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Research Article
Human Health Risk Assessment with Reference to the Consumption of Shrimp and Marine Fish

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Abstract
Background and Objective: Meghna river estuary plays a major role in the national fish production and is being connected to other channels that might accelerate the magnification of heavy metals in human tissue through the food chain after fish consumption. Therefore present study aimed to elucidate possible human health risks should people consume fishes from this river. **Materials and Methods:** Total 5 heavy metals (Cu, Zn, Pb, Cd and Cr) in 6 being exported and highly consumed fish species (*Lates calcarifer*, *Penaeous monodon*, *Encrasicholina heteroloba*, *Polynemus paradiseus*, *Sillaginopsis panijus* and *Ilisha megaloptera*) from fish landing center during January 2016 to February 2017, near the Meghna river, Noakhali, Bangladesh were measured in the present study by using atomic absorption spectrometry (AAS). **Results:** The metal concentration (μg g^{-1}) varied as Cu 4.63- 73.57, Zn 39.54-180.44, Pb 0.011-0.019, Cd .003-.122 and Cr 4.92-15.88 where Zn and Cr surpassed the different food safety guidelines. Estimation of daily dietary intake (EDI) of all the elements was measured from the national fish consumption data. Value <1.0 of estimated Target Hazard Quotients (THQ) for all fish species indicated the absence of public health hazard in the area for continuous consumption for 70 years. Besides, the Target carcinogenic risk (TR) for Pb (1.92 E-08) was also lying below the lifetime carcinogenic risk (E-05). **Conclusion:** Although, this result pointed out an almost safe level of metal content in fishes for human consumption still continuous monitoring is necessary to ensure the safety of humans who rely heavily on aquatic resources in that area.

Key words: Shrimp, marine fish, heavy metal, human health, carcinogenic risk, target hazard quotients, meghna river estuary

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Industrialization and urbanizations made the metal pollution globally as a matter of major health issues in the last few decades[1]. Recent studies revealed that heavy metal contamination poses a serious threat to humans as well as to the health of ecosystems[2,3]. Metal entrance from natural and anthropogenic sources to the aquatic ecosystem also pose a serious threat due to their toxic, stable, non-biodegradable and long persistent properties[4-6]. As they are toxic and non-biodegradable, even at low temperatures they can bio-concentrate and biomagnifies through food chain[7]. Although, Metals play double edge roles which also include the dietary requirement of essential trace elements[8]. Heavy metals (Cu, Co, Zn, Fe, Ca, Se, Ni and Mn) play a key role in the formation of hemoglobin, functioning enzymes and in the synthesis of vitamin in human; However the excessive level of these elements including Hg, As, Cr and Pb brought about many physiological disorders like renal failure, liver dysfunction, pulmonary disorders and cardiovascular disease) in human[9,10]. Despite low concentrations, Cd and Pb were found very toxic to humans[11]. Accumulation of Cd as a single element was reported for different organ disorders in human[12]. Cd was categorized as a carcinogenic element by the International Agency for Cancer Research in Cancer (IARC) and as cell death/cell proliferation by World Health Organization[13]. Not only that, but lead toxicity might also cause cardiovascular disease in adult[11].

Dietary intake of contaminated food, more specifically seafood is considered as one of the major sources of total human exposure to toxic chemicals such as heavy metals[14-17]. Water body can be contaminated by heavy metals in various ways such as domestic activities, industrial activities and also through atmospheric deposition[18]. Therefore, the coastal belt is well-known as the main receptors of heavy metals either directly or indirectly[19].

Fish plays a vital role in the human diet owing to its high nutritional quality[20,21]. In recent years, prospective nutritional and therapeutic benefits have made the fish's first choice to world consumer[22]. Eventually, fish itself is the single source of high-quality protein contributing about 17% of animal protein and 6.7% of all protein consumed by the world population[23]. Moreover, in Bangladesh fish accounted for 55% of animal protein intake[24] and contributes 42.1 g/capita/day[25].

Many studies have been conducted worldwide on the contamination of different fish species to determine their heavy metal contamination and human health risk[26-33]. Estuarine fish contamination by heavy metals has meagerly been investigated in Bangladesh in general and no information was available for the Meghna River estuary and its associated tributaries. In Bangladesh, the Meghna River estuary plays a very noteworthy role in supporting millions of livelihood[34]. But no significant studies have been undertaken to investigate the risk assessment on human health from the consumption of fish of this coastal belt region of Meghna estuary. Recent studies reported the enrichment of heavy metals and fish in various rivers in Bangladesh[35-40]. In this study, it emphasized the measurement of Cu, Zn, Cd, Pb and Cr in muscle tissues of fish from Meghna River Estuary and estimated the health risk posed by fish ingestion of this coastal region of Bangladesh.

