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A Probabilistic-Deterministic Approach Towards Human Health Risk Assessment and Source Apportionment of Potentially Toxic Elements (PTEs) in Some Contaminated Fish Species

Yeasmin N. Jolly[1] · Sadia A. Surovi[2] · Sheikh M. Mizanur Rahman[2] · Jamiul Kabir[1] · Shirin Akter[1] · Khan M. Mamun[1] · Arafat Rahman[3]

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Abstract
Contamination of fish species with potential toxic elements (PTEs) has caught the prime attention globally including Bangladesh. The present study enlightened on the accumulation, origin, and associated health implications of Mn, Fe, Cu, Zn, As, Hg, Pb, and Cr in ten varieties of fish species collected from the heavily polluted river Buriganga. Levels of PTEs in the studied fish species were found within the legislative value suggested by the World Health Organization (WHO) and Federal Environmental Protection Agency (FEPA) except for Fe, Cu, Zn, and Hg and can be assembled as Zn > Fe > Cu > Mn > Cr > Hg > As > Pb. The origin of PTEs in fish species apportioned mostly anthropogenic coupled with natural sources. Among the anthropogenic sources, industrial wastewater, recycling of leaded and lithium-ion batteries, metallurgical industries, shipyards, tannery, cosmetics, and chemical industries are the major contributors. This study identified children are exposed to As and Zn as their estimated targeted hazard quotient (THQ) value exceeded the threshold limit of safety, whereas adults are exposed to As only. The estimated, hazard index (HI) for children was found more than four times of adults; however, both the population groups are in vulnerable situation considering HI value (HI > 1), indicating possible non-carcinogenic health risk. Moreover, cumulative cancer risk TCR appraised that all the fish species exceeded the threshold limit of > 1E-03 for children and > 1E-04 for adults, which are level VII and level V contamination state for child and adult, respectively, and manifested consumption of the studied fishes arises a high probability for lifetime cancer risk.

Keywords Bioaccumulation · Cluster analysis · EDXRF · Health risk · Toxic elements

Introduction

The aquatic ecosystem has been endangered from long by continuous introduction of various metal(loids) originated from lithogenic or manmade activities, thus making vulnerable to human and environmental health, as metals are toxic and non-degradable and can enter the food web by bioaccumulation and biomagnifications [1]. However, the trend of health risks owing to intake of adulterant aquatic foodstuff is rising up progressively worldwide and this scenario is more acute in developing countries like Bangladesh. Fishes are notably the most popular aquatic food that supplies necessary energy, proteins, vitamins, and various nutrients [2] for human body, consequently making themselves an integral part of human diet around the world.

Fishes are cheap and most available source of protein [3] which obliges it very popular among the community but potential toxic elements (PTEs)-contaminated fish can pose serious health hazards. Expeditious industrialization and urbanization cause pollution of maximum water bodies with various PTEs and other toxins, consequently fish, as a potential receptor easily accumulates those PTEs in their different body parts. Numerous researchers believe that biomagnifications of toxins and succeeding dispersal in the organs are greatly dependent on each other and the influencing factors

✉ Yeasmin N. Jolly
jolly_tipu@yahoo.com

1 Atmospheric and Environmental Chemistry Laboratory, Chemistry Division, Atomic Energy Centre, Dhaka 1000, Bangladesh

2 Department of Chemistry, University of Dhaka, Dhaka 1000, Bangladesh

3 Department of Soil, Water and Environment, University of Dhaka, Dhaka 1000, Bangladesh

are gender, age, size, reproductive cycle, swimming behavior, feeding behavior, metal detoxification capacity, and the environment where they reside [4, 5]. Moreover, different accumulation patterns are manifested by different metals depending on the organ type—thus, gills, liver, and kidneys accumulate PTEs in higher concentrations while the muscles with the least [6]. Since muscles are used as the edible part of human diet, researchers are more concerned about their contamination level. As such, numerous investigations on tracking PTE contamination level in fishes have been carried out all over the world [7–11]. It is well established that populations are exposed by PTEs through ingestion of food mostly [12] and fish is considered the major contributor among all [13]. As a result, fish has been treated as a significant index for freshwater system for imaging the toxic element pollution level and its hazardous impact on human health [14–19]. Elevated metal concentration caused lethal and chronic effects on fishes [20] and therefore, it not only indicates the contamination status of the aquatic ecosystem but also influenced the food web [21].

The Buriganga River, the largest riverine system in Bangladesh, is very important as the urban dwellers rely largely on it to ensure their domestic water supply and it is a natural source of huge varieties of fish species. In recent years, the flow of water and ecological function of the river have been aggravated by intensive human interventions like rapid industrialization, unplanned urbanization, and economic development [22–24]. Thus, a considerable amount of PTEs inaugurate into the river by industrial waste disposal; agricultural runoff; gasoline leaking from cargoes, ships, barges, and mechanized boats; improper disposal of household wastes; toxic wastes dumped by sewerage lines; etc. [24]. Moreover, a large number of rivers flowing through Bangladesh but originated from outside the country are bringing on heavy loads of sediment and various elements, thus making the rivers saturated and sometimes over-saturated with organic and inorganic pollutants and causing serious damage to the aquatic environment and habitat. Khan et al. [25] reported that there are 249 factories along the river Buriganga identified by the Department of Environment (DoE), from where a huge volume of untreated effluent and solid wastes are discarded into the river, and hence fishes and other aquatic animals concentrate these metals in their bodies which, in the long run, enters human body via the food cycle.

Numerous studies have been conducted reporting enrichment of heavy metals in fishes of various rivers, including the Buriganga River [10, 23, 26–29], but the risk assessments with a particular focus on human health and apportionment of the source of potential toxic elements in fishes are scant. As accumulation and magnification of metals varied widely depending on fish species and contamination is a continuous process, monitoring of PTE level in fish and other aquatic animals is essential from time to time from the point of environmental and food safety. However, monitoring is not enough for a constructive solution to mitigate the problem of metal contamination of fishes and other aquatic organisms; it is more important to trace out the pollution sources. With this thought in front, an approach was made to apportion the possible source of PTEs in fish species using multivariate statistical analysis in the present study.

Usually, multivariate statistical analysis is employed to find out the possible sources of metals in the different environmental components like soil, sediment, surface, and groundwater. Numerous studies were conducted previously to identify possible sources of metals in water, sediment, or soil [11, 24, 30, 31] but using chemometric technique in fish species for source apportionment is still very uncommon. Considering all these consequences, present experiment insights on the measurement of the level of PTEs in fish muscles, and evaluate their current status by comparing with other similar studies worldwide, pointing out required toxicological and nutritional values. Evaluating exposure level of health hazards of PTEs in both children and adults due to consuming contaminated fishes and calculation of various indices using multivariate techniques with the special emphasis on possible sources apportionment of PTEs were performed.

Materials and Methods

Study Area

Fish samples have been collected randomly from five different locations (Silicon city, Bosila, Kamrangir char, Hasanabad, Fatullah) recognized as popular fishing points of the river Buriganga, the most polluted riverine system of Bangladesh. However, selection of sampling sites was made, focusing on the study area should be a representative one for all sorts of toxic metals, and hence river Buriganga came to the fore (Fig. 1). A wide variety of metals (heavy/trace/toxic) are regularly introduced into the river from the indiscriminate discharge of nearby industries, leakage of gasoline from different water-based vehicles, domestic wastes, agricultural runoff, etc., eventually making the whole river biologically and hydrologically dead.

