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Heavy Metal Concentrations in Different Organs of Fishes of the River Meghna, Bangladesh

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ABSTRACT

The objective of this study was to observe heavy metal (As, Pb, Cr, Ni, Hg and Cd) contamination in different organs (liver, intestine, gill, scale and muscle from different portions of body as well as whole body) of three fish species (*Channa striatus*, *Glossogobius giuris* and *Clupisoma garua*) of the river Meghna. Pb was highly concentrated among all the measured heavy metals in different organs of fishes. Cumulative mean concentrations of heavy metals in different organs of the studied fishes were observed in the order: liver > intestine > gill > scale > muscle. Two age groups of *G. giuris* were also examined to find out the variation of heavy metal concentrations within age group (3-to-4 and 7-to-8 months' old); except for Hg, the contamination level was higher in the tissues of the younger age group compared to the older group.

Keywords: *Channa striatus*, *Clupisoma garua*, fish liver, *Glossogobius giuris*, lead concentration, mercury contamination

INTRODUCTION

Bangladesh is predominantly an agriculture-based country and in the past pollution was never even felt in this region. Since the early 1960's, industries of various kinds started to spring up slowly, mainly along the banks of rivers. Now our country is at a high risk of environmental pollution, especially inland water bodies which face the highest pollution problems as most sewage and industrial wastes are flushed directly into the Ganges and Brahmaputra Rivers leading to high levels of heavy metals in water bodies.

Among different pollutants of river water, heavy metals are gaining importance due to their toxicity, persistence and accumulation problems (Tam and Wong 2000). Though some metals like Cu, Fe, Mn, Ni and Zn are essential as micronutrients for plants and microorganisms, many other metals like Cd, Cr, Pd, Hg, etc. have no known physiological activity, but are detrimental beyond a certain limit (Bruins *et al.* 2000). Deadlier diseases like edema of eyelids, tumors, congestion of nasal mucous membranes and pharynx, stuffiness of the head and gastrointestinal, muscular, reproductive, neurological and genetic malfunctions caused by some of these heavy metals have been documented (Johnson 1998; Tsuki and Karagatzides 2001). Therefore, monitoring these metals in water, sediments, and aquatic animals is important for safety assessment of the environment and human health in particular.

Over the last few decades, there has been growing interest in determining heavy metal levels in the aquatic environment and attention was drawn to the measurement of contamination levels in public food supplies, particularly in fishes (Kalay *et al.* 1999). The river Meghna is one of the major rivers of Bangladesh, especially famous for its great estuary that discharges the flows of the Ganges-Padma, the Brahmaputra-Jamuna and the Meghna itself. Different mills and factories, especially of urea and TSP fertilizer, are situated on its bank. These industries have limited effluent processing arrangements leading to a threatened level of heavy metals into the river.

Concentrations of heavy metals in some fresh water and marine water fishes as well as in mollusks and oysters have been reported (Sharif *et al.* 1991, 1993a, 1993b, 1993c, 1993d; Haque *et al.* 2006, 2007; Ahmed *et al.* 2009). However, data on heavy metal concentrations in fishes of the Meghna River, especially in fishes of different age groups are limited. Furthermore, it is important to observe the levels of heavy metals in fishes to get some idea about the safety of fish protein supplied from that river and to understand its harmful effects among individuals, population or ecosystem. So the objective of this study was to examine the heavy metal (As, Pb, Cr, Ni, Hg and Cd) concentrations accumulated in different organs (liver, intestine, gill, scale, different portion of body muscle and whole body of each species) of three fresh-water fishes (*Channa striatus*, *Glossogobius giuris* and *Clupisoma garua*) in the river Meghna.

MATERIALS AND METHODS

Heavy metals concentrations were studied in three species of fishes of the River Meghna from a definite sample station, near the Meghna Bridge at Gazaria upazila, Monshigonj, Bangladesh (**Fig. 1**) during February, 2007. *C. striatus* and *C. garua* 7 to 8 months old and *G. giuris* of two age groups (3-to-4 and 7-to-8 months' old) were collected from the study area. The fishes were transported to the laboratory in an icebox and kept in a deep freezer. After thawing the fishes were thoroughly washed with tap water and finally with distilled water. Then liver, intestine, gill, scale (except for *C. garua* due to the absence of scales), dorsal, ventral and caudal muscle, and whole body were isolated from each experimental species to analyze metal concentrations.