MATERIALS AND METHODS

Study area: The present study was conducted from January 2016 to February 2017 in Meghna river estuary, Noakhali, Bangladesh. Noakhali region located at the southern coastal belt of Bangladesh adjacent to Meghna River. This Largest River of the country receives the flow from other rivers and directly connected to the Bay of Bengal. As a result, this river not only polluted by the industries which situated on the banks of this river or very close to the river system but also from the pollutants receives from other river systems. A total of 900 industries was found to be involved in disposing untreated industrial wastes into the rivers in Bangladesh[41]. No doubt, the presence of pollutants degrades the water quality and impairs its utility for drinking purposes and other aquatic animals, which serves as food for human being[42,43]. All samples (six different fresh marine fish species) of this study were collected from the fish landing center of Chairmanghat (Latitude: 22°31'19.88" Longitude: 91°5'21.68") near Meghna River estuary just after the landing of fish from the fishing vessel on June 2016. Chairmanghat is one of the busiest and well-known fish landing centers of the fish fished from the Meghna River estuary.

Sample collection and their preparation: Total of 60 samples of six different fresh marine fish species available in the Meghna River estuary was collected from the Chairmanghat fish landing center. These species were *Lates calcarifer* (local name Koral), *Penaeous monodon* (Shrimp), *Encrasicholina heteroloba* (anchoby), *Polynemus paradiseus* (Taposhi) *Sillaginopsis panijus* (Tular Dandi) and *Gudusia chapra* (Chapila). Fish samples were washed very carefully with distilled water and were packed into the cleaned plastic bags. Finally, they were carried to the laboratory of Fisheries and

Marine Science Department, Noakhali Science and Technology University (NSTU) for sample preparation. The edible part of cleaned fish samples was cut into small pieces after being thawing and they were oven-dried at 105°C to attain constant weight. Before being done the chemical analysis, dried samples were crumbled, pulverized with a porcelain mortar and pestle and eventually they were sieved through 2 mm nylon sieve. Prepared powdered samples were then stored in an airtight clean ziplock bag in freezing conditions for analysis.

Analytical method

Chemical analysis: The processed samples were brought to the Bangladesh Agricultural Research Institute (BARI) for further analysis. Digestion procedure was performed by Kotze *et al.*[44]. About 1 gram of each powdered sample was weighted and transferred to a screw cap digestion vessel. Mixture (HNO_3 55% and $HClO_4$ 70% (2:1 ratio) was added at room temperature. The vessels were then placed on a microwave digestion unit and continued digestion procedure until clear solution was observed. Once the digestion was complete, the vessels were allowed to cool to room temperature. The digest was diluted to 50 mL with Milli-Q water.

Sample preparation: About 0.25 mg samples were taken from each specimen and weighted by an electric balance. A digestion reagents were made by adding 5 mL of distilled water, 5 mL 65% HNO_3 acid and 2 mL 30% H_2O_2. Then the weighed samples were placed into the digestion reagent in a Teflon vessel. Samples were digested in a microwave system (Berghof-MWS2, Berghof speed wave, Eningen, Germany) overnight. After digestion, the solution was then filtered by using Whatman 0.42 µm filter paper and stored in 50 mL polypropylene centrifuge tubes (Nalgene, New York).

Sample analysis: The concentrations of heavy metals Cu, Zn, Pb, Cr and Cd were measured by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) ELAN 9000 (Perkin Elmer) and results were expressed as parts per million, which were changed into micro-grams per gram (µg g^{-1} dry wt. of muscle tissue). The certified reference materials were analyzed to confirm analytical performance and good calibration precision (relative standard deviation below 20%) of the applied method.

Health risk assessment

Estimated daily intake assessment: Estimated daily intake (EDI) of heavy metals through fish was measured by using metal concentrations in samples, daily consumption and body weight by using following formula where the parameters are shown in Table 1[28,45,46]:

$$EDI = \frac{MC \times FIR}{BW} \quad (1)$$

The daily fish consumption rate for an adult (60 kg) was an average of 42.1 g on fresh weight basis in Bangladesh which was obtained from the 'Report of the household income and expenditure survey[25].

Daily consumption limit: Based on the carcinogenic effect, maximum allowable daily consumption rate/limit (CR_{lim}) of fish (kg day^{-1}), of the contaminants, was calculated by the following equation[47-49]:

$$CR_{lim} = \frac{ARL \times BW}{CSF \times MC} \quad (2)$$

In case of non-carcinogenic effects of the contaminants, the maximum allowable daily consumption of fish was determined using the following equation[47-50]:

Table 1: Summary statistics of input parameters in the health risk estimation

Symbols	Description	Units	Values
Mc	Metal concentration	µg g^{-1}	Presented in Fig. 1 and Table 2
FIR	Fish ingestion rate	g day^{-1}	42.1 g/person/day[25]
EF	Exposure frequency	days $year^{-1}$	365 days/year
ED	Exposure duration	years	70
RfD	Reference dose	mg/kg/day	Cu = 4.0E-02, Zn = 3.0E-01, Pb = 2.0E-03, Cd = 1.0E-03, Cr = 3.0E-03[50,52,78]
CF	Conversion factor		0.208 use to convert fresh weight to dry weight considering 79% moisture content of the fish fillet[75]
BW	Body weight	Kg	60[25]
ATn	Averaging time for noncarcinogen	days	25550 (70 years used in the study)
ATc	Averaging time for carcinogen	days	25550
CSF	Carcinogenic slope factor	mg/kg/day	Pb = 0.0085[52,78]

$$CR_{lim} = \frac{RfD \times BW}{MC} \quad (3)$$

where, CR_{lim} is the maximum allowable daily consumption rate/limit of contaminated fish (kg day^{-1}), ARL indicates the maximum acceptable individual lifetime risk level (in the present study 10-5 was used[49]), BW is the mean body weight of consumer population (kg), CSF shows the cancer slope factor; RfD stands for the oral reference dose (mg kg per day) and MC is the metal concentration in the edible part of fish (mg kg^{-1})[50].