Sample Collection and Formation of Sample Pellets

Ten indigenous fish species, viz., Tengra (*Batasio batasio*), Kholshe (*Colisa fasciata*), Chapila (*Gonialosa manmina*), Mola (*Amblypharyngodon microlepis*), Baila (*Awaous guamensis*), Shing (*Heteropneustes fossilis*), Poa (*Otolithoides pama*), Baim (*Mastacembelus armatus*), Kalibaos (*Labeo calbasu*), and Taki (*Channa punctata*), were

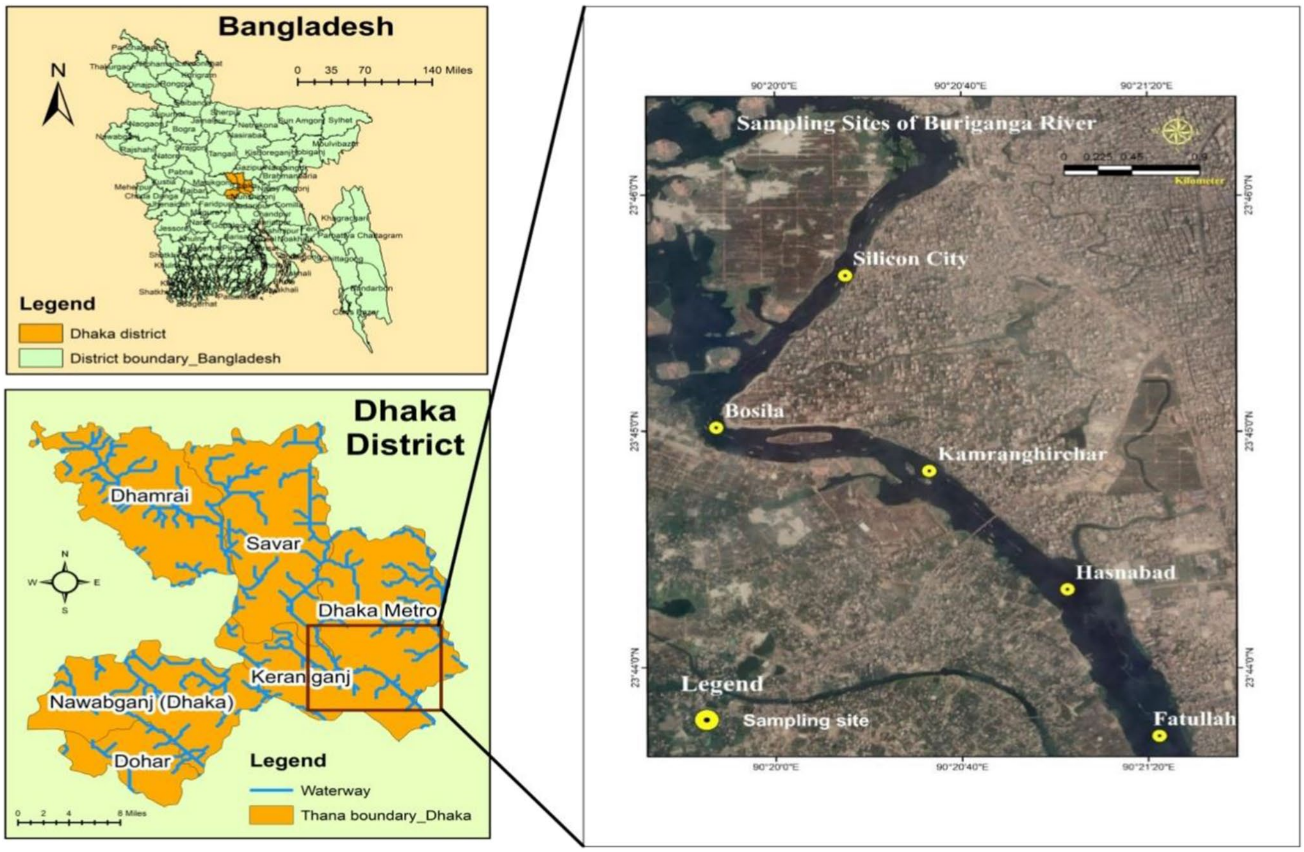


Fig. 1 Map representing the sampling sites of the present study

randomly collected depending on the availability of the mentioned fish species from the different locations of the study area during the period from November to December 2017. Basically, the fish samples were purchased from the fishermen for this study from the respective locations. It should be mentioned worthy that the fishermen did not obtain those fishes from the respective locations specifically for the project; rather, they collect those fishes for their consumption, and moreover, in most cases, are brought by the vendors to the different markets for sale. Regardless, the collected fish samples were tagged with an identification number and brought to the laboratory for subsequent analysis. In the laboratory, the collected fish samples were washed with tap water several times and cut into small pieces prior to sample preparation. Separated edible fish portions were washed with tap water and finally made ion free by rinsing with deionized water several times [8, 25]. All the fish samples were dried and grounded to fine powder, and from each sample, pellets were prepared in triplicate for irradiation with EDXRF following Hasan et al. [10].

Sample Irradiation and QA/QC

The analytical tool used for PTE determination in fish samples was energy-dispersive X-ray fluorescence (EDXRF) spectroscopy, a multi-elemental nuclear analytical technique well suited for samples of solid matrix [10, 11]. The entire set-up of EDXRF and functioning procedure is described elsewhere [32–34]. To get precise and accurate data, all the laboratory materials and glass wares were cleaned, acid washed, and rinsed with deionized water, several times, to avoid any risk of contamination. For QA/QC of the obtained results of elements in the fish muscles, very widely used certified reference material (CRM) Tuna fish homogenate/IAEA-350 was used, from which pellets were prepared for establishing a calibration curve [11, 31]. The validity of the calibration curve was assured by addressing certified reference material (CRM) "DORM-2" obtained from the National Research Council of Canada, following similar procedure as reported by Wahiduzzaman et al. [35], and obtained results are found in good agreement with the certified values, which is presented in Table 1.

Table 1 Comparison between experimental results and certified values (mg kg^{-1}, dry weight, DORM-2)

Element	Results obtained	Certified values	Relative error,%	MDL, mg kg-1
Cr	30.07	34.70	13.34	0.27
Mn	-	-	-	0.28
Fe	139	142	2.11	0.27
Cu	2.41	2.34	−2.99	0.19
Zn	25.3	26.6	4.88	0.15
Hg	4.87	4.64	−4.96	0.12
Pb	0.071	0.065	−9.23	0.03
As	16.9	18.0	6.11	0.41

Multivariate Analysis

The present study employed principal component analysis (PCA) and hierarchical cluster analysis (HCA) to find out possible sources of PTEs in the fish samples. PCA was employed by applying varimax rotation with Kaiser normalization by extracting the eigen values and eigenvectors from the correlation matrix. The number of significant factors and the percent of variance explained by each of them were calculated by using the software package of SPSS v25.0. The groupings of PTEs in fish species are identified by HCA through the dendrogram, which indicates an arrangement or association between the elements and displays the information as degree of contamination of PTEs.

Estimation of Metal Pollution Index (MPI) in Fish Species

Accumulation of all the PTEs studied in the different fish species denoted as MPI was calculated following Ureso et al. [35][36], which is principally the geometrical mean of the measured PTEs in the concerned fish species. The formula used to calculate MPI is:

$$MPI = (Cf1 \times Cf2 \times \ldots ..Cfn)\ ^{1}/_{n} \quad (1)$$

where *Cfn* is the concentration of the *n*th element(mg/kg dry wt.) in the muscle of a certain fish species. MPI value has been categorized by Jamil et al. [28] as not impacted (MPI > 2); very low contamination (2 < MPI < 5); low contamination (5 < MPI < 10); medium contamination (10 < MPI < 20); high contamination (20 < MPI < 50); very high contamination (50 < MPI < 100); and extreme contamination (MPI > 100).

Index Analyses for the Risk of Human Health

Health hazard indices like estimated daily intake (EDI), non-carcinogenic risk (THQ), hazard index (HI), carcinogenic risk (CR), and cumulative carcinogenic risk (TCR) can portray the clear picture of PTE toxicity in human through ingestion of contaminated food items. Quite a few studies have been conducted [8, 25, 27, 32, 37, 38] all over the world regarding this matter; however, a brief information on hazard parameters used in this study is presented concisely in Table 2.