Samples were weighed and then heated to make ash into a muffle furnace at 100, 200, 300, and 400°C for 1 h each and at 500°C for 6 to 7 hours. The samples were then cooled at ambient temperature and acidified by 1:1 HNO_3: dH_2O and heated again at 500°C for 1 h to make ashes completely. After cooling, the sample ashes were digested by adding 1:1 HCl: dH_2O and heated in a hot plate until boiling. Then cooled digested samples were measured

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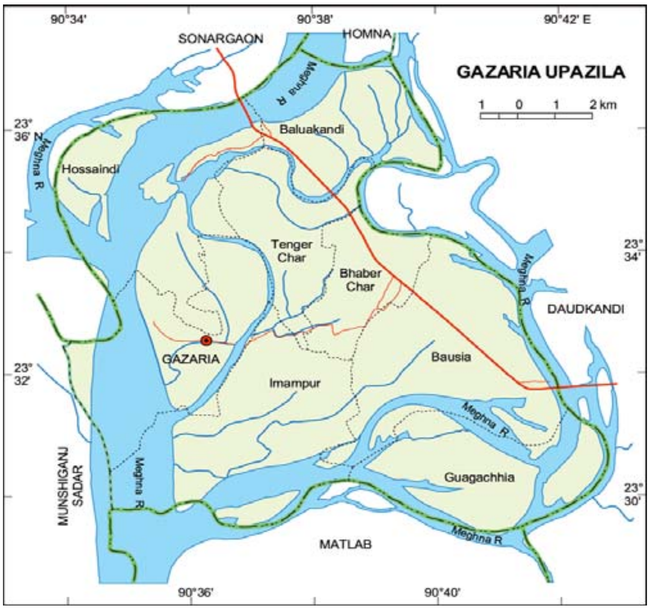

Fig. 1 Sampling location.

to 50 ml and filtered with a 100 S&S round filter (150 mm). Blank digestion served as the control. These samples were stored in a refrigerator at 4°C for further analysis. Heavy metal concentrations were measured using air acetylene flame with combination, as well as single element hollow cathode lamps into an atomic absorption spectrophotometer (Shimadzu AA-6401F). To determine Ar and Hg concentrations, the samples were diluted 5 times before analysis. Standard solutions (BDH Laboratories Supplies, England) of the respective elements in different concentrations were prepared before spectrophotometric and flame photometric determination.

RESULTS

Arsenic (As)

In *C. striatus* the maximum concentration (10.73 mg/kg) of As was observed in gills and minimum concentration (3.85 mg/kg) was found in the ventral muscle (**Table 1**). In *G. giuris* of same age group maximum and minimum concentrations were in the scale (28.37 mg/kg) and ventral group of muscle (1.51 mg/kg), respectively. In *C. garua*, maximum and minimum concentrations were detected in intestine (11.4 mg/kg) and ventral group of muscle (2.15 mg/kg), respectively. However, the mean As concentration was higher in gill (10.43 mg/kg) and scale (18.35 mg/kg) whereas lower in body muscle that was 3.56 mg/kg, as shown in **Table 2**.

Lead (Pb)

In *C. striatus*, maximum concentration (323.24 mg/kg) of Pb was observed in liver and lowest concentration (73.33 mg/kg) was in muscle of dorsal portion (**Table 1**) whereas in *G. giuris*, fish of same age group the Pb concentrations were recorded 375.45 and 50.33 mg/kg in liver and intestine respectively. In *C. garua*, maximum and minimum concentrations were detected in intestine (852.76 mg/kg) and muscle of dorsal portion (15.29 mg/kg) respectively (**Table 1**).

