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Exploration of Metallic Contamination in Fish Species of the Polluted Rivers in Bangladesh

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Abstract An attempt was made to assess metal ionic toxicity levels of different fishes in the polluted rivers *viz.*, Buriganga and Turag. Fish samples collected from two polluted rivers were analyzed for the levels of metals such as Cd, Cr, Cu, Mn, Pb, and Zn in order to elucidate the status of these contaminants in fish meant for human consumption. The detected concentrations of Cr, Cu, Mn, and Zn ions in fish species collected from the polluted rivers were below the toxic levels and did not appear to pose a threat. Among the analyzed metals, Cd and Pb ions were detected above the permissible levels in liver and muscle tissues of stinging catfish (*Heteropneustesfossilis*), spotted snakehead (*Channapunctata*) and wallago (*Wallagoattu*) collected from the polluted rivers causing toxicity for human consumption. Stinging catfish (*Heteropneustesfossilis*) was the species found to highly bioaccumulate these metals. Fish species bioconcentrated appreciable amounts of Cd and Pb as toxic metals in the liver as compared to the muscle. Levels of these toxic metals varied depending on different tissues in fish species.

Keywords fishes · metallic contamination · pollution · river water

Introduction

Riverine ecology is under threat mainly due to the uncontrolled disposal of untreated industrial wastes directly. In Bangladesh, ecological imbalance of riverine ecosystem is being caused continuously with acceleration of industrial pollution as anthropogenic activities and natural activities such as decreased water flow during dry season. Anthropogenic processes mainly both industrial and agricultural operations contribute significant amount of heavy or toxic metals to water ecosystem.

Waterborne toxic chemicals pose the greatest threat to aquatic environment. The toxic chemicals adversely affect the production of fish in water system (Lloyd, 1992). The contaminant load transported by rivers and industrial activities are the main causes of contamination (Sainz et al., 2005). Metals from anthropogenic source continuously enter the aquatic ecosystem where they pose serious threat because of their toxicity, long persistence, bioaccumulation and biomagnification in the food chain (Papagiannis et al., 2004). Fish being at the higher level of the food chain accumulate large quantities of these xenobiotics and the accumulation depends upon the intake and the elimination from the body (Karadede et al., 2004).

However, the accumulation of heavy metals in fish is of great importance to man as fish is consumed by a large section of the population. In fish, the most vulnerable organ to acute exposures is thought to be the gills (McDonald and Wood, 1993). Fishes are dietary items with such characteristics i.e., they are bioaccumulators with the highest potential to transfer residues from water to humans (Dorea, 2006). They are also special carriers of functional substances that are crucial to human health. Fishes are important dietary items that provide essential nutrients. Fish bioaccumulates metals that are persistent bioaccumulative and toxic substances. The contaminated metal ions are bonded into protein biologically. In some cases, metal ion may be bound directly to protein or it may be a part of a prosthetic group (Glusker et al., 1999).

In a developing country like Bangladesh, where most of the developmental activities are still dependent upon rivers for cleaning

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as well as disposal purposes, it becomes very important to systematically study the status of metal ions as pollutants in fish species of the polluted rivers of study areas. Therefore, the present investigation accounts for the recent evidence of the effect of these metal ions on human health and their possible implications in fish consumption. Keeping these above facts in mind, this research work was undertaken to assess the degree of metallic toxicity in different fish species of the polluted rivers.

Materials and Methods

Fish sampling. Four fish species namely stinging catfish (*Heteropneustesfossilis*), spotted snakehead (*Channapunctata*), wallago (*Wallagoattu*), and zig-zag eel (*Mastacembelusarmatus*) were sampled by net from the polluted rivers during dry season. Fishes were dissected and tissue sub-samples were taken out quickly from liver and muscle. The lengths and weights of fish were measured. All tissues were placed in aluminum foilon ice and immediately transported to the laboratory. Tissues were weighed and frozenat −20°C until analysis for metals.

Water sampling. Water samples were collected from different components of polluted rivers viz., Buriganga and Turag representing the upstream and downstream stations in all directions during dry season (Fig. 1). In sampling, 10 grab or catch water samples were collected from non-point sources in 1 L pre-cleaned polyethylene bottles rinsed with 10% HNO_3 and deionised water and mixed to obtain the integrated water sample following the technique as outlined by APHA (2005). These samples were immediately preserved by the addition of a few drops of concentrated HNO_3. Water samples were filtered through filter paper (Whatman No. 1, UK) to remove undesirable solid and suspended materials before chemical analysis. The collected water samples were tightly sealed as early as possible to avoid air exposure. All sample bottles were stored in iceboxes till brought to the laboratory for analysis.