Results and Discussion

Relative Abundances of Heavy Metals in Fish Species

The levels of eight heavy metals, viz., Mn, Fe, Cu, Zn, As, Hg, Pb, and Cr, are measured using the EDXRF technique in all fish samples and the results obtained are presented in Table 3. Detailed findings can be delineated as follows:

Manganese (Mn) is considered an essential element for human health. In this study, the mean Mn concentration was found 1.01, 0.42, and 0.39 mg kg^{-1} in *Channa punctata*, *Mastacembelus armatus*, and *Heteropneustes fossilis*, respectively, whereas the level of Mn in the rest of the fish species was too low to be detected by the system. However, the detected values were higher than the WHO [39] suggestive guideline (0.01 mg kg) but within the safe limit (0.05) suggested by the Federal Environmental Protection Agency (FEPA) [40] except *Heteropneustes fossilis*. In an article, Bristy et al. [41] reported the ranges of Mn were < 0.40–1.45 and 0.78–2.03 mg kg^{-1} in coastal and river fishes, respectively, which agreed with the present findings. According to the measured value of Mn, fish species can be assembled as *Otolithoides pama* (1.31 mg kg) > *Channa punctata* (1.01 mg kg) > *Mastacembelus armatus* (0.42 mg kg) > *Heteropneustes fossilis* (0.39 mg kg) > *Colisa fasciata* (< 0.31 mg kg) = *Amblypharyngodon microlepis* (< 0.31 mg kg) = *Awaous guamensis* (< 0.31 mg kg) = *Batasio batasio* (< 0.31 mg kg) = *Gonialosa manmina* (< 0.31 mg kg) = *Labeo calbasu* (< 0.31 mg kg).

Iron (Fe) is present in every living cell and contributes significantly in the production of hemoglobin and certain enzymes in human body. Weakness, inattentiveness, and poor immunity system are the common features of Fe deficiency. In a report, the WHO declared that "anemia" caused by lack of Fe in the body is one of the most common nutrient deficient diseases globally [42].

Table 2 The description of used indices of heavy metals

Indices	Purposes	Equation used to calculate the index	References
Estimated daily intake (EDI)	The EDI was assessed using the metal concentrations in the studied fish muscles and their daily consumption	$EDI = \frac{Cn \times IGr}{Bwt} \ldots\ldots\ldots\ldots (2)$ where Cn represents the determined concentrations of heavy metal estimated in the fish tissues (mg/kg dry wt); IGr is the ingestion rate adopted by FAOSTAT database (55.5 g/day for adults and 52.5 g/day for children); and Bwt is the body weight (70 kg for adults and 15 kg for children)	[61, 65]
Target hazard quotient (THQ)	THQ was calculated to get an indication of non-carcinogenic risk assessments through the consumption of contaminated fish species	$THQs = \frac{Ed \times Ep \times EDI}{At \times RfD} \times 10^{-3} \ldots\ldots\ldots\ldots (3)$ where Ed is the exposure duration (65 years), EP is the exposure frequency (365 days/year); A_T is the average time for non-carcinogens (ED × EP); and R_fD is the oral reference dose (mg/person/day) of metals, viz., Mn (0.14), Fe (0.7), Cu (.3), Zn (0.3), As (0.003), Hg (0.0001), Pb (0.002), and Cr (0.14) respectively. TQH values less than 1 denote non-significant risk effects	[65, 71, 72]
Hazard index (HI)	The HI has been calculated to determine the amount of multiple elements intake by multiple fish species by the consumer. It is the summation of THQ value	$HI = \sum_{i=k}^{n} THQ \ldots\ldots\ldots\ldots\ldots (4)$ where HI > 1 refers that the consumers will experience significant health hazards due to non-carcinogenic metals exposure	[11, 71, 72]
Cancer risk (CR)	Carcinogenic risk describes the incremental probability of cancer in an individual, over a lifetime, due to exposure to a substantial carcinogen	$CR = \frac{Ed \times Ep \times EDI \times CSF}{AT} \times 10^{-3} \ldots\ldots\ldots\ldots (5)$ where CSF is the oral slope factor of carcinogens (mg/kg/day) provided by the USEPA (2010a, 2010b); all the heavy metals do not have carcinogenic health effect; in this study, only Pb, Cr, and As are considered and the CSF (slope factor) are available only for 0.0085, 0.003, and 15×10^{-3} for Pb, Cr, and As respectively	[14, 65]
TCR	Cumulative cancer risk	$\sum CR \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$	[10]

Table 3 Distribution of heavy metals in different fish species

Element, mg/kg	Sample ID										WHO (mg/Kg) [39]	FEPA (mg/kg) [40]
	Kholshe fish (*Colisa fasciata*)	Poa fish (*Otolithoides pama*)	Mola fish (*Amblypharyngodon chulabhornae*)	Baila fish (*Glossogobius giuris*)	Tengra fish (*Batasio tengana*)	Taki fish (*Channa punctata*)	Baim fish (*Mastacembelus armatus*)	Chapila fish (*Gudusia chapra*)	Shing fish (*Heteropneustes fossilis*)	Kalibaos fish (*Labeo calbasu*)		
Mn	<0.31	1.31 ± 0.11	<0.31	<0.31	<0.31	1.01 ± 0.09	0.42 ± 0.02	<0.31	0.39 ± 0.01	<0.31	0.01	0.5
Fe	72.76 ± 5.83	98.58 ± 10.84	59.63 ± 6.56	69.90 ± 6.70	92.84 ± 11.16	65.67 ± 9.18	73.67 ± 11.02	83.78 ± 11.76	78.50 ± 10.87	65.67 ± 7.88	50	-
Cu	17.92 ± 1.61	19.68 ± 1.77	24.99 ± 3.25	24.75 ± 2.97	26.70 ± 2.94	16.09 ± 1.78	18.03 ± 1.62	21.41 ± 1.93	17.10 ± 1.54	20.36 ± 2.09	30	1.3
Zn	90.83 ± 9.23	189.64 ± 19.06	160.25 ± 14.42	128.42 ± 16.69	89.92 ± 11.58	82.07 ± 11.49	89.44 ± 10.73	117.99 ± 17.62	148.92 ± 18.34	107.16 ± 10.79	50	75
As	0.41 ± 0.03	0.46 ± 0.04	0.43 ± 0.03	0.51 ± 0.04	0.43 ± 0.03	0.47 ± 0.02	0.50 ± 0.04	0.51 ± 0.03	0.46 ± 0.03	0.45 ± 0.02	0.001	-
Hg	1.36 ± 0.12	0.39 ± 0.03	0.40 ± 0.02	0.38 ± 0.02	0.33 ± 0.02	0.40 ± 0.01	0.34 ± 0.01	0.43 ± 0.02	0.36 ± 0.01	0.35 ± 0.02	0.5	-
Pb	0.50 ± 0.06	0.32 ± 0.03	0.32 ± 0.02	0.45 ± 0.06	0.65 ± 0.05	0.43 ± 0.01	0.44 ± 0.03	0.47 ± 0.03	0.43 ± 0.35	0.33 ± 0.02	0.5	2.0
Cr	< 0.41	0.51 ± 0.04	0.48 ± 0.03	< 0.41	< 0.41	0.94 ± 0.04	0.62 ± 0.03	0.44 ± 0.01	< 0.41	0.63 ± 0.02	0.05	0.15
MPI	5.625	3.301	3.494	5.174	5.231	3.005	2.634	3.660	3.431	3.350	-	-

However, the maximum and minimum concentration of Fe was found in *Otolithoides pama* (98.58 mg kg^{-1}) and *Amblypharyngodon microlepis* (59.63 mg kg^{-1}). Khan et al. [25] reported the mean Fe concentrations in spotted snakehead, Tatina, and Mozambique tilapia of river Buriganga were 83.48, 93.53, and 217.49 mg kg^{-1} respectively. However, in the present study, the value of Fe exceeded the WHO [39] recommended value of 50 mg kg^{-1} for all the investigated fish species. The sequence of Fe in the studied fish species can be ranked as *Otolithoides pama* (98.58 mg kg^{-1}) > *Batasio batasio* (92.84 mg kg^{-1}) > *Gonialosa manmina* (83.78 mg kg^{-1}) > *Heteropneustes fossilis* (78.50 mg kg^{-1}) > *Mastacembelus armatus* (73.67 mg kg^{-1}) > *Colisa fasciata* (72.76 mg kg^{-1}) > *Awaous guamensis* (69.90 mg kg^{-1}) > *Channa punctata* (65.67 mg kg^{-1}) = *Labeo calbasu* (65.67 mg kg^{-1}) > *Amblypharyngodon microlepis* (59.58 mg kg^{-1}).