Cromium (Cr)

In *C. striatus* maximum concentration (252.49 mg/kg) of Cr was in liver and minimum concentration (29.93 mg/kg) was observed in muscle of dorsal but in same age group of *G. giuris*, the concentrations were 67.51 and 9.69 mg/kg in scale and muscle of dorsal portion, respectively while in *C. garua*, it was 52.89 and 12.16 mg/kg in caudal muscle and liver, respectively. Data in **Table 2** shows that among all the tissues, the highest mean concentration of Cr was found in the liver (93.23 mg/kg) and lowest in the muscle (30.07 mg/kg).

Table 1 Heavy metal concentrations (mg/kg in wet weight basis) in different organs of *Channa striatus*, *Glossogobius giuris*, and *Clupisoma garua* of the River Meghna.

Fishes	Organs	As (mg/kg)	Pb (mg/kg)	Cr (mg/kg)	Ni (mg/kg)	Hg (mg/kg)	Cd (mg/kg)
C. striatus	Liver	ND	323.4	252.4	186.3	11.5	73.6
G. giuris		11.3	375.4	15.1	32.3	5.8	11.1
C. garua		9.7	595.8	12.2	ND	ND	9.3
C. striatus	Intestine	ND	231.8	146	86.4	5.4	37.2
G. giuris		8.5	50.3	22.9	83.5	11.8	20.2
C. garua		11.4	852.8	26.8	104.2	12.2	6.5
C. striatus	Gill	10.7	313.7	74.9	46.2	26.3	3.1
G. giuris		12.9	314	17.7	37.6	7.6	ND
C. garua		7.7	247.9	22.1	116.9	2	ND
C. striatus	Scale	8.3	171.67	77.8	130.5	53.8	6.2
G. giuris		28.4	236	67.5	32	5.3	ND
C. garua		-----	------	-----	------	------	-----
C. striatus	Muscle (dorsal)	5.6	73.3	29.9	24.7	114.9	0.1
G. giuris		1.8	132.6	9.7	ND	5.3	1.9
C. garua		3.5	15.3	12.9	57.2	1.8	ND
C. striatus	Muscle (ventral)	3.8	89	35.4	83.7	6.1	4.4
G. giuris		1.5	105.5	15.4	ND	3.9	ND
C. garua		2.1	15.7	38.4	0	5.2	ND
C. striatus	Muscle (caudal)	7.3	73.7	54	30	5.8	0.9
G. giuris		2.6	133.5	22.1	ND	2.8	ND
C. garua		3.9	162.7	52.9	35.5	14.9	3.3

Table 2 Cumulative mean concentrations of heavy metals (mg/kg in wet weight basis) in different organs of the Meghna fishes.

Organs	Arsenic (As)	Lead (Pb)	Chromium (Cr)	Nickel (Ni)	Mercury (Hg)	Cadmium (Cd)	Mean of heavy metals
Liver	7.00	431.53	93.23	72.86	5.76	31.33	106.95
Intestine	6.63	378.3	62.23	91.36	9.8	21.3	94.94
Gill	10.43	291.86	38.23	66.9	11.96	3.1	70.41
Scale	18.35	203.83	72.65	81.25	29.55	6.2	68.64
Muscle	3.56	89.03	30.07	25.67	17.85	2.15	28.06

Nikel (Ni)

Ni content was recorded (186.34 and 30.01 mg/kg) in the liver and caudal muscle of *C. striatus*, respectively. But in *G. giuris* of same age group maximum and minimum concentrations were in the intestine (83.55 mg/kg) and scale (32.01 mg/kg), respectively. However, in *C. garua*, highest concentration was detected in gill (116.88 mg/kg) and lowest in muscle (35.45 mg/kg) (**Table 1**).

Mercury (Mg)

In *C. striatus*, maximum concentration (114.97 mg/kg) of Hg was observed in muscle of dorsal portion and minimum concentration (5.39 mg/kg) was observed in intestine (**Table 1**). However, *G. giuris* of same age group accumulated maximum (11.82 mg/kg) in intestine and minimum (2.86 mg/kg) in caudal muscle. In *C. garua* maximum and minimum concentrations were detected in caudal muscle (14.97 mg/kg) and muscle of dorsal portion (1.82 mg/kg), respectively.

