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Assessment of heavy metals contamination and human health risk in shrimp collected from different farms and rivers at Khulna-Satkhira region, Bangladesh

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ABSTRACT

This study is aimed to assess the heavy metals contamination and health risk in Shrimp (*Macrobrachium rosenbergii* and *Penaeus monodon*) collected from Khulna-Satkhira region in Bangladesh. The results showed that the Pb concentrations (0.52–1.16 mg/kg) in all shrimp samples of farms were higher than the recommended limit. The Cd levels (0.05–0.13 mg/kg) in all samples and Cr levels in all farms except tissue content at Satkhira farm were higher than the permissible limits. The individual concentration of Pb, Cd, and Cr between shrimp tissue and shell in all rivers and farms were not statistically significant ($P > 0.05$). Target hazard quotient (THQ) and hazard index (HI) were estimated to assess the non-carcinogenic health risks. Shrimp samples from all locations under the current study were found to be safe for consumption, the possibility of health risk associated with non-carcinogenic effect is very low for continuous consumption for 30 years.

1. Introduction

The processed frozen shrimp industry is one of the largest export industries in Bangladesh, earning about $448 million per year. Shrimp exports represent 80% of the frozen food exports from Bangladesh and also 2.5% of world shrimp market [9]. The shrimp consumption has increased in recent years. The change shifted towards better understanding of healthy diet and nutritional importance of seafood consumption, for example high protein source, vitamin D, vitamin B_3 and zinc being beneficial for health [5]. Heavy metals are potentially gathered in aquatic environments including water, sediments, fish and shrimp. These are later transmitted into human body through the food chain [11,21]. Increased levels of heavy metals like Pb, Cd, and Cr in shrimp may constitute a food safety risk. However, heavy metals pollution in shrimp has become an important worldwide concern, not only because of the threat to shrimp, but also due to the non-carcinogenic health risks related with shrimp consumption. For example, renal failure and liver damage may occur due to the presence of lead in food [10]. Prolonged exposure to lead can result in coma, mental retardation and even death [2]. Cadmium injures the kidneys and causes symptoms of chronic toxicity including impaired kidney function, infertility, hypertension, tumours and hepatic dysfunction [15]. Likewise, Chromium could attack proteins and membrane lipids, thereby disrupt cellular integrity and functions [12,13]. Therefore, the global attention is increasing on the heavy metals contamination in shrimp.

The increased urbanisation, fast industrial development and population explosion contributed to rapid pollution growth. Owing to their persistence and bio accumulative nature, the discharge of heavy metals into the marine environment can reduce the biodiversity of marine ecosystems [15,18]. The consumption of such polluted marine based food by human may result in health risks such as liver damage and hepatic dysfunction. Likewise, tannery and poultry wastes are often used as a cheap source of fish feed in Bangladesh. The use of such feed stocks may theoretically increase

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the accumulation of toxic contaminants such as lead, cadmium and chromium in cultured fish and may cause a food safety risk [19].

Many studies have been performed to examine the heavy metals contamination in fish. In a recent study, concentration of heavy metals (Pb, Cd, Ni, Cr, Cu, Zn, Mn and As) in some fish species was measured in two different seasons from Bansi river in Bangladesh [16]. They reported no probable health risk to consumers under the current consumption rate. In another study, Ahmed et al. [1] studied the human health risk assessment of heavy metals in tropical fish and shellfish collected from the Buriganga river, and reported probable cancer risk. However, the evaluation of heavy metals such as Pb, Cd, and Cr in shrimp has not been reported at Khulna and Satkhira region in Bangladesh.

Although shrimp is one of the most important protein sources its contamination can be dangerous to public health. Therefore, the objective of this study is to assess the contamination status and health risk of lead, cadmium and chromium in two shrimp species of different farms and rivers at Khulna and Shatkhira region in Bangladesh.

2. Materials and methods

2.1. Materials

All chemicals were of analytical reagent grade.