Copper (Cu) is an indispensable part of several enzymes and is important for the synthesis of hemoglobin, but excess amount causes detrimental effects on the human body. Maximum Cu was found in *Batasio batasio* (26.70 mg kg^{-1}) and minimum in *Channa punctata* (16.09 mg kg^{-1}), which are within the legislative value (Table 2) suggested by the WHO [39] but higher than the FEPA [40] recommended value of safety. A comparatively lower Cu concentration (1.44–2.25 mg/kg) was found in the literature reported by Köse et al. [43] in the fish muscles of Sakarya River and Dam Lakes, Turkey. Meanwhile, Bristly et al. [41] reported the range of Cu was < 0.60–8.42 and 1.64–8.52 mg kg^{-1} in coastal and river fishes respectively. The sequence for Cu in studied fish species was *Batasio batasio* (26.70 mg kg^{-1}) > *Amblypharyngodon microlepis* (24.99 mg kg^{-1}) > *Awaous guamensis* (69.90 mg kg^{-1}) > *Gonialosa manmina* (21.41 mg kg^{-1}) > *Labeo calbasu* (20.36 mg kg^{-1}) > *Otolithoides pama* (19.68 mg kg^{-1}) > *Mastacembelus armatus* (18.03 mg kg^{-1}) > *Colisa fasciata* (17.92 mg kg^{-1}) > *Heteropneustes fossilis* (17.10 mg kg^{-1}) > *Channa punctata* (16.09 mg kg^{-1}).

Zinc (Zn) is an essential element for both animals and humans and its toxic effects are rarely found. However, muscle stiffness and soreness, anorexia, nausea, and irritability are found to complain due to excess amount of Zn exposure [44]. The present study quantified the maximum and the minimum amount of Zn in Poa (189.65 mg kg^{-1}) and Taki fish (82.07 mg kg^{-1}) and level of zinc in all the studied fishes were higher than the WHO standard value of 50 mg kg^{-1} [39]. A higher Zn concentration compared to the guidelines values of various authorities is also recorded by other researcher [35, 45] which is consistence with the present findings. However, in a study, Xu et al. [46] delineated a lower Zn value (6.508–35.713 mg/kg) in cave fish muscle of Libo, Guizhou, China, which complied the fact that accumulation of metal in fishes varies from species to species and also the environment they live. The sequence for Zn in studied fish species was *Otolithoides pama* (189.64 mg kg^{-1}) > *Amblypharyngodon microlepis* (160.25 mg kg^{-1}) > *Heteropneustes fossilis* (148.92 mg kg^{-1}) > *Awaous guamensis* (128.42 mg kg^{-1}) > *Gonialosa manmina* (117.99 mg kg^{-1}) > *Labeo calbasu* (107.16 mg kg^{-1}) > *Colisa fasciata* (16.09 mg kg^{-1}) > *Batasio batasio* (89.92 mg kg^{-1}) > *Mastacembelus armatus* (89.44 mg kg^{-1}) > *Channa punctata* (82.07 mg kg^{-1}).

Arsenic (As) is basically considered a toxic element, and skin lesion, cardiovascular diseases, diabetes, and even cancer are reported to occur owing to arsenic (As) exposure. The present study quantified the maximum concentration of As in *Awaous guamensis* (0.51 mg kg^{-1}) and *Gonialosa manmina* (0.51 mg kg^{-1}), whereas the minimum concentration in *Colisa fasciata* (0.41 mg kg^{-1}). A contradictory result was reported by Islam et al. [27] where the determined As concentrations in spotted snakehead, Tatina, and Mozambique tilapia of river Buriganga were 3.39, 3.09, and 3.10 mg kg^{-1} respectively, which were more than sixfold higher than the present value. The sequence for As in the studied fish species can be assembled as *Awaous guamensis* (0.51 mg kg^{-1}) = *Gonialosa manmina* (0.51 mg kg^{-1}) > *Mastacembelus armatus* (0.50 mg kg^{-1}) > *Channa punctata* (0.47 mg kg^{-1}) > *Otolithoides pama* (0.46 mg kg^{-1}) = *Heteropneustes fossilis* (0.46 mg kg^{-1}) > *Labeo calbasu* (0.45 mg kg^{-1}) > *Amblypharyngodon microlepis* (0.43 mg kg^{-1}) = *Batasio batasio* (0.43 mg kg^{-1}) > *Colisa fasciata* (0.41 mg kg^{-1}).

Mercury (Hg) is considered a redundant element for human body, which less effectively excreted and thus holds on to the body tissues for a long time arising cognitive changes, neurological impairment, and lesions [47]. Nonetheless, Hg can enter into the fetus through the placenta and affect the central nervous system [48]. The maximum and the minimum mercury (Hg) contents were observed in *Colisa fasciata* (1.36 mg kg^{-1}) and *Batasio batasio* (0.33 mg kg^{-1}) fish; however, almost all the fish species have Hg in a level lower than the WHO [39] and EC [49] suggestive value with an exception of *Colisa fasciata*. A consistent Hg content (0.15–0.35 mg/kg) was reported by Effah et al. [50] in the fish samples of the Ankobra River, Ghana. However, a contradictory higher value of Hg was found [27] in spotted snakehead, Tatina, and Mozambique tilapia of river Buriganga likewise 2.24, 1.67, and 1.47 mg kg^{-1} respectively. The sequence for Hg in studied fish species can be ranked as *Colisa fasciata* (1.36 mg kg^{-1}) > *Gonialosa manmina* (0.43 mg kg^{-1}) > *Amblypharyngodon microlepis* (0.40 mg kg^{-1}) = *Channa punctata* i (0.40 mg kg^{-1}) > *Otolithoides pama* (0.39 mg kg^{-1}) > *Awaous guamensis* (0.38 mg kg^{-1}) > *Heteropneustes fossilis* (0.36 mg kg^{-1}) > *Labeo calbasu* (0.35 mg kg^{-1}) > *Mastacembelus armatus* (0.34 mg kg^{-1}) > *Batasio batasio* (0.33 mg kg^{-1}).

Lead (Pb) is an inessential element that endures neurotoxicity and nephrotoxicity in human body [51]. The present study confined the maximum and the minimum Pb level in *Batasio batasio* (0.65 mg kg^{-1}) and *Amblypharyngodon microlepis* and *Otolithoides pama* (0.32 mg kg^{-1}). Ahmed et al. [23] reported a higher value of Pb in *Gonialosa manmina* fish (13.52 mg kg^{-1}) from the Buriganga River; meanwhile, Islam et al. [27] reported a mean Pb concentration of 16.18, 6.03, and 6.04 mg kg^{-1} in spotted snakehead, Tatina, and Mozambique tilapia of river Buriganga respectively. Moreover, a similar Pb concentration (0.042–0.240 mg/kg) was reported by Jiang et al. [52] in fish species sampled from Dongting Lake, China. The decreasing order of Pb in studied fish species was *Batasio batasio* (0.65 mg kg^{-1}) > *Colisa fasciata* (0.50 mg kg^{-1}) > *Gonialosa manmina* (0.47 mg kg^{-1}) > *Awaous guamensis* (0.45 mg kg^{-1}) > *Mastacembelus armatus* (0.44 mg kg^{-1}) = *Heteropneustes fossilis* (0.43 mg kg^{-1}) > *Labeo calbasu* (0.33 mg kg^{-1}) > *Otolithoides pama* (0.32 mg kg^{-1}) = *Amblypharyngodon microlepis* (0.32 mg kg^{-1}).