For managers and individual persons, the USEPA notes that daily fish consumption limits may be more conveniently expressed as the allowable number of fish meals of a specified meal size that may be consumed over a given time period[51]. The maximum allowable consumption level of fish contaminated with heavy metals in terms of meals per month can be obtained by Eq. 4, in which the maximum allowable daily consumption in terms of kilograms is converted to meal consumption per month considering meal size[47-49]:

$$CR_{mm} = \frac{CR_{lim} \times T_{AP}}{MS} \quad (4)$$

where, CR_{mm} is the maximum allowable consumption rate in terms of meals month^{-1}, T_{AP} is the average period (30.44 day month^{-1}) and MS is the meal size (0.227 kg fish meals^{-1})[47]. If the number of meals of a contaminated fish species is higher than 16 per month, it suggests that there is no obvious human health risk by consumption of the fish species[51].

Non carcinogenic risk: The non-carcinogenic risk was investigated with the Target hazard quotient (THQ) which is an estimate of the risk level (non-carcinogenic) due to pollutant exposure. It was calculated as per US EPA Region III Risk-Based Concentration Table[52]. Here the input parameters used in the health risk estimation for fish intake from Meghna River Estuary is given in Table 1. The equation used for estimating THQ was as follows:

$$THQ = \frac{MC \times EF \times ED \times FIR \times CF}{BW \times AT \times RfD} \times 10^{-3} \quad (5)$$

Exposure to two or more metal pollutants may result in additive and/or collaborating effects. So, the cumulative health risk is evaluated by summing THQ that is known also as the Hazard Index (HI) as follows[51]:

$$HI = THQ\ (toxicant\ 1) + THQ\ (toxicant\ 2) + THQ\ (toxicant\ 3) + \cdots THQ\ (toxicant\ n) \cdots \quad (6)$$

The greater value of HI possesses a greater concern. HI above 1 indicates an unfavorable human health effect and suggests the need for possible remedial action[53].

Carcinogenic risk: Target cancer risk (TR) was used to indicate carcinogenic risks. The method to estimate TR was also provided in USEPA Region III Risk-Based Concentration Table[51,52,54]. The model for estimating TR was shown as follows:

$$TR = \frac{MC \times FIR \times CPSo \times EF \times ED}{BW \times AT} \times 10^{-3} \quad (7)$$

where, CSF is the cancer slope factor (mg/kg/day), while the other parameters have been defined previously. The US Environmental Protection Agency set an acceptable lifetime carcinogenic risk of 10^{-5} [52].

Statistical analysis: The means, standard deviations of metals in fish and other mathematical equations were performed by using Microsoft Excel version 10. Cluster Analysis (CA) and related figures were carried out by PAST version 3 and Microsoft Excel version 10.

RESULTS AND DISCUSSION

Trace elements level in fish: Relative distribution of metal (Cu, Zn, Pb, Cd and Cr) concentration (µg g^{-1}) in the muscle tissue of studied fish sample from Meghna River Estuary are presented in Fig. 1 where the starting of the bar from upper and lower (before and after box) indicate the minimum and

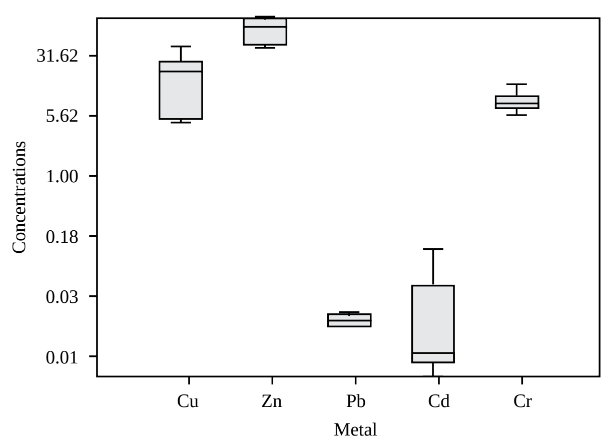

Fig. 1: Box plot showing the relative distribution of metal concentration (µg g^{-1}) in fish samples

Table 2: Level of Cu, Zn Pb, Cd and Cr in sampled fish muscle (μg g^{-1}) compared with different international organizations