Metal analysis. For the analysis of metal ions under test, fish samples were digested as per the standard method (Cunniff, 1995). Exactly 1 g fish sample was subjected to wet mineralization using a mixture of nitric and sulphuric acids (2:1) as outlined by Zolotov and Kuzmin (1982). The digested samples were filtered using glass wool to remove fat and made up to a known volume. Blanks were also performed and measured for all metals following the same procedure. After cooling, the digested samples were appropriately made up to a known volume. The concentrations of metal ions such as Cd, Cr, Cu, Mn, Pb, and Zn in fish species as well as the contents of Cd and Pb ions in the polluted river water samples were analysed by atomic absorption spectrometric method using appropriate hollow cathode lamps. The bioaccumulation of individual toxic metal ion in a particular tissue was calculated using the following formula:

$$\text{Bioaccumulation } (\mu g\ g^{-1}) = \text{Concentration of sample } (\mu g\ mL^{-1}) \times \text{Sample volume (mL)} / \text{Dry wt. of sample (g)}$$

Fig. 1 Sampling sites of the polluted rivers in Bangladesh. -▲-Buriganga river and -●-Turag river.

Statistical analyses. Statistical analyses of the analytical results obtained from different fish species of the polluted river waters were performed (Gomez and Gomez, 1984). Statistical analyses were also done following the standard method of Computer Programme.

Results and Discussion

Assessment of metallic contamination in different fishes

Cadmium. In the polluted river namely Buriganga, 0.96, 0.71, 0.64, and 0.34 μg g^{-1} Cd in muscles and 1.20, 0.86, 0.75, and 0.48 μg g^{-1} Cd in livers were detected in stinging catfish (*Heteropneustesfossilis*), spotted snakehead (*Channapunctata*), wallago (*Wallagoattu*) and zig-zag eel (*Mastacembelusarmatus*) fish species, respectively (Fig. 2). In the Turag river, Cd levels were 0.76, 0.61, 0.52, and 0.26 μg g^{-1} in muscles and 0.98, 0.78, 0.67, and 0.32 μg g^{-1} in livers of stinging catfish (*Heteropneustesfossilis*), spotted snakehead (*Channapunctata*), wallago (*Wallagoattu*), and zig-zag eel (*Mastacembelusarmatus*), respectively (Fig. 3). According to FAO (Nauen, 1983), Cd level exceeded the legal limit (0.50 μg g^{-1}) in all fish species of the Buriganga and Turag rivers except zig-zag eel (*Mastacembelusarmatus*) showing Cd toxicity for fish consumption. As because, the detected concentration of Cd in water samples of the polluted rivers *viz*., Buriganga and Turag ranged from 0.045 to 0.032 μg mL^{-1} where its content exceeded maximum recommended limit (0.005 μg mL^{-1}) for aquaculture purpose indicating Cd toxicity as per Meade (1989). The reason of Cd concentration in the investigated river waters might be due to the industrial and agricultural activities. The source of this toxic metal might be due to the discharge of industrial and municipal wastes, which contributed significantly to

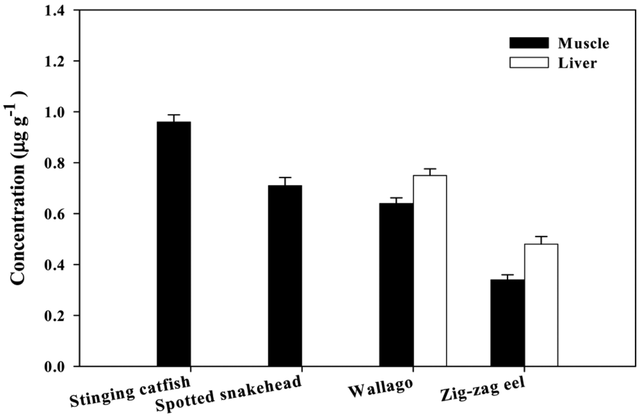

Fig. 2 Cadmium content in tissue of fishes in the Buriganga river. Error bars indicate standard deviation of mean (n =4).