Chromium (Cr) is somehow an essential element and its toxic effects are dependent on its oxidation state. Generally, the hexavalent state of Cr is toxic and has adverse effects on the skin like ulcerations, dermatitis, and allergic skin reactions. Irregular heartbeats, insomnia, headaches, depression, allergic reactions, and kidney or liver damage are some of the diseases caused by excessive Cr exposure. The maximum and the minimum concentration of Cr was found in *Channa punctata* (0.94 mg kg^{-1}) and *Gonialosa manmina* (0.44 mg kg^{-1}) and the concentration of Cr in all fish samples exceeded the WHO [39] suggestive value (Table 2). A lower Cr concentration was also reported (Cr: 0.28 ± 0.06 mg/kg) by Agah, H. [53] in the muscle of tiger tooth croaker fish from Chabahar Bay, Makoran, Iran. However, in a previous study [27], more than 12 folds higher Cr value was reported in spotted snakehead, Tatina, and Mozambique tilapia of river Buriganga, which might be the effect of tannery effluent, situated near the river. Concentration of Cr in studied fish species can be ranked as *Channa punctata* (0.94 mg kg^{-1}) > *Labeo calbasu* (0.63 mg kg^{-1}) > *Mastacembelus armatus* (0.62 mg kg^{-1}) > *Otolithoides pama* (0.51 mg kg^{-1}) > *Amblypharyngodon microlepis* (0.48 mg kg^{-1}) > *Gonialosa manmina* (0.44 mg kg^{-1}) > *Colisa fasciata* (< 0.41 mg kg^{-1}) = *Awaous guamensis* (< 0.41 mg kg^{-1}) = *Batasio batasio* (< 0.41 mg kg^{-1}) = *Heteropneustes fossilis* (< 0.41 mg kg^{-1}).

Multivariate Statistical Analysis

Principal Component Analysis (PCA)

The number of PCs is recognized by constructing a scree plot considering eigenvectors as a function of the factor number depicted in Fig. 2. From Fig. 2, it is evident that the first four PCs accounted 87.16% of variation with eigen value > 1, rendering 29.03%, 23.99%, 17.92%, and 16.21% variance in the fish samples, respectively (Table 4). However, PC1 is heavily loaded with Mn, Cu, and Cr, PC2 is loaded with Zn and Pb, PC3 is loaded very strongly with Hg and As, and PC4 is highly loaded with Fe (0.98) and moderately loaded with Mn (0.51).

Hierarchical Cluster Analysis (HCA)

The bunch of PTEs in studied fish species was recognized through HCA by plotting a dendrogram (Fig. 3) from Ward's method. The present study elucidated three distinct clusters supported by equal and difference of variables (Fig. 3). Cluster 1 is dominated by Mn and Cr that could have been derived from anthropogenic activities like chemical and tannery industries; however, As is also adjacent to cluster 1. Cluster 2 is governed by Cu and Zn, describing possible sources which are textile industries, agricultural runoff, and oil leakage from boats, cargoes, and ships. Finally, Fe, Pb, and Hg formed the third cluster—Cluster 3.

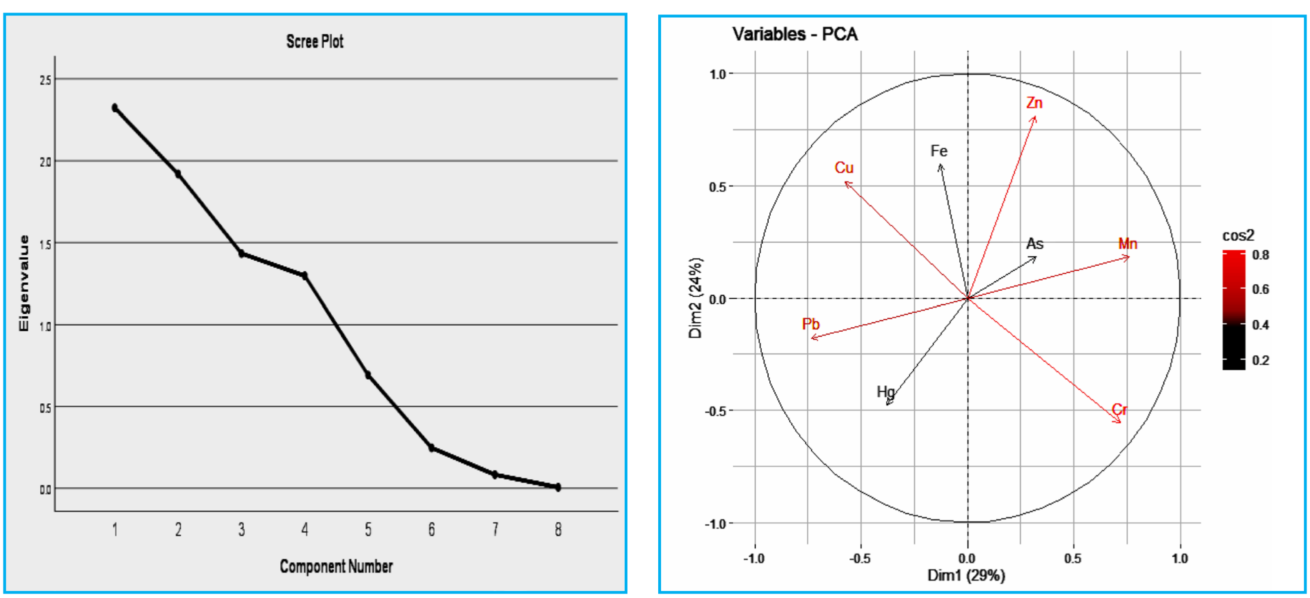
Table 4 Rotated component matrix and total explained variance of metals of fish species in Buriganga River where extraction method was principal component analysis and rotation method was varimax with Kaiser normalization

Elements	PC1	PC2	PC3	PC4
Mn	**0.697**	0.401	0.101	**0.509**
Fe	−0.115	−0.023	0.044	**0.977**
Cu	**−0.839**	0.003	0.198	0.04
Zn	−0.219	**0.917**	0.047	0.288
As	0.081	−0.071	**0.821**	0.001
Hg	0.067	−0.216	**−0.886**	−0.059
Pb	−0.302	**−0.86**	−0.091	0.345
Cr	**0.848**	−0.092	0.279	−0.283
Total	2.32	1.92	1.43	1.30
% Variance	29.03	24.00	17.92	16.21
% Cumulative	29.03	53.03	70.95	86.16

*Bold numbers represent significant loading

Source Apportionment

Chen et al. [37] believed that correlated pairs of metals are usually governed by similar local input, reciprocal subservience, and the same dispersion process with equal attitude towards their survival media. However, the PCA and HCA indicated that metals are mostly originated from anthropogenic sources like municipal wastes, discharge from industries, and agricultural activities which are a very common feature for the river Buriganga. Notably, solid and liquid wastes from the tannery industries at the Hazaribagh were



(a) (b)

Fig. 2 **a** Scree plot with drastic slopes and eigen values. **b** Variable factor map showing the quadrant to which trace metal belongs in PCA