Fish species	Cu	Zn	Pb	Cd	Cr
L. calcarifer	4.63±0.10	44.84±0.003	0.014±0.0009	0.006±0.001	7.58±0.75
P. monodon	41.34±0.97	93.29±0.92	0.018±0.0005	0.006±.0005	7.43±.56
E. heteroloba	21.27±1.07	88.88±1.69	0.017±0.00	0.017±0.001	8.55±0.46
P. paradiseus	5.32±0.05	57.94±0.14	0.013±0.0005	0.003±.0005	13.75±1.05
S. panijus	19.80±2.002	39.54±2.86	0.013±0.0002	0.122±.003	8.48±0.03
I. megaloptera	19.96±1.19	83.85±1.05	0.019±0.005	0.005±.002	5.68±0.905
Guideline value	30	30	2, 1.5	0.5, 0.005	12-13
Reference	WHO[16]	FAO[24]	WHO, EC[16,56]	FAO, EC[24,56]	USFDA[55]

Table 3: Comparison of the dietary intakes of trace elements of studied fish samples with the corresponding maximum tolerable daily intake (MTDI)

Trace elements	Average concentration	Estimated daily intake (EDI)	Maximum tolerable daily intake (MTDI) mg day^{-1}	Reference
Cu	18.72	0.0027	4.5	FAO/WHO[13]
Zn	68.05	0.0099	60	WHO[16]
Pb	0.015	0.0000023	0.21	JECFA[60]
Cd	0.03	0.0000039	0.06	JECFA[60]
Cr	8.58	0.0011	0.2	RDA[61]

maximum value respectively. The starting and ending of the WHISKER box (from the top) indicate 1st quartile and 3rd quartile respectively (Fig. 1). Bars inside the box (Fig. 1) indicate the median while the length of each box showing the interquartile range of the concentration of each metal. The concentration in fishes varies considerably among the species. Ranking order follows the path of mean concentrations of heavy metals in fish muscles as, Zn (68.05)>Cu (18.72)>Cr (8.58)>Cd (0.03) >Pb(0.015) respectively.

The concentrations of metal in six different fish species are listed in Table 2 with the threshold level set by the international agencies[16,24,55,56]. In this study, the highest and the lowest accumulation of Cu was found in *Penaeous monodon* (37.70±2.50 μg g^{-1}) and in *Lates calcarifer* (4.63±0.10 μg g^{-1}) respectively (Table 2). *Penaeous monodon* as because of bottom-dwelling species might result in a slightly higher concentration of Cu compared to the suggested value (30 μg g^{-1})[16]. Besides, Zn is known to be involved in most metabolic pathways in human and its deficiency is responsible for the loss of appetite, growth retardation, skin changes and immunological abnormalities[48]. In this study, a very high concentration of Zn was observed (39.54-88.88 μg g^{-1}) in all fish species that superseded the guideline[24] (Table 2).

Pb has been characterized as one of the toxic and detrimental substances to most of the life forms which can cause many undesirable health effects such as behavioral malfunction, slow growth and metabolism rate with other neuro and nephro toxicity[57]. The minimum and maximum Pb level observed were 0.013 μg g^{-1} in *S. panijus* and 0.019 μg g^{-1} in *I. megaloptera* respectively and these values were much lower than the maximum legislative value (2.0 and 1.5 μg g^{-1}) (Table 2) indicated acceptable limit for human consumption[16,56]. It is reported that, if Cd accumulates in the human body it may give rise to renal, pulmonary, hepatic, skeletal, reproductive effects and cancer[45]. The maximum Cd concentrations in fish samples allowed by the FAO and the European Community (EC) are 0.5 and 0.05 μg g^{-1}, respectively[24,56]. In the present experiment, Cd concentration in fish samples ranged from 0.006 to 0.122 μg g^{-1} (Table 2) which was little bit higher than the guideline of European Community[56]. The highest and the lowest amount of Cr recorded in our study was in *Polynemus paradiseus* and in *Ilisha megaloptera* respectively (Table 2). Although the concentration of Cr triggers in lipid metabolism and in insulin secretion[58]. However, all the observed values are within the guideline values of different organizations[55] (Table 2).

Estimated daily intake (EDI): Based on the assumption of 60 kg body weight per person and 70 years of exposure duration daily dietary exposure of the five heavy metals is determined. The Estimated Daily Intakes (EDIs) of heavy metal were evaluated based on each heavy metal average concentration and the respective consumption rate[59]. From Table 3, it can be seen that here an order of Zn>Cu>Cr>Cd>Pb maximum dietary intake followed. In this study, the average EDI values for all the studied metals are significantly below the standard[13,16,60,61]. Cr concentration in the studied fish species (5.68-13.75 μg g^{-1}, Table 3) was much higher than by Ahmed *et al.*[46].

Consumption rate limits: Based on the data presented in Table 4, daily consumption rate limits (kg day^{-1}) for six fish based on non-carcinogenic effects ranged from 0.024-10, 0.024-10, 0.0205-7.05, 0.013-9.21 , 0.02-9.21 and 0.031-12. Based on the carcinogenic effect of Pb, the daily consumption rate of six fish species are 5.042, 3.92, 4.14, 5.42 and 5.42 kg day^{-1} respectively.