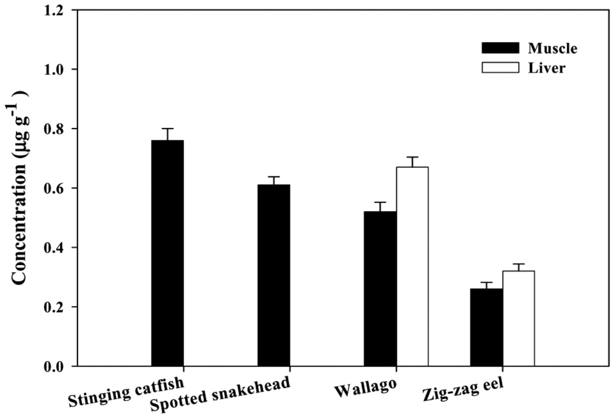

Fig. 3 Cadmium content in tissue of fishes in the Turag river. Error bars indicate standard deviation of mean (n =4).

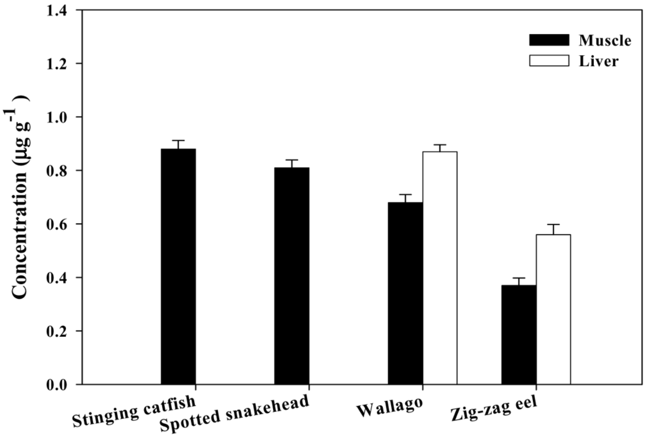

Fig. 4 Chromium content in tissue of fishes from the Buriganga river, Error bars indicate standard deviation of mean (n =4).

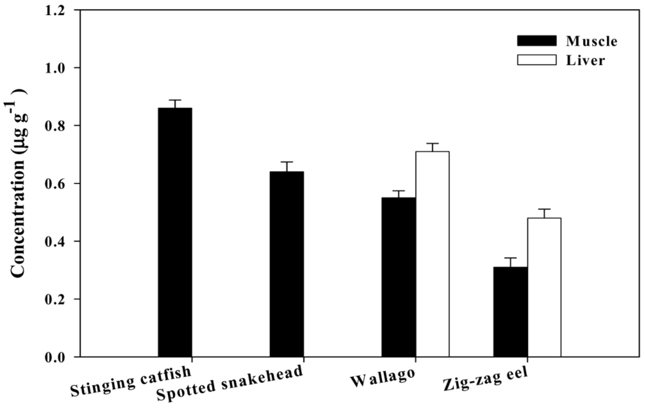

Fig. 5 Chromium content in tissue of fishes from the Turag river. Error bars indicate standard deviation of mean (n =4).

the level of this heavy metal in the aquatic environment. Similar findings were reported by Talbot and Chegwidden (1983) and Sharif et al. (1993). The experimental result revealed that the level of Cd in liver of the fish species was higher than that in muscle. Maximum level of Cd in muscle was higher than the permissible limit indicating toxicity for fish consumers. The accumulation of Cd in fish was higher than the permissible limit causing potential dangers for river environment especially in river based community and its aquatic life for subsistence (Allen-Gil and Martynov, 1995). In man, Cd poisoning could lead to anaemia, renal damage, nerve damage, bone disorder and lung cancer (Manahan, 2005).

Chromium. In the polluted river namely Buriganga, 0.88, 0.81, 0.68 and 0.37 μg g^{-1} Cr were detected in muscles and 1.10, 0.98, 0.87, and 0.56 μg g^{-1} Cr were obtained in livers of stinging catfish (*Heteropneustesfossilis*), spotted snakehead (*Channapunctata*), wallago (*Wallagoattu*), and zig-zag eel (*Mastacembelusarmatus*) fish species, respectively (Fig. 4). The concentrations of Cr in muscles of stinging catfish (*Heteropneustesfossilis*), spotted snakehead (*Channapunctata*), wallago (*Wallagoattu*), and zig-zag eel (*Mastacembelusarmatus*) were 0.86, 0.64, 0.55, and 0.31 μg g^{-1} and its levels in livers of these fish species were 1.06, 0.78, 0.71, and 0.48 μg g^{-1} Cr in the Turag river, respectively (Fig. 5). The content of Cr in the fish species collected from the Buriganga and Turagrivers did not exceed the legal limit (1.10 μg g^{-1}) as per FAO (Nauen, 1983). From these findings, it was noted that Cr ion was not considered as toxicant for fish consumers in these polluted rivers. Accordingly, this metal ion was not hazardous for human consumption.The observed variability of metal levels in different species depends on feeding habits (Amundsen et al., 1997; Romeoa et al., 1999; Mormede and Davies, 2001; Watanabe et al., 2003), ecological needs and metabolism (Canli and Furness, 1993; Canli and Kalay, 1998), age, size and length of the fish (Linde et al., 1998; Al-Yousuf et al., 2000) and their habitats (Canli and Atli, 2003).