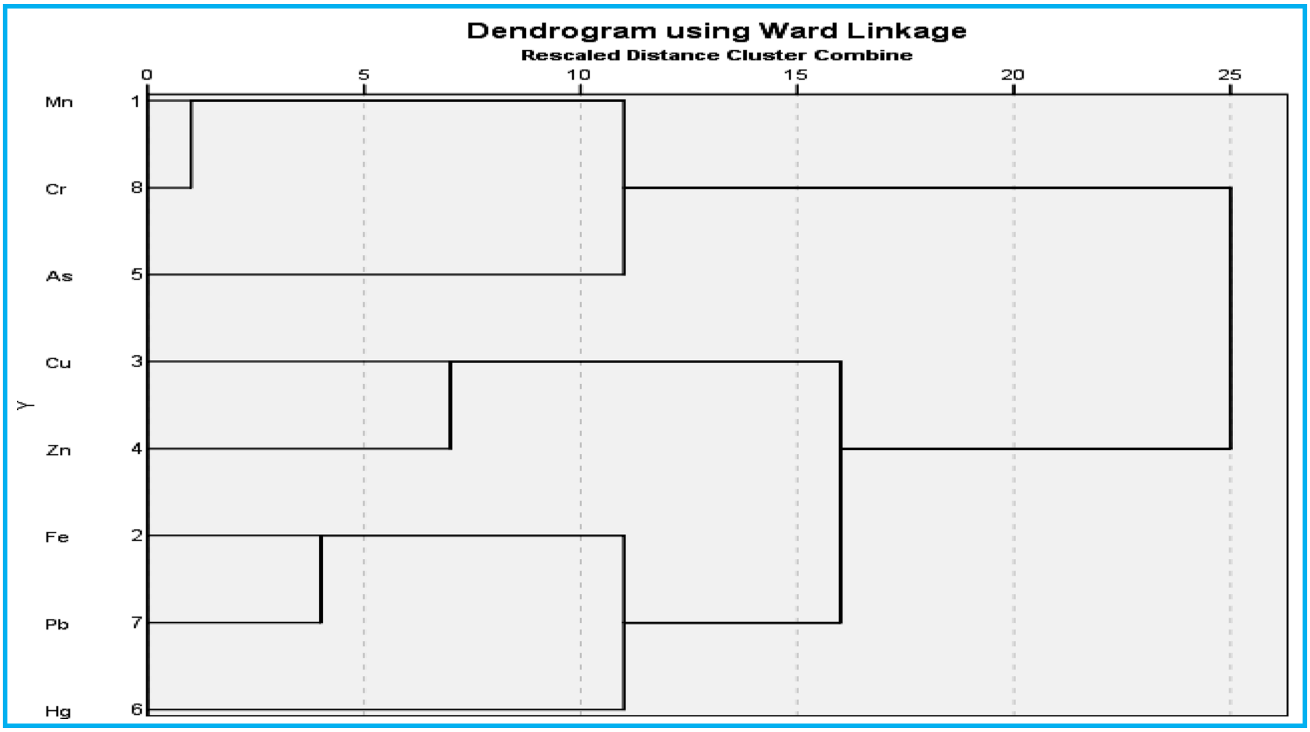


Fig. 3 Dendrogram showing clusters of trace metals as per their similarity

discharged regularly into the river till 2017 which contribute to elevate the level of Cr as tanning effluents mostly contained Cr; however, Zn, Pb, As, and Cu are also found in tanning effluent [26] as well. The source of Mn is mostly lithogenic combined with anthropogenic activities like leaching of agrochemicals from nearby land. Usually, Pb is considered a universal element and available in huge amounts in the riverine ecosystem, which could be originated from the discharge of dyeing, printing industries, oil refineries, and textile industries situated in both the sides of the river. Moreover, the high level of Pb in the river can be explained by the leakage of vehicle oils coming from more than hundreds of launches, engine boats, and cargoes used for transportation in the river daily. In chemical and electrical industries, waste incineration processes are the common sources for riverine Hg. Moreover, wastes from the cosmetic sectors also contribute to elevate the level of Hg in the river. Furthermore, in recent years, an elevated level of environmental Hg, which originated from atmospheric deposition, especially in the highly populated industrial prone area, has been observed worldwide [54] that can act as a potential source of Hg as well.

Ecological and Health Risk Assessment

Metal Pollution Index (MPI) in Various Fish Species

The present study computed metal pollution index (MPI) for Mn, Cu, Zn, As, Hg, Pb, and Cr in the studied fish species and the results obtained are presented in Table 3. Calculated MPI of studied fish species followed a declining trend of *Colisa fasciata* (5.625) > *Batasio batasio* (5.231) > *Awaous guamensis* (5.179) > *Gonialosa manmina* (3.660) > *Amblypharyngodon microlepis* (3.494) > *Heteropneustes fossilis* (3.431) > *Labeo calbasu* (3.0350) > *Otolithoides pama* (3.301) > *Channa punctata* (3.005) > *Mastacembelus armatus* (2.634). *Colisa fasciata*, *Awaous guamensis*, and *Batasio batasio* fish lied in 5 < MPI < 10 class indicating low contamination, whereas *Otolithoides pama*, *Amblypharyngodon microlepis*, *Channa punctata*, *Gonialosa manmina*, *Heteropneustes fossilis*, and *Colisa fasciata* lied in 2 < MPI < 5 class, comprising very low contamination, and nonetheless, *Awaous guamensis* fish lied in MPI > 2 class indicating no contamination and has no negative impact on human health

[28]. A low level of metal contamination was reported by Ghosh el al. [9] in the fish samples collected from Mymensing, Bangladesh; in contrast, Khan et al. [27] reported a higher value of MPI in fishes of the Buriganga River. It is mentioned worthy that carnivorous and omnivorous fish species are fascinated to heavy metal accumulation in a higher concentration [29, 55] and hence most of the fish species belong to either carnivorous or omnivorous group.

Human Health Risk Analysis

Non-carcinogenic and carcinogenic effect on human health due to dietary intake of PTEs via fish consumption is evaluated and projected in Fig. 4 and Table 5. Measurement of EDI is the first step to calculate the non-carcinogenic and carcinogenic effects of human health. The maximum EDI value (Sect. 4a of Table 5) for Mn, Fe, Cu, Zn, As, Hg, Pb, and Cr was estimated in *Otolithoides pama* (4.585), *Otolithoides pama* (345.030), *Batasio batasio* (93.450), *Otolithoides pama* (663.740), *Awaous guamensis* and *Gonialosa manmina* (1.785), *Colisa fasciata* (4.760), *Batasio batasio* (2.275), and *Channa punctata* (3.290) fish in children, whereas the minimum for *Heteropneustes fossilis* (0.309), *Channa punctata* and *Labeo calbasu* (52.067), *Channa punctata* (12.757), *Channa punctata* (65.070), *Amblypharyngodon microlepis* and *Batasio batasio* (0.341), *Batasio batasio* (0.262), *Otolithoides pama* and *Amblypharyngodon microlepis* (0.254), and *Amblypharyngodon microlepis* (0.381) fish in adult respectively. However, the mean value of EDI for Mn, Fe, Cu, Zn, As, Hg, Pb, and Cr was estimated 2.739, 266.350, 72.461, 421.624, 1.621, 1.659, 1.519, and 2.112 for children and 0.621, 60.337, 16.415, 95.511, 0.367, 0.376, 0.344, and 0.479 for adults, respectively. However, the allowable daily intake (ADI) for Mn, Fe, Cu, Zn, As, Hg, Pb, and Cr are 2300, 8700, 900, 8000, 2.2, 0.6, 3.6, and 0.474 μg/kg-bw/day, respectively, suggested by different authorities [56–60], and rather than Hg and Cr, estimated EDI values of the rest of the elements were found within the allowable daily intake (ADI) value. However, regardless of age, the sequence of mean estimated EDI value of the studied PTEs is Zn > Fe > Cu > Mn > Cr > Hg > As > Pb and found children are more pregnable compared to adults (Fig. 4A), which is also supported by other researchers [8, 11, 61].