Table 4: Estimated data of CR_{lim} (carcinogenic and non-carcinogenic), CR_{mm}, THQ, CSF and TR

Fish species	Metal	RfD	Non carcinogenic CR_{lim}	Non carcinogenic CR_{mm}	Carcinogenic CR_{lim}	Carcinogenic CR_{mm}	THQ	HI	CSF	TR
L. calcarifer	Cu	0.04	0.51	69			1.7E-2	0.408		
	Zn	0.3	0.4	54			2.2E-2			
	Pb	0.002	8.6	1153	5.042	677	1.0E-3		8.5E-3	1.7E-8
	Cd	0.001	10	1340			9.0E-4			
	Cr	0.003	0.024	4			3.7E-1			
P. monodon	Cu	0.04	0.058	8			1.5E-1	0.558		
	Zn	0.3	0.19	26			4.5E-2			
	Pb	0.002	6.66	893	3.92	526	1.3E-3		8.5E-3	2.20E-8
	Cd	0.001	10	1340			8.7E-4			
	Cr	0.003	0.024	4			3.6E-1			
E. heteroloba	Cu	0.04	0.13	15			7.7E-2	0.539		
	Zn	0.3	0.205	27			4.3E-2			
	Pb	0.002	7.05	947	4.14	555	1.2E-3		8.5E-3	2.10E-8
	Cd	0.001	3.53	473			2.4E-3			
	Cr	0.003	0.021	3			4.2E-1			
P. paradiseus	Cu	0.04	0.45	61			1.9E-2	0.716		
	Zn	0.3	0.31	42			2.8E-2			
	Pb	0.002	9.23	1238	5.42	726	9.4E-4		8.5E-3	1.60E-8
	Cd	0.001	20	2681			4.4E-4			
	Cr	0.003	0.013	2			6.7E-1			
S. panijus	Cu	0.04	0.1212	17			7.2E-2	0.522		
	Zn	0.3	0.46	62			1.9E-2			
	Pb	0.002	9.23	1237	5.42	726	9.5E-4		8.5E-3	1.60E-8
	Cd	0.001	0.491	66			1.7E-2			
	Cr	0.003	0.021	3			4.1E-1			
I. megaloptera	Cu	0.04	0.12	17			7.3E-2	0.391		
	Zn	0.3	0.215	29			4.0E-2			
	Pb	0.002	6.315	846	3.71	497	1.4E-3		8.5E-3	1.60E-8
	Cd	0.001	12	1609			7.3E-4			
	Cr	0.003	0.031	5			2.7E-1			

*THQ: Target Hazard Quotient, HI: Hazard Index, CSF: Carcinogenic Slope Factor, TR: Target Cancer Risk, RfD: Reference oral dose, CR_{lim}: Maximum allowable daily consumption limit of contaminated fish (kg day^{-1}), CR_{mm}: Maximum allowable consumption rate in terms of meals month^{-1}

Also the meal size of fish consumption per month based on carcinogenic and non-carcinogenic effects was determined and the results are listed in Table 4. Here, CR_{mm} values of the contaminants for carcinogenic effects were lower than the non-carcinogenic effects. Considering the non-carcinogenic effect, six fish species contaminated by Cu, Zn, Pb, Cd and Cr ranged from 8-69, 26-64, 846-1237, 29-1340 and 2-5 meals per month respectively. On the other hand, it is ranged from 497-726 for six fish species when considering the carcinogenic effects of Pb.

Risk assessment through THQ (target hazard quotient) and TR (target cancer risk): To portray the risk of fish consumption by the consumer, some indices were investigated and the results are shown in Table 4. THQs of each fish sample of individual heavy metal as well as average THQs are presented in Table 4 and Fig. 2, respectively. Here Cr shows the highest target hazard quotient, followed by the descending order Cu>Zn>Cd>Pb. Considering all the metal, the Hazard index

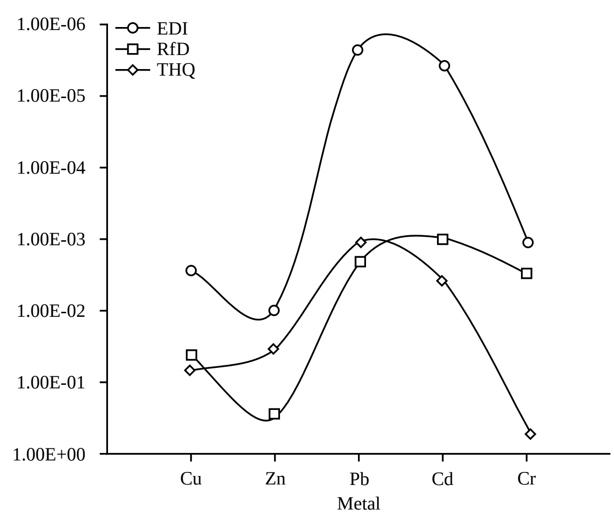

Fig. 2: Relationship among estimated average dietary intake (EDI), oral reference dose (RfD) and average Target Hazard Quotient (THQ) of individual metal observed in the studied fishes