Cadmium (Cd)

In *C. striatus* maximum concentration (73.62 mg/kg) of Cd was observed in liver and minimum concentration (0.13 mg/kg) in the muscle of the dorsal portion but in *G. giuris* of same age group, maximum and minimum concentrations were in the intestine (20.22 mg/kg) and in the muscle of the dorsal portion (1.98 mg/kg), respectively (**Table 1**). In *C. garua*, maximum and minimum concentrations were detected in intestine (6.51 mg/kg) and caudal muscle (3.34 mg/kg), respectively. Among all the tissues examined liver contained highest amount (31.33 mg/ kg) of Cd and the least amount (2.15 mg/kg) in muscle, as shown in **Table 1**.

Table 3 Comparisons of mean values of metal concentrations in different organs of Shol (*Channa striatus*), Bele (*Glossogobius giuris*) and Ghaura (*Clupisoma garua*) of Meghna River, Bangladesh.

Metal and fish species	P values	
	G. giuris	*C. garua*
Arsenic (As)		
C. straitus vs	0.102^{ns}	0.515^{ns}
G. giuris vs		0.335^{ns}
Lead (Pb)		
C. striatus vs	0.766^{ns}	0.101^{ns}
G. giuris vs		0.161^{ns}
Chromium (Cr)		
C. striatus vs	0.020*	0.022*
G. giuris vs		0.916^{ns}
Nickel (Ni)		
C. striatus vs	0.034*	0.005**
G. giuris vs		0.268^{ns}
Mercury (Hg)		
C. striatus vs	0.025*	0.023*
G. giuris vs		0.861^{ns}
Cadmium (Cd)		
C. striatus vs	0.176^{ns}	0.155^{ns}
G. giuris vs		0.873^{ns}

ANOVA (multiple comparisons)
ns = Not significant
* = Significant at P < 0.05
**= Significant at P < 0.01

DISCUSSION

Heavy metal concentrations varied among different tissues of a species as well as between species. Among different observed values of heavy metals, we found that Pb concentrations in different tissues of the experimental species were much higher than any other values whereas Cd showed lowest values in almost all experimental tissues (**Table 1**). Previous data showed that different fish species contained strikingly different metal levels in their tissues that might be related to the differences in ecological needs, swimming behaviors and the metabolic activities among different fish species (Kalay *et al.* 1999). However, the Meghna river water might be highly polluted with Pb due to effluent discharge from the industries located along its bank.

It was also observed that *C. striatus* showed the highest accumulation value compared to the other two species. As *C. striatus* is a carnivorous fish that occupies a higher trophic level of the food chain, the biomagnification process may increase the concentration of heavy metals in their bodies. According to Goel (1996) the mechanism of biomagnification involves uptake of the heavy metal with ingested food. The food is digested, assimilated and excreted, but the heavy metal accumulates in the tissues of the organism. As the assimilation efficiency of each trophic level is only 10%, each higher trophic level consumes 10 times more than its immediately preceding trophic level to gain the same weight. This leads to a 10-fold increase in concentration of heavy metals as the food passes through from one trophic level to another. Another important result was a high Pb concentration in the liver and intestine, especially those of *C. garua*, 595.8 and 852.8 mg/kg, respectively (**Table 1**). This might be related to the feeding behavior of *C. garua* which feeds on decayed organic matter.