2.2. Study area

Rupsha is an important river in southwestern region of Bangladesh formed from Bhairab and Atrai rivers and flowing by the side of Khulna city. Rivers are being polluted by increasing concentration of various types of contaminants including heavy metals causing tremendous health complications to the community in surrounding area. Above mentioned contaminants come from chemical industries, poultry farms, textile manufacturers and printing units established in this area. This fact leads to selection of Rupsha and Bhairab rivers for this study. Shrimp species were collected from various shrimp farms in Khulna and Shatkhira area in Bangladesh (Fig. 1). Two species of shrimp available in Rupsha and Bhairab rivers and some aquaculture were collected directly from professional fishermen from July to September 2013. The species were *Macrobrachium rosenbergii* (common Bengali name Golda) and *Penaeus monodon* (Bagda).

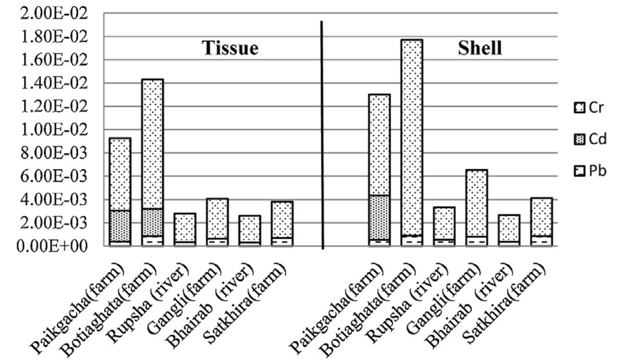

Fig. 2. Hazard index of three heavy metals from different locations at Khulna-Satkhira zone.

2.3. Preparation of shrimp sample

For the preparation process, 10 gm tissue and 1 gm shell of shrimp sample were taken and cut into small pieces using a clean knife and clean polyethylene sheet. The samples were then dried on the hot plate and placed in the Muffle furnace at 450 °C for 8 h. The samples were then cooled until white or grey colour ashes were obtained. 5 ml of 6 M HCl was introduced and the mixture was heated slowly on the hot plate with the addition of 5 drops of water. This step was repeated until all of the ash came into contact with the acid. The samples were heated again to evaporate. The residue was filtered with 50 ml of 0.1 M HNO_3. Filtered solution was preserved in plastic container and the solution was used for AAS analysis (Fig. 2).