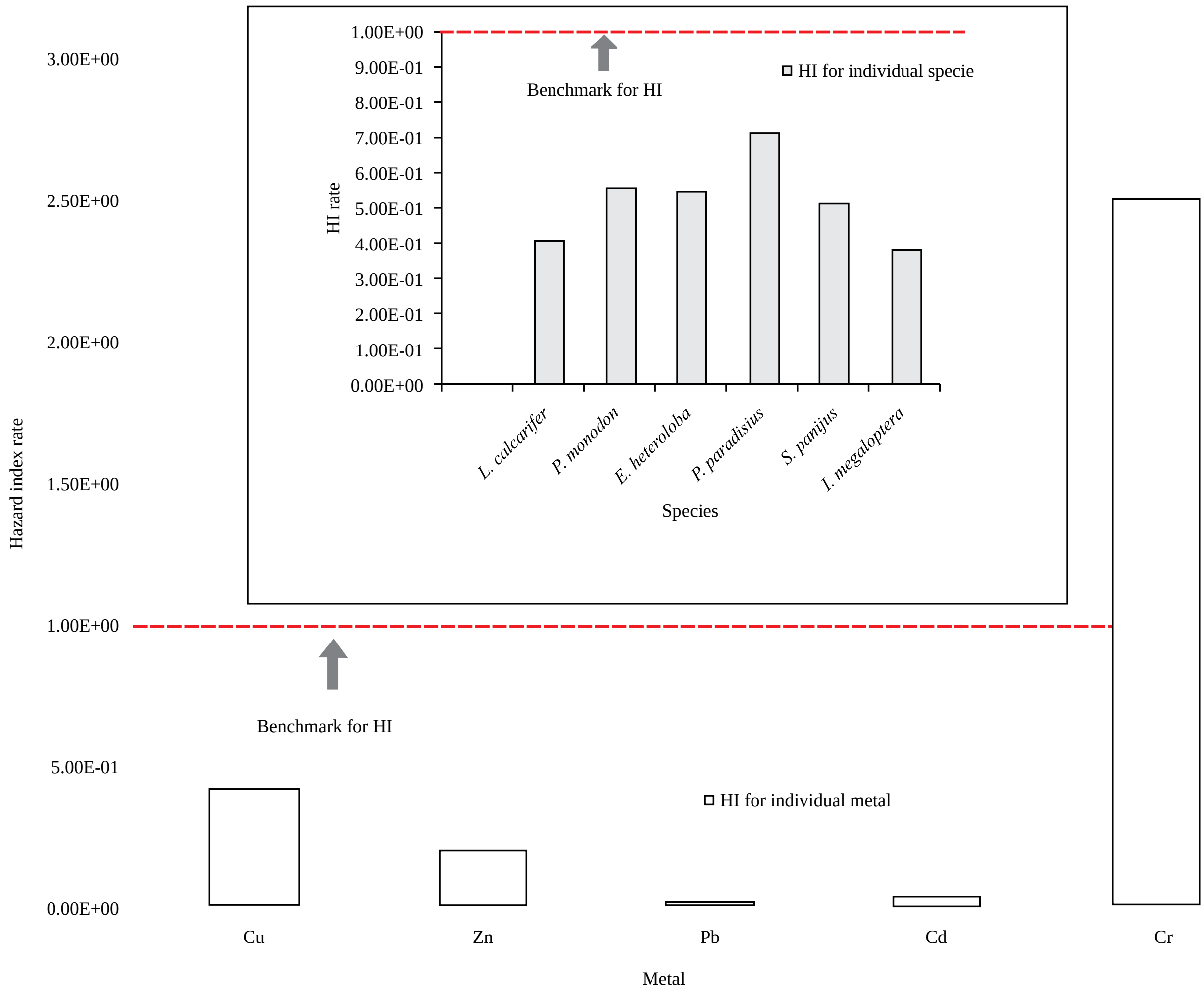

Fig. 3: Estimated Hazard Index (HI) rate for both metal and species with the benchmark value
HI benchmark for metal: Red-colored broken line at an upper position of inset, HI benchmark for species: Red-colored broken line at the lower position of inset

(HI/TTHQ) rate in this study found in a concerning condition. Here, HI (TTHQ) rate was calculated both for metal and specie (Fig. 3) where this rate was much concerning for metal rather than species. In the case of Cr, this value crossed their benchmark value 1, indicating potential health risk. These species of fish in the diet for a long time might expose to a considerable risk. Based on the exposure dose Target carcinogenic risk (TR) may have carcinogenic and non-carcinogenic effects. For this, in this study TR value resulting from the intake of Pb was calculated and listed in Table 4. USEPA[52,54] reported the excess cancer risk lower than E-06 is considered to be negligible, cancer risk above E-04 is considered to be unacceptable while risks lying between E-06 and E-04 are generally considered to be an acceptable range (Fig. 4). In the present study, TR value for Pb is measured 2.20E-08 to 1.60E-08 (average 1.92E-08) and therefore, the carcinogenic risk for Pb appears to be negligible. However, in this study, the probable health risk for the consumer due to metal exposure through fish consumption may not have possible health risk but as many other food stuffs (i.e. vegetables, meat, eggs, rice etc) and dust inhalation, which were not integrated in this study, could be a source of metal contamination and these sources should not be overlooked. So it is recommended that a study on both toxic and essential elements in all food commodities could be a possible solution in order to evaluate if any risk does exist in the study area.