The data in **Table 2** shows that metal concentrations in the liver were highest among different tissues of Meghna fishes following the order: liver > intestine > gill > scale > muscle. The total mean metal concentration (mg/kg in wet weight basis) in liver was 106.95 mg/kg whereas it was only 28.06 mg/kg in muscle tissues. In the case of *C. striatus*, high contamination with heavy metals was always found in the liver whereas *C. garua* showed high accumulation in intestine; however liver, gill and scale of *G. giuris* also contained high levels of heavy metals (**Table 2**). It is well known that considerable metallothionein induction occurs in the liver tissue of fishes. A recent report revealed that heavy metals induce the synthesis of metal-binding protein metallothionein in the liver of *Tilapia* (Cheung *et al.* 2004). In the work of Shanti *et al.* (2000), a higher concentration of heavy metals was found in the intestine, especially of detrivorous species, as compared to other parts of the body which supports our findings that the intestine of *C. garua* was highly contaminated. High levels of heavy metal contamination were also observed in the gill, scale and intestine of each of the experimental species. An MSDS (2006) report showed that in fish in general, Pb accumulates primarily in the gill, liver, kidney and bone. The adsorption of metals onto the gill surface could also be an important influence in total metal levels of the gill (Canli and Furness 1993a, 1993b), although many organisms can tolerate high concentrations of essential or non-essential metals by accumulating them at non-active sites like bone, feathers or exoskeleton (Goel 1996). In the case of *C. garua*, maximum and minimum concentrations were detected in the intestine (11.4 mg/kg) and ventral group of muscle (2.15 mg/kg), respectively. According to Goel (1996) heavy metals are accumulated by the digestive system through ingested food, particulates and water, so a high concentration might be found in the intestine. However, it was observed that the maximum concentration of heavy metals was in the non-edible portions like the scales, gills and intestine of fresh water fishes.

The mean values of metal concentrations in different organs of *C. striatus*, *G. giuris* and *C. garua* of the same age group (7-8 months) were statistically analyzed to understand the relationships among theses experimental species. **Table 3** shows that in terms of Hg concentration, the relationship between *C. striatus* and *C. garua* was significant at P<0.01. A significant correlation at P<0.05 was found between *C. striatus* and *G. giuris* for the accumulated values of Cr, Ni and Hg as well as between *C. striatus* and *C. garua* than for Cr and Hg concentrations. However, no significant relationship between *G. giuris* and *C. garua* was found for the observed metal concentrations.

Table 4 Correlation coefficient matrix of heavy metals concentrations in different organs of *Channa striatus*, *Glossogobius giuris* and *Clupisoma garua* of Meghna River, Bangladesh.

	As	Pb	Cr	Ni	Hg	Cd
C. striatus						
As	1.000	0.310	-0.756	-0.518	0.709	- 0.836
Pb		1.000	0.351	0.377	-0.020	0.247
Cr			1.000	0.818	-0.719	0.989
Ni				1.000	-0.207	0.788
Hg					1.000	-0.733
Cd						1.000
G. giuris						
As	1.000	0.345	0.902	0.111	-0.109	-0.295
Pb		1.000	-0.025	-0.319	-0.423	-0.364
Cr			1.000	0.028	-0.168	-0.305
Ni				1.000	0.963	0.795
Hg					1.000	0.775
Cd						1.000
C. garua						
As	1.000	0.942	-0.616	0.099	0.099	0.695
Pb		1.000	-0.437	0.328	0.328	0.795
Cr			1.000	0.706	0.706	-0.633
Ni				1.000	1.000	-0.048
Hg					1.000	-0.048
Cd						1.000

This study also investigated the relationships among heavy metal concentrations in *C. striatus*, *G. giuris* and *C. garua*. The correlation among the heavy metal concentrations in different organs of *C. striatus*, *G. giuris* and *C. garua* of the Meghna River was statistically analyzed (**Table 4**). In *C. striatus*, it was observed that As has a strong negative relation with Cd (r = -0.836) and Cr (r = -0.756) concentrations whereas with Ni it has a linear negative correlation (r = -0.518). However, with Hg, As showed a moderate positive correlation (r = 0.709). Cr has a strong positive relation with Cd (r = 0.989) and Ni (r = 0.818) but moderate negative relation with Hg (r = -0.733). In *G. giuris*, Ni showed positive correlation with Cd (r = 0.795) whereas Hg showed a strong positive relation with Ni concentration (r = 0.963). As showed a strong positive relation with Cr (r = 0.902). Pb showed a negative relation with all the heavy metals studied, although Hg also showed a negative correlation with all the metals, except with Ni, with which a strong positive relation was found. In *C. garua*, it was found that As was strongly positively correlated with Pb (r = 0.942) and moderately positively correlated with Cd (r = 0.695). Pb showed a moderate positive relation with Cd (r = 0.795) while Cr showed a moderate negative relation with Cd (r = -0.633); Ni, however, showed a strong positive relation with Hg (r = 1.000).