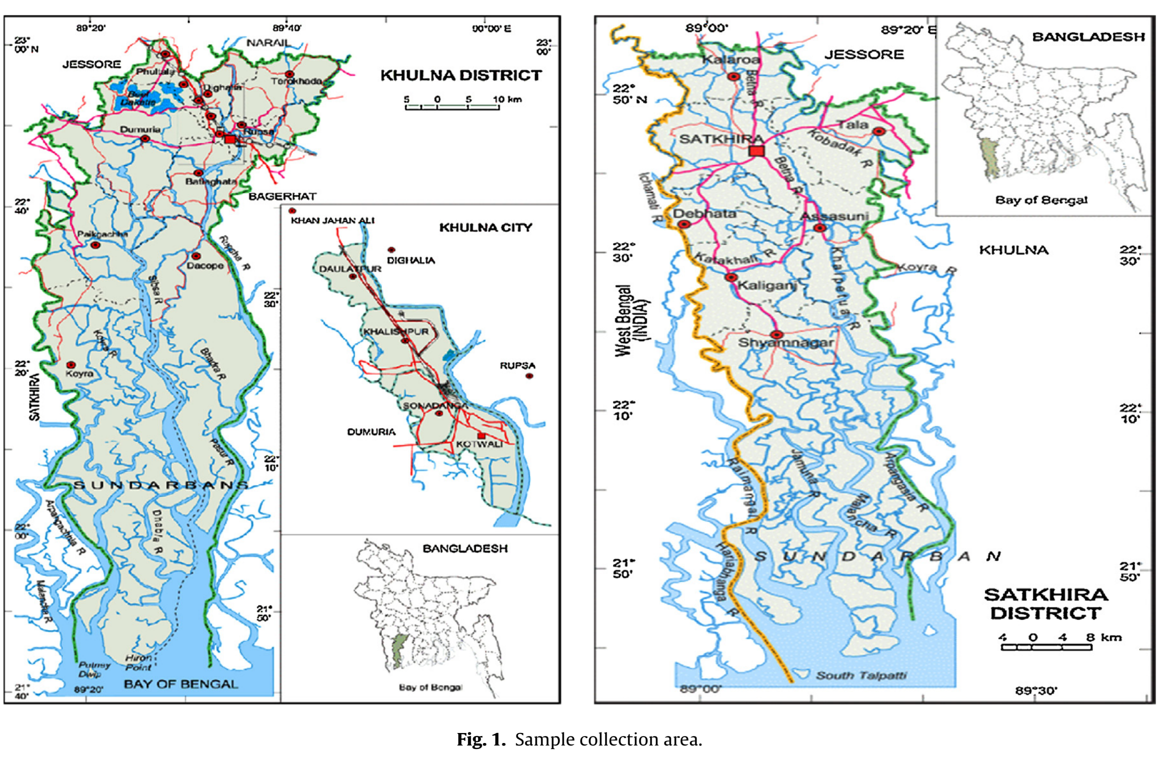

Fig. 1. Sample collection area.

2.4. Preparation of water sample

Water samples were collected and filtered through Whatman no. 41 filter paper in acid cleaned bottles. The samples were then acidified with 4 ml of supra pure HNO_3 and stored at 40 °C for 16 h. Amount of 2 ml HNO_3 was added into the sample of 250 ml using beaker of equal size. The sample beaker was covered with watch glass and kept on the hot plate to almost evaporate. The samples were removed from the hot plate and allowed to cool at room temperature. The samples were again filtered into 25 ml volumetric flask by Whatman no. 41 and levelled up to the mark with deionized water to be analysed.

2.5. AAS analysis

All samples were analysed for Pb, Cd and Cr by an atomic absorption spectrophotometer (Model GFA-EX7i, Shimadzu Corporation, Japan) using an air acetylene flame with digital read out system. The limits of detection of Pb, Cd and Cr were 0.04 mg/l, 0.006 mg/l and 0.01 mg/l respectively, and the wavelengths were 283.3 nm for Pb, 228.8 nm for Cd and 357.9 nm for Cr. All analyses were replicated three times to assess the reproducibility of measurement. The accuracy of analysis was verified by analysing the certified reference materials from International Atomic Energy Agency (IAEA). Blanks and calibration standard solutions were also analysed through the same method. The results were expressed as mg/kg.

2.6. Statistical analysis

This statistical analysis was carried out using Statistical Package for the Social Sciences (SPSS) version 20. Independent *t*-test was performed to understand statistically significant differences of metal concentrations between tissue and shell. The significance was set at 5% confidence level.

2.7. Hazard risk estimation

2.7.1. Target hazard quotient (THQ)

The THQ is used to determine the non-carcinogenic risk level due to pollutant exposure. To assess the health risk from metal contaminated shrimp, the THQ was calculated as per USEPA Region III Risk Based Concentration Table [20] by using the following equation:

$$THQ = \frac{MC \times IR \times EF \times ED \times CF}{RfD \times BW \times ATn} \times 10^{-3}$$

Here, MC is the heavy metal concentration in shrimp (mg/kg d.w.), IR is the fish ingestion rate (49.5 g/kg d.w.) [3], EF is the exposure frequency (365 days/year), ED is the exposure duration (30 years or 10950 days) for non-cancer risk as used by USEPA, CF is the conversion factor 0.208 (to convert fresh weight to dry weight by considering 79% of moisture content), RfD is the reference dose of individual metal (0.2 mg/kg for Pb, 0.005 mg/kg for Cd and 0.009 mg/kg for Cr) [20], BW is an average adult body weight (70 kg) and ATn is the average exposure time for non-carcinogens (10,950 days) [20].

2.7.2. Hazard index (HI)

The hazard index from THQs is denoted as the total of the hazard quotients [20].

$$HI = THQ(Pb) + THQ(Cd) + THQ(Cr)$$

Table 1
Heavy metals contamination in water sample (mg/l).

Location	Lead (mg/l)	Cadmium (mg/l)	Chromium (mg/l)
Paikgacha (farm)	0.013	0.002	0.010
Botiaghata (farm)	0.010	0.002	0.030
Rupsha river	0.011	0.001	0.021
Gangli (farm)	0.014	0.001	0.010
Bhairab river	0.010	0.001	0.013
Satkhira (farm)	0.018	0.001	0.017
WHO*	0.010	0.003	0.050

* Ref. [6].