Cluster analysis: Cluster analysis as discussed by Ward's[62] was performed with dendrogram (Fig. 5.) where cluster-I was composed of *P. paradiseus*, *S. panijus* and *L. calcarifer* while cluster-II consisted of *E. heteroloba*, *I. megaloptera* and *P. monodon*. Fish species in these clusters bear a

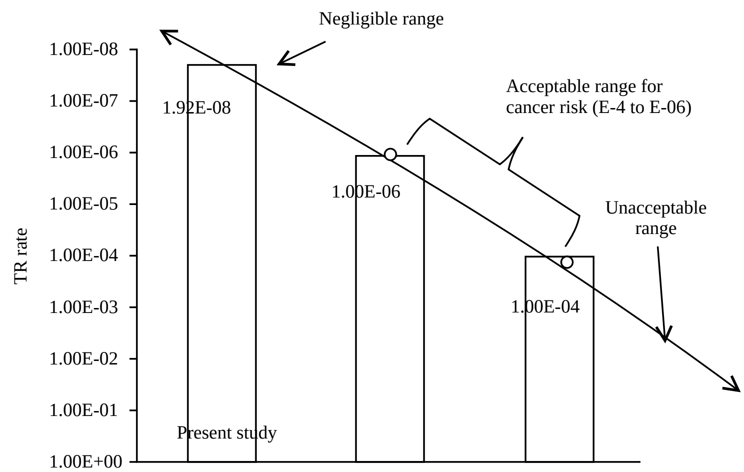

Fig. 4: Estimated target cancer risk (TR) for studied fish species compared with guideline (arrow on bars) value of United States Environment Protection Agency[51,52]

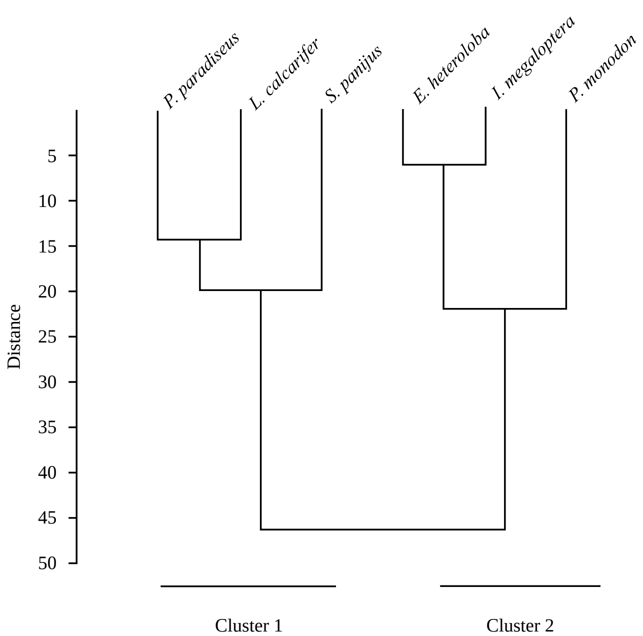

Fig. 5: Cluster analysis (dendrogram) of metal concentrations in studied fish species lying under two distinct clusters

resemblance in terms of their relative distribution of heavy metals and thus their nutritional value might be comparable to each other. Fish species under each cluster based on metal concentration are clearly distinct from each suggesting different sources of contamination[63-65].

Fish have a nature of the bioaccumulating high amount of metals in their tissues. Previous research suggested that fish can biomagnify the least water-soluble toxic metals. The reason behind this might be close contact with toxic metal with sources in soluble form. The concentration of metal in fishes varies considerably among the species. This could be due to variation in absorption and accumulation capabilities, growth period and stages of foods and climatic conditions[56,66]. From Table 5, it could portray the overall findings of the various river from the world. In this study, Cu concentration (μg g^{-1}) ranged from 4.63-37.70. Other workers reported the Cu levels (μg g^{-1}) in the literature in the range of 0.38-3.16 in Fish from Lake Macquarie, Australia[67], 0.06-0.35 in market fish from South China[28], 2.09±0.40 from Taiwan[68], Turkey[33] and also 5.90-11.52 from Buriganga River Bangladesh[45] and 5.17-7.48 in fish muscles from Dhaleswari River Bangladesh[69] (Table 5).