Target Hazard Quotient (THQ)

The THQ values are basically calculated to estimate non-carcinogenic effect, which is the ratio of EDI and Rfd (oral reference dose) value of the particular element present in the foodstuff. The present study enumerated threats of PTEs (Mn, Fe, Cu, Zn, As, Hg, Pb, and Cr) in human body through ingestion of contaminated fish species (Sect. 4b of Table 5 and Fig. 4B). Notably, a THQ value greater than 1 is the indication of vulnerable health conditions, while THQ < 1 is the indication of safe condition. Among the elements studied, the estimated THQ values of Mn, Fe, Cu, Pb, and Cr were found below the unity for both the population groups

Fig. 4 Comparative study of health risk assessment

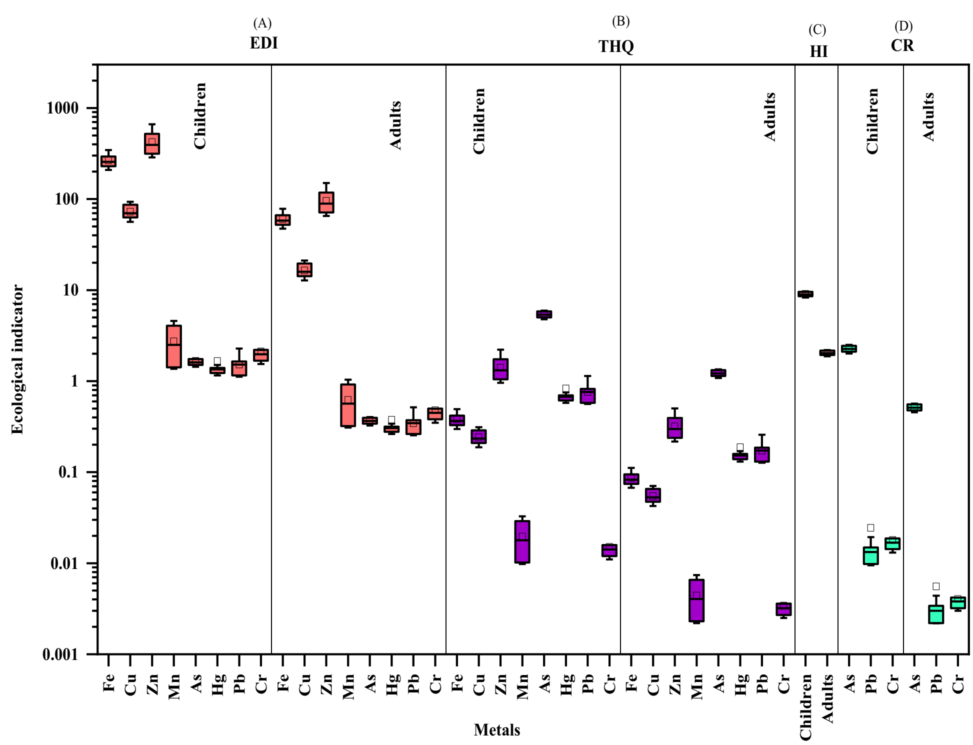


Table 5 Value of calculated health risk indices for each fish species in the studied metal for child and adult

Risk indices	Metal	Fish species																			
		Kholshe fish		Poa fish		Mola fish		Baila fish		Tengra fish		Taki fish		Baim fish		Chapila fish		Shing fish		Kalibaos fish	
		Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult
EDI µg/kg 4a	Mn	-	-	4.585	1.039	-	-	-	-	-	-	3.535	0.801	1.470	0.333	-	-	1.365	0.309	-	-
	Fe	254.660	57.688	345.030	78.160	208.705	47.278	244.650	55.421	324.940	73.609	229.845	52.067	257.845	58.410	293.230	66.426	274.750	62.239	229.845	52.067
	Cu	62.720	14.208	68.880	15.603	87.465	19.814	86.625	19.623	93.450	21.169	56.315	12.757	63.105	14.295	74.935	16.975	59.850	13.558	71.260	16.143
	Zn	317.905	72.015	663.740	150.357	560.875	127.055	449.470	101.819	314.720	71.294	287.245	65.070	313.040	70.913	412.965	93.549	521.220	118.072	375.060	84.963
	As	1.435	0.325	1.610	0.365	1.505	0.341	1.785	0.404	1.505	0.341	1.645	0.373	1.750	0.396	1.785	0.404	1.610	0.365	1.575	0.357
	Hg	4.760	1.078	1.365	0.309	1.400	0.317	1.330	0.301	1.155	0.262	1.400	0.317	1.190	0.270	1.505	0.341	1.260	0.285	1.225	0.278
	Pb	1.750	0.396	**1.120**	0.254	**1.120**	0.254	1.575	0.357	2.275	0.515	1.505	0.341	1.540	0.349	1.645	0.373	1.505	0.340	1.155	0.262
	Cr	-	-	1.785	0.404	1.680	0.381	-	-	-	-	3.290	0.745	2.170	0.492	1.540	0.349	-	-	2.205	0.500
THQ 4b	Mn	-	-	0.033	0.007	-	-	-	-	-	-	0.025	0.006	0.011	0.0024	-	-	0.010	0.002	-	-
	Fe	0.364	0.082	0.493	0.112	0.298	0.068	0.350	0.079	0.464	0.105	0.328	0.074	0.368	0.083	0.419	0.095	0.393	0.089	0.328	0.074
	Cu	0.209	0.047	0.230	0.052	0.292	0.066	0.289	0.065	0.312	0.071	0.188	0.043	0.210	0.048	0.250	0.057	0.110	0.045	0.238	0.054
	Zn	1.060	0.240	2.213	0.501	1.870	0.424	1.498	0.339	1.049	0.238	0.958	0.217	1.044	0.236	1.377	0.312	1.737	0.394	1.250	0.283
	As	4.783	1.084	5.367	1.216	5.017	1.136	5.950	1.348	5.017	1.136	5.483	1.242	5.833	1.321	5.950	1.348	5.367	1.216	5.250	1.189
	Hg	2.380	0.539	0.683	0.155	0.700	0.159	0.665	0.151	0.578	0.131	0.700	0.159	0.595	0.135	0.753	0.171	0.630	0.143	0.613	0.139
	Pb	0.875	0.198	0.560	0.127	0.560	0.127	0.788	0.178	1.138	0.258	0.753	0.171	0.770	0.174	0.823	0.186	0.753	0.170	0.578	0.131
	Cr	-	-	0.013	0.003	0.012	0.003	-	-	-	-	0.024	0.005	0.016	0.004	0.011	0.003	-	-	0.016	0.004
HI 4c		9.671	2.191	9.590	2.172	8.748	1.982	9.539	2.161	8.556	1.938	8.458	1.916	8.847	2.004	9.581	2.170	9.088	2.059	8.272	1.874
CR 4d	As	2.01E-03	4.55E-04	2.25E-03	5.11E-04	2.11E-03	4.77 E-04	2.50E-03	2.50E-04	2.11E-03	4.77E-04	2.30E-03	5.22E-04	2.45E-03	5.55E-04	2.50E-03	5.66E-04	2.25E-03	5.11E-04	2.21E-03	5.00E-04
	Pb	1.49E-05	3.40E-06	9.50E-06	2.20E-06	9.50E-06	2.20E-06	1.34E-05	3.00E-06	1.93E-05	4.40E-06	1.28E-05	2.90E-06	1.31E-05	3.00E-06	1.40E-05	3.20E-06	1.28E-05	2.90E-05	9.80E-06	2.20E-06
	Cr	-	-	1.52E-05	3.40E-06	1.43E-05	3.20E-06	-	-	-	-	2.80E-05	6.30E-06	1.85E-05	4.20E-06	1.31E-05	3.00E-06	-	-	1.87E-05	4.20E-06
TCR 4e		2.02E-03	4.59E-04	2.28 E-03	5.16 E-04	2.13 E-03	4.83 E-04	2.51 E-03	5.69 E-04	2.13 E-03	4.82 E-04	2.34 E-03	5.31 E-04	2.48 E-03	5.62 E-04	2.53 E-03	5.72 E-04	2.27 E-03	5.14 E-04	2.23 E-03	5.06 E-04

for all the fish species, revealing no non-carcinogenic health risk from ingestion of individual PTE through the consumption of fish. In contrast, THQ > 1 was estimated in As for both the population groups, while Zn exceeded the THQ threshold value of 1 for children in all the fish species but remained below 1 for adults. Furthermore, THQ value for Hg in both the population groups in all fish species was calculated THQ < 1 with an exception in *Colisa fasciata* (2.38) for children. Nevertheless, mean THQ (Fig. 4B) was found higher than unity for Zn and As for children, but for adult, it was greater than unity for As only. However, children are more susceptible to THQ compared to adult, and long-term exposure to any PTEs is harmful to health in any age group; thus, regular monitoring is suggested.