The variation among the heavy metal concentrations between two age groups of *G. giuris* was studied (**Table 5**). The liver of younger *G. giuris* fish contained more heavy metals than older *G. giuris* fish. Mean concentrations (mg/kg) of As (12.60 ± 9.76), Pb (219.96 ± 133.51), Cr (27.79 ± 22.41), Ni (37.09 ±29.93), Hg (6.92 ± 3.03) and Cd (6.40 ± 9.06) in older *G. giuris* was always lower than the mean concentrations in younger *G. giuris* which were 21.29 ± 24.00, 441.41 ± 391.12, 57.57 ± 22.15, 92.31 ± 101.96, 5.53 ± 7.30 and 4.60 ± 8.84 respectively. No age related significant difference of heavy metal concentrations in same species of fishes was found. The negative relationships between heavy metal levels in the tissues and fish sizes were generally supported in the literature. Nussey *et al.* (2000) showed that accumulation of metals (Cr, Mn, Ni, and Pb) decreased with an increase in the length of fish *Labeo umbratus*. Widianarko *et al.* (2000) investigated the relationship between metal (Pb, Zn, Cu) concentrations and fish (*Poecilia reticulata*) size and found that there was a significant decline in Pb concentrations with the increase in size, whereas concentrations of Cu and Zn did not depend on body weight. It is also known that the metabolic activity of a young individual is normally higher than that of an older individual, thus, metal accumulation was shown to be higher in younger individuals than the older ones (Douben 1989; Elder and Collins 1991; Canli and Furness 1993b; Nussey *et al.* 2000; Widianarko *et al.* 2000). However, the variation found in this study between two age groups of *G. giuris* was not statistically significant as age variation (7-8 months and younger 3-4 months) between them was not sufficient to get a significant change.

Table 5 Comparison of mean concentrations of heavy metals between two age groups of *Glossogobius giuris* of Meghna River, Bangladesh.

Metals	Metal concentrations (mg/kg) (Mean ± SD)		
	Older	Younger	P value
Arsenic (As)	12.60 ± 9.76	21.297 ± 24.00	0.475 ns
Lead (Pb)	219.96 ± 133.51	441.41 ± 391.12	0.265 ns
Chromium (Cr)	27.79 ± 22.41	57.57 ± 22.15	0.068 ns
Nickel (Ni)	37.09 ± 29.93	92.31 ± 101.96	0.279 ns
Mercury (Hg)	6.92 ± 3.03	5.53 ± 7.30	0.705 ns
Cadmium (Cd)	6.40 ± 9.06	4.60 ± 8.84	0.758 ns

Unpaired Student's *t*-test; ns = Not significant

This study also found that the accumulation level of heavy metals in different organs of fishes was higher than the standard reference values recommended by IAEA (International Atomic Energy Agency). High concentrations were found in non-edible portions of fish body. But this threatened concentration of metals can retard fish development causing possible alterations in fish size (Weis and Weis 1989; Friedmann *et al.* 1996). Fish development can be affected by the presence of heavy metals in water and especially the early life stages such as hatching time, larval development and juvenile growth as they are more sensitive than the mature stages. Friedmann *et al.* (1996) showed that even low levels of dietary Hg inhibited growth of juvenile walleye, *Stizostedion vitreum*. Weis and Weis (1989) also indicated that both essential and non-essential metals could alter embryonic development of fish embryos causing retardation of normal development, disability of organs or mortality. However, fish growth and its relationship with metal concentration in the aquatic environment should be monitored occasionally in the field to better understand the effects of metals on fish development and the current situation of population dynamics.

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