0160-4120(97)00030-5
25. FAO/WHO. Human vitamin and mineral requirements. Report of a Joint FAO/WHO expert consultation, Bangkok, Thailand. Food and Nutrition Division, FAO, Rome; 2001.
26. Islam MR. Consumption of unsafe foods: Evidence from heavy metal, mineral and trace element contamination. The National Food Policy Capacity Strengthening Programme (NFPCSP) sponsored project, Dept. of Soil Science, BAU, Mymensingh; 2013.
27. Alas A, Ozcan MM, Harmankaya M. Mineral contents of head, caudal, central fleshy part, and spinal columns of some fishes. Environ Monit Assess. 2014;186: 889-894.
DOI: 10.1007/s10661-013-3429-3
28. Tao NP, Wang LY, Gong X, Liu Y. Comparison of nutritional composition of farmed puffer fish muscles among *Fugu obsurus*, *Fugu flavidus* and *Fugu rubripes*. J Food Comp Anal. 2012;28:40-45.
DOI: 10.1016/j.jfca.2012.06.004
29. Martinez-Valverde I, Periago MJ, Santaella M, Ros G. The content and nutritional significance of minerals on fish flesh in the presence and absence of bone. Food Chem. 2000;71:503-509.
DOI: 10.1016/S0308-8146(00)00197-7
30. European Food Safety Authority. Tolerable Upper Intake Levels for Vitamins and Minerals. Scientific Committee on Food; Scientific Panel on Dietetic Products, Nutrition and Allergies; 2006.
31. Bogard JR, Thilsted SH, Marks GC, Wahab MA, Hossain MAR, Jakobsen J, Stangoulis J. Nutrient composition of important fish species in Bangladesh and potential contribution to recommended nutrient intakes. J Food Comp Anal. 2015; 42:120-133.
DOI: 10.1016/j.jfca.2015.03.002
32. Flora G, Gupta D, Tiwari A. Toxicity of lead: a review with recent updates. Interdiscip Toxicol. 2012;5(2):47-58.
DOI: 10.2478/v10102-012-0009-2
33. Gu YG, Lin Q, Wang XH, Du FY, Yu ZL, Huang H-H. Heavy metal concentrations in wild fishes captured from the South China Sea and associated health risks. Mar Pollut Bull. 2015;96(1-2):508-512.
DOI: 10.1016/j.marpolbul.2015.04.022
34. Nordic Council of Ministers. Cadmium review. Report no. Copenhagen K, Denmark. 2003;1(4):1-26.
35. WHO (World Health Organization). Cadmium. Environmental Health Criteria 134. World Health Organization, International Programme on Chemical Safety (IPCS), Geneva, Switzerland; 1992.
36. Jaffal A, Paris-Palacios S, Jolly S, Thailly AF, Delahaut L, Beall E, Roche H, Biagianti-Risbourg S, Betoulle B. Cadmium and copper contents in a freshwater fish species (brook trout, *Salvelinus fontinalis*) from the sub-antarctic Kerguelen Islands. Polar Biol. 2011;34:397-409.
DOI: 10.1007/s00300-010-0895-8
37. FDA (Food and Drug Administration). Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium,

Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. Report of the Panel on Micronutrients. National Academy Press, Washington, DC, Food and Drug Administration. Dietary supplements. Center for Food Safety and Applied Nutrition; 2001.
38. Shakeri A, Shakeri R, Mehrabi B. Potentially toxic elements and persistent organic pollutants in water and fish at Shahid Rajaei dam, north of Iran. Int J Environ Sci Tech. 2015;12(7):2201-2212. DOI: 10.1007 /s13762-015-0754-9
39. Connie WB, Christine SR. Handbook of clinical nutrition and aging. Springer Publishing, New York; 2009.
40. Aleksandra DC, Urszula B. The impact of nickel on human health. J Elementol. 2008; 13(4):685-696.
41. NRC (National Research Council). *Copper*. In*:* Recommended dietary allowances. National Research Council, Food Nutrition Board, Washington, DC: NRC/NAS; 1980.
42. US EPA. Wildlife exposure factor handbook. U.S. Environmental Protection Agency, Washington, D.C. EPA/600/R-93/187a. 1993;1.
43. Roger M. The minerals you need. Safe Goods Publishing, 561 Shunpike Road, Sheffield, MA 01257, USA; 2011.
44. Teodorovic I, Djukic N, Maletin S, Miljanovic B, Jugovac N. Metal pollution index: proposal for freshwater monitoring based on trace metal accumulation in fish. TISCIA, 2000;32:55-60.
45. HIES (Household Income and Expenditure Survey). Preliminary report on household income and expenditure survey 2016. Bangladesh Bureau of Statistics, Ministry of Planning, Govt. of the People's Republic of Bangladesh, Dhaka-1000; 2017.
46. Garcia-Rico L, Leyva-Perez J, Jara-Marini ME. Content and daily intake of copper, zinc, lead, cadmium, and mercury from dietary supplements in Mexico. Food Chem Toxicol. 2007;45:1599-1605. DOI: 10.1016/j.fct.2007.02.027
47. US EPA. Human Health Risk Assessment: Risk-Based Concentration Table; 2010. Available:http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/
48. IRIS (Integrated Risk Information System). Chemical Assessment Summary (Chromium VI; CASRN 18540-29-9). National Center for Environmental Assessment, U.S. Environmental Protection Agency. 1987;33.
49. Khan S, Cao Q, Zheng YM, Huang YZ, Zhu YG. Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. Environ Pollut. 2008;152:686-692. DOI: 10.1016/j.envpol.2007.06.056
50. US EPA. Office of Water Regulations and Standard: Guidance manual for assessing human health risks from chemically contaminated, fish and shellfish. U.S. Environmental Protection Agency, Washington, D.C; EPA-503/8-89-002; 1989.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/56342