Table 2
Mean (±SD) heavy metals concentration (mg/kg) in shrimp of different farms and rivers.

Location	Variety	Sample	Lead[a]	Cadmium[a]	Chromium[a]
Paikgacha (farm)	Golda	tissue	0.54 ± 0.09	0.09 ± 0.02	0.38 ± 0.01
		shell	0.73 ± 0.44	0.13 ± 0.02	0.53 ± 0.02
Botiaghata (farm)	Bagda	tissue	1.16 ± 0.12	0.08 ± 0.01	0.68 ± 0.02
		shell	1.23 ± 0.11	0.12 ± 0.04	1.03 ± 0.01
Rupsha river	Bagda	tissue	0.46 ± 0.18	0.05 ± 0.01	0.15 ± 0.02
		shell	0.76 ± 0.19	0.10 ± 0.03	0.17 ± 0.03
Gangli (farm)	Golda	tissue	0.86 ± 0.57	0.07 ± 0.01	0.21 ± 0.02
		shell	1.09 ± 0.25	0.09 ± 0.01	0.35 ± 0.02
Bhairab river	Golda	tissue	0.42 ± 0.12	0.06 ± 001	0.14 ± 0.01
		shell	0.52 ± 0.21	0.08 ± 0.01	0.14 ± 0.01
Satkhira (farm)	Golda	tissue	0.96 ± 0.38	0.06 ± 0.01	0.19 ± 0.01
		shell	1.16 ± 0.37	0.11 ± 0.02	0.20 ± 0.02

[a] Average of three trials ± standard deviation. The means are not significantly different at ($P > 0.05$).

3. Results and discussion

3.1. Heavy metal concentration in water

Concentrations of three heavy metals such as Pb, Cd, and Cr in water samples from different farms and rivers are listed in Table 1. The lead, cadmium and chromium concentrations in water were in the range of 0.01–0.018 mg/l, 0.001–0.002 mg/l and 0.10–0.030 respectively. All water samples in the present study were below the permissible limits (0.010 mg/l for Pb, 0.003 mg/l for Cd and 0.050 mg/l for Cr) recommended by WHO [6].

3.2. Heavy metals concentration in shrimp tissue and shell

Mean concentrations and standard deviations of heavy metals of two shrimp species (*M. rosenbergii* and *P. monodon*) in different farms and rivers of Khulna-Satkhira zone are shown in Table 2. Considerable variations in the concentration of Pb, Cd, and Cr were observed among all locations. This may be likely due to the differences of feeding habits and bioaccumulation factor.

3.2.1. Lead

The concentrations of lead in shrimp tissue ranged from 0.54 to 1.16 mg/kg, with the lowest content of approximately 0.42 mg/kg found in Bhairab river. However, the lead levels in shell samples were in the range of 0.52–1.23 mg/kg. These levels were considerably higher than the maximum permissible value of 0.50 mg/kg [8]. The shrimp shell contained higher concentration of lead level than the tissue, while the lead level in water was relatively low (Table 1). Statistically, there was no significant difference ($P > 0.05$) between shrimp tissue and shell. The values especially in all shrimp farms were higher than the recommended value. Ahmed et al. reported the lead contamination in *M. rosenbergii* (0.51 mg/kg) from the Buriganga river [1]. From the literature survey, it was apparent that the shrimp samples of *M. rosenbergii* and *P. monodon* were bottom living almost always in contact with sediments, and therefore the

Table 3
Target hazard quotient (THQ) for different heavy metals, their hazard index (HI) from consumption of two shrimp species collected from different locations at Khulna-Satkhira zone.