In our study concentration (μg g^{-1}) of Zn (39.54-88.88) exceeded the guideline value wherein the literature it had been reported in the range of 2.67-19.1in market fish from South China[28], 14.0-75.4 in fish from Lake Macquarie, New South Wales, Australia[67], 37.98±6.49 in fish muscles from Taiwan[68], 10.49 in fish collected from Pennar estuary, India[69]. Cr contents in the literature have been reported in the range of 6.92-12.23 mg kg^{-1} dry weight in fish species from the Dhaleshwari river, Bangladesh[70]. Similar results for freshwater fish from Buriganga river of Bangladesh has been reported[41]. It is also relevant to the study of Islam *et al.*[71] (Sitalakhya, Bangladesh); De *et al.*[29] (Hoogly, India); Rajeshkumar and Li[72] (Taihu Lake, China); Hilala and Ismailb[73] (Red sea, Jordan) and Ezemonye *et al.*[74] (Benin, Nigeria) (Table 5).

Previous studies suggested that a long term discharge of untreated industrial wastes could pollute the marine organisms and the addition of fertilizers could increase the Cd concentration in the farms water. The concentration of Cd in

Table 5: Concentration of the metals (µg/g wet weight) in the fish sample muscles of the river with different studies in the world.

River, location	Cu	Zn	Pb	Cd	Cr	References
Dhaleshwari, Bangladesh	5.17-9.45	ND	4.25-8.17	0.51-0.73	6.92-12.23	Ahmed *et al.*[36]
Bangshi, Bangladesh	8.33-43.18	42.83-418	1.76-10.27	0.09-0.87	0.47-2.07(1.12)	Rahman *et al.*[75]
Shitalakhya, Bangladesh	ND	ND	11.44-17.03	0.77-1.42	9.39-21.72	Islam *et al.*[71]
Buriganga, Bangladesh	5.90-18.77	194.68-292.13	ND	ND	3.57-18.84	Ahmed *et al.*[41]
Hoogly, India	16.22-47.97	12.13-44.74	12.40-19.96	0.62-1.20	N/A-3.89	De *et al.*[29]
Taihu lake, China	0.034-0.097	ND	0.036-0.087	0.023-0.042	0.032-0.092	Rajeshkumar and Li[72]
Red sea, Jordan	0.5-2.0	1.9-28.3	1.5-8.3	0.5-2.0	1-10.3	Hilala and Ismailb[73]
Benin, Nigeria	7.05	51.94	36.04	0.98	ND	L.I. Ezemonye *et al.*[74]
Meghna, Bangladesh	4.63-19.96	39.54-93.29	0.013-0.019	0.006-0.122	5.68-13.75	Present study

*ND: Not detected

the study was 0.003 µg g^{-1} which was in line with our current study[46]. Cd concentration if freshwater fishes of different rivers in Bangladesh was reported as 0.51-0.73 mg kg^{-1} in Dhaleshwari[36], Bangshi[75] and 0.77-1.42 in Sitlakhya River[71] (Table 5).

On the other hand, the highest concentration of Pb determined by Ahmed *et al.*,[46] was 0.017-0.090 which is in contrast with the present study. In the present study, highest amount of Pb was found in shrimp species (*Penaeous monodon*) which remain always in contact with sediment favor higher accumulation and similarly high content of this Pb concentration was reported to another bottom-dwelling shrimp species (*M. rosenbergii*) at Buriganga river[76]. Pb in the literature has been reported in the range of 4.25-8.17 mg kg^{-1} dry weight in fish species from Dhaleshwari river, Bangladesh[36] and 1.76-10.27 mg kg^{-1} in some edible fishes from Bangshi River, Savar, Dhaka, Bangladesh[75] (Table 5).

In previous studies, a higher concentration of metal had been reported in various findings. This could be due to a large amount of contamination of collection sites and reservoirs due to indiscriminate industrial discharge and other domestic and municipal effluents which is considered as the major source of accumulation of heavy metal in fish[77,78].

This study attempted in the best possible ways to provide important input on health risk and the maximum allowable fish consumption rate. But these inputs as only metal studies are not fully sufficient to provide in-depth information for minimizing the potential health risk in population especially those who consume local marine fish in coastal areas. In addition to metal studies, other chemical organic contaminants of concern such as dioxins/furans, chlorinated pesticides and polychlorinated biphenyls (PCBs) must be evaluated in edible fish from Meghna estuary. A long term monitoring program is crucial to be performed in coastal areas with high consumption of local marine fish to obtain the actual consumption rates and other cofounders factors on all food products in order to have an idea on potential health risk and food safety issues. This is to understand the actual possibilities to develop health risks on consuming local marine fish.

CONCLUSION

The current study showed the selected fish individuals had metal levels below the guideline values established by different environmental agencies and also the estimated daily intake from the targeted fish samples was not more than the respective recommended daily dietary allowance. Exposure to the studied metal showed that there is no health risk in this belt. Based on the obtained results, THQ values for all the trace elements were lower than the baseline value 1 and TR value was above a safe level, conveying a hopeful health risk-free message for consumers.

SIGNIFICANCE STATEMENT

Present findings are about health risk assessment through highly consumed fishes in upper Meghna river estuary and no study touched focusing the most commercial shrimp species (*Penaeous monodon*) that play a key role in foreign earnings in Bangladesh. Thus this study will be helpful to researchers as this site of the coastal area was not explored as well as data on these edible species data will provide a health initiative for the risk assessment and food safety of this belt.

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