Hazard Index (HI)

HI is the summation of THQ of each element studied in individual fish species and an indicator of potential non-carcinogenic risk to humans. Lemly [62] and USEPA [63] categorized HI as negligible (HI < 0.1), low significant health effect (0.1 < HI < 1), medium significant health effect (1 < HI < 4), and very high risk (HI > 4). As mentioned in Sect. 4c of Table 5, estimated HI for all the fish species lied in the category of very high risk (HI > 4) for children and medium significant risk (1 < HI < 4) for adults via dietary intake. However, the HI value for each fish species for children and adult (Sect. 4c of Table 5) follows the same order and can be expressed as *Colisa fasciata* > *Otolithoides pama* > *Gonialosa manmina* > *Awaous guamensis* > *Heteropneustes fossilis* > *Mastacembelus armatus* > *Amblypharyngodon microlepis* > *Batasio batasio* > *Channa punctata* > *Colisa fasciata.* Human takes a wide variety of fish in their lifetime. Hence, estimation of hazard index (HI) considering the average value of elements in all fish species is more realistic. On the contrary, the average of HI is calculated (Fig. 4C) and observed that HI value for children and adults exceeded the threshold value of 1, indicating the studied fish species are not suitable for human consumption. In a previous study, Ahmed et al. [64] also recorded a higher HI value (1.255–1.773) in five fish species which were collected from the river Buriganga from August to September 2013.

Carcinogenic Risk (CR)

Among the elements studied, Pb, As, and Cr are considered carcinogenic and may stimulate both carcinogenic and non-carcinogenic effects on human health. USEPA group A prescribed inorganic arsenic (As) as a carcinogen, while Pb is a probable carcinogen based on animal studies according to USEPA group B2 [65]. Moreover, the WHO [51] and FAO [66] suggested Pb and Cr as highly toxic elements that contribute to the cancer risk via ingestion of fish species based on exposure duration and magnitude. However, Li et al. [67] and Orosun [68] classified precisely the cancer risk as extremely low (< 1E-06), low (1E-06 to 1E-05), low-medium (1E-05 to 5E-05), medium (5E-05 to 1E-04), medium–high (1E-04 to 5E-04), high (5E-04 to 1E-03), and extremely high risk (> 1E-03). The estimated CR values (Sect. 4d of Table 4 and Fig. 4D) of As due to ingestion of targeted fish species in children ranged between 2.50E-03 and 2.01E-03, which is a level VII contamination and revealed extremely high risk, while CR for As in adult ranges between 5.66 E-04 and 4.55E-04, expressing a level V contamination and rendering medium to high risk. CR value for Pb was found between 1.93E-05 and 9.50E-06 for children and 4.40E-06 and 2.20E-06 for adults, which are a level II contamination, indicating low risk for both population groups. In a study [69], it was found *M. vittatus* posed a moderate carcinogenic risk due to Pb while for other fish species of Buriganga River, a low cancer risk was found by Pb contamination. Nevertheless, CR value for Cr ranges between 2.80E-05 and 1.31E-05 for children that represent level II category and manifested low risk and 6.30E-06 to 3.00E-06 for adults, which imply level I category, indicating an extremely low risk. CR values for both adults and children regarding Cr and Pb were estimated safe in dried marine fish of Bangladesh [70]. Nonetheless, the cumulative cancer risk (TCR) was measured (Sect. 4e in Table 5) 2.20E-03, 2.28E-03, 2.13E-03, 2.51E-03, 2.13E-03, 2.34E-03, 2.48E-03, 2.53E-03, 2.27E-03, and 2.23E-03 and 4.59E-04, 5.16E-04, 4.48E-04, 5.69E-04, 4.82E-04, 5.31E-04, 5.62E-04, 5.72E-04, 5.14E-04, and 5.06E-04 for *Colisa fasciata*, *Otolithoides pama*, *Amblypharyngodon microlepis*, *Awaous guamensis*, *Batasio batasio*, *Channa punctata*, *Mastacembelus armatus*, *Gonialosa manmina*, *Heteropneustes fossilis*, and *Labeo calbasu* for children and adults respectively, indicating extremely high risk for children and high risk for adults. Thus, studied fish species contaminated with such high level of carcinogenic elements are in no way safe for human consumption.

Conclusion

Ten varieties of popularly consumed fish species were randomly collected from the highly polluted river Buriganga in triplicate, from five designated fishing spot, and analyzed for potential toxic elements (PTEs) Mn, Cu, Zn, As, Hg, Pb, and Cr by EDXRF spectrometry, and a diversified concentration of PTEs was observed among the fish species, which may be explained by their varied metal uptake capabilities and further translocation in different body parts. Mn, Cr, As, and Pb were found within the safe limit, while Fe, Cu, Zn, and Hg surpassed the threshold limit suggested by the WHO and FEPA. MPI value manifested an insignificant to low PTE contamination of the studied fish samples. The THQ-Mn, THQ-Fe, THQ-Cu, THQ-Pb, and THQ-Cr were found lower than the legislative value (THQ < 1) regardless of age group, whereas THQ-As was found unsafe for both the population groups (child: 5.402 and adult: 1.224); in addition, THQ-Zn and THQ-Hg are estimated unsafe for children but safe for adults. Mean HI value was found 9.03 and 2.05 for children and adults respectively; stipulated receptors are susceptible to high risk; however, children are noticeably at high risk than adults. As, Cr, and Pb are elements contributing significantly to the lifetime cancer risk through ingestion of the studied fish species and found arsenic (As) as the dominant among the three. Nevertheless, the cumulative carcinogenic risk (TCR) indicated all the fish samples are highly contaminated with As, Cr, and Pb and TCR for children lied in class VII category, suggesting to must solve the problem, whereas for adults, TCR lies in the VI category and suggesting need to pay attention. Chemometric analysis revealed Mn, Cu, Zn, and Fe are originated from both natural and anthropogenic sources; however, Pb, Cr, As, and Hg originated mainly from man-made sources. The industrial, municipal, agricultural, and urban activities near the river are responsible for the elevation of overall metal concentration in the Buriganga River from where fishes accumulate these elements via their gills, skin, and ingestion, increasing the level of metals in their body tissues and endangering their consumer's life, thus suggesting not consuming those fishes. However a vast investigation is required on the fishes of the Buriganga River as it is a major source of fish protein for peoples of home and abroad. Therefore, monitoring is necessary on regular basis to control the further deterioration of the river environment. Moreover, a strong and active management system needs to establish to ensure proper conservation of fish resources.

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Author Contribution Yeasmin N. Jolly: conceptualization, designing, supervision, visualization, writing (review and editing), final approval of the manuscript; Sadia A. Surovi: sample collection, preparation, and analysis; Shrin Akter, Jamiul Kabir, Khan M. Mamun: sample and data analysis; Arafat Rahman: statistical analysis and editing; Sheikh M. Mizanur Rahman: supervision.

Data Availability The datasets generated and analyzed during the current study are available within the text.

Declarations

Ethics Approval This is an observational study jointly conducted by the Atomic Energy Centre, Dhaka, and University of Dhaka. Both the organizations had confirmed that no ethical approval is required for this study.

Consent to Participate N/A

Consent to Publish N/A

Conflict of Interest The authors declare no competing interests.

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