Location	Sample	Lead	Cadmium	Chromium	HI
Paikgacha (farm)	tissue	3.97E-04	2.65E-03	6.21E-03	0.0092
	shell	5.37E-04	3.82E-03	8.66E-03	0.0130
Botiaghata (farm)	tissue	8.53E-04	2.35E-03	1.11E-02	0.0143
	shell	9.05E-04	3.53E-03	1.68E-02	0.0212
Rupsha river	tissue	3.38E-04	1.47E-03	2.45E-03	0.0042
	shell	5.59E-04	2.94E-03	2.78E-03	0.0062
Gangli (farm)	tissue	6.32E-04	2.06E-03	3.43E-03	0.0061
	shell	8.02E-04	2.65E-03	5.72E-03	0.0091
Bhairab river	tissue	3.09E-04	1.77E-03	2.29E-03	0.0043
	shell	3.82E-04	2.35E-03	2.29E-03	0.0050
Satkhira (farm)	tissue	7.06E-04	1.77E-03	3.11E-03	0.0055
	shell	8.53E-04	3.24E-03	3.27E-03	0.0073

sediments could be the major sources of Pb contamination. Moreover, lead is an ubiquitous pollutant which could find its way into the rivers through discharge of industrial effluents from various industries such as poultry farms, oil refineries, textile manufacturers, and other sources.

3.2.2. Cadmium

Cadmium is an element capable of producing chronic toxicity present at minimal concentration of 1 mg/kg [17]. According to FAO/WHO, Cd concentration in fish should not exceed 0.05 mg/kg [4]. The Australian National Health and Medical Research Council (ANHMRC) standard for Cd in seafood is 2.0 mg/kg [14]. In the present experiment, Cd concentration in shrimp samples of farms and rivers ranged from 0.06 to 0.13 mg/kg and0.05 to 0.10 mg/kg, respectively. The highest amount of cadmium was found in the shrimp tissue (0.09 mg/kg) and shell (0.13 mg/kg) of *M. rosenbergii* at Paikgacha farm. The lowest amount of Cd was found in the shrimp tissue of *P. monodon* (0.05 mg/kg) at Rupsha river (Table 2). Statistically, shrimp tissue and shell did not show significance difference ($P > 0.05$). Experimental study observed that Cd in the selected samples from all areas were slightly higher than the permissible limits [4], while water samples did not contaminated with Cd (Table 1). Ahmed et al. found high Cd concentration in crustaceans (1.51 mg/kg) in the Buriganga river [1]. Cd concentration in fish samples of Bangshi river on another study ranged from 0.09 to 0.87 mg/kg in two different seasons [16]. Previous studies suggest 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.

3.2.3. Chromium

Mean concentration of chromium was high as 1.03 mg/kg in shell and 0.68 mg/kg in tissue of *P. monodon* at Botiaghata farm. The lowest concentration was in *M. rosenbergii* (0.14 mg/kg) for both tissue and shell at Bhairab river. In the current study, Cr levels in all farms except tissue content at Satkhira farm were higher than the permissible limits. However, shrimp samples of rivers and water for all locations did not show Cr contamination (Tables 1 and 2). The permissible limit of Cr in fish is 0.2 μg/g according to FAO [7]. Tannery and poultry wastes are used as fish feed in Bangladesh that may contribute to high contamination of Cr in shrimps.

3.3. Health risk estimation

The target hazard quotients for Pb, Cd, and Cr estimated through the consumption of two shrimp species are shown in Table 3. The assessment of health risk is done based on assumptions. According to USEPA, the acceptable value is 1 for THQ [20]. In the present study the THQ and HI were less than 1 for all heavy metals from all locations. Therefore, there is no non-carcinogenic health risk from ingestion of these three metals individually and collectively through the shrimp consumption in these areas. The highest THQ was in shell (1.68E-02) and in tissue (1.11E-02) for Cr at Botiaghata farm which is significantly lower than the acceptable limits. Although the shrimp species from all locations under the current study were found safe for consumption, the possibility of health risk associated with non-carcinogenic effect is very low for continuous consumption for 30 years.

4. Conclusion

The current study showed that shrimp samples collected from Khulna-Satkhira area in Bangladesh accumulate Pb, Cd, and Cr at high concentrations compared to the maximum acceptable limits. This study recommends continuous monitoring of this area. However, no metals were found to be considered as potential health hazard for consumer. The THQ values of Cr at Botiaghata farm is comparably lower than the standard values, therefore continuous consumption of shrimp in this area may create health risk in the long run.

Conflict of interest statement

The authors declare that there are no conflicts of interest.

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