Copper. The respective contents of Cu were 0.84, 0.78, 0.60, and 0.32 μg g^{-1} in muscles and were also 1.30, 1.00, 0.93, and 0.79 μg g^{-1} in livers of stinging catfish (*Heteropneustesfossilis*), spotted snakehead (*Channapunctata*), wallago (*Wallagoattu*), and zig-zag eel (*Mastacembelusarmatus*) collected from the Buriganga river (Table 1). The levels of Cu were 0.50, 0.31, 0.20, and 0.17 μg g^{-1}

Table 1 Metal concentrations in tissue of fishes in the Buriganga river

Sample No.	Fish species	Organ	Zn	Cu	Mn
				$\mu g\ g^{-1}$	
1	Stinging catfish (*Heteropneustesfossilis*)	Muscle	3.34	0.84	0.38
2		Liver	4.66	1.30	0.63
3	Spotted snakehead (*Channapunctata*)	Muscle	2.82	0.78	0.52
4		Liver	5.20	1.00	0.84
5	Wallago (*Wallagoattu*)	Muscle	1.78	0.60	0.21
6		Liver	3.43	0.93	0.49
7	Zig-zag eel (*Mastacembelusarmatus*)	Muscle	0.86	0.32	0.08
8		Liver	2.96	0.79	0.11
	Range		0.86–5.20	0.32–1.30	0.08–0.84
	$\bar{x}$		3.13	0.80	0.41
	SD		1.41	0.31	0.26
	CV (%)		44.94	37.58	65.03

Table 2 Metal concentrations in tissue of fishes in the Turag river

Sample No.	Fish species	Organ	Zn	Cu	Mn
				$\mu g\ g^{-1}$	
1	Stinging catfish (*Heteropneustesfossilis*)	Muscle	2.24	0.50	0.47
2		Liver	3.56	0.78	0.72
3	Spotted snakehead (*Channapunctata*)	Muscle	1.72	0.31	0.26
4		Liver	3.82	0.56	0.58
5	Wallago (*Wallagoattu*)	Muscle	0.68	0.20	0.51
6		Liver	2.33	0.32	0.90
7	Zig-zag eel (*Mastacembelusarmatus*)	Muscle	0.34	0.17	0.19
8		Liver	1.86	0.21	0.74
	Range		0.34–3.82	0.17–0.78	0.19–0.90
	$\bar{x}$		2.06	0.38	0.55
	SD		1.22	0.21	0.24
	CV (%)		59.12	54.61	44.03

in muscles and were 0.78, 0.56, 0.32, and 0.21 $\mu g\ g^{-1}$ in livers of stinging catfish (*Heteropneustesfossilis*), spotted snakehead (*Channapunctata*), wallago (*Wallagoattu*), and zig-zag eel (*Mastacembelusarmatus*) collected from Turag river, respectively (Table 2). According to FAO (Nauen, 1983), maximum legal limit of Cu for fish species is 30.00 $\mu g\ g^{-1}$. Accordingly, Cu level was far below the specified limit in all fish species of two polluted rivers. Maximum level of Cu in muscle and liver was lower than the permissible tolerable limit (Nauen, 1983) and did not threat for fish consumers. The recorded limit of Cu did not exceed in tissues of fishes analyzed in this study. The result revealed that Cu concentration in liver was higher than that in muscle. Similar trends of results were observed by Sankar et al. (2006) and Yilmaz et al. (2007).

Manganese. In the polluted river like Buriganga, the contents of Mn were 0.38, 0.52, 0.21, and 0.08 $\mu g\ g^{-1}$ in muscles and 0.63, 0.84, 0.49, and 0.11 $\mu g\ g^{-1}$ in livers of stinging catfish (*Heteropneustesfossilis*), spotted snakehead (*Channapunctata*), wallago (*Wallagoattu*), and zig-zag eel (*Mastacembelusarmatus*) as presented in Table 1. For the Turag river, Mn levels were 0.47, 0.26, 0.51, and 0.19 $\mu g\ g^{-1}$ in muscles and 0.72, 0.58, 0.90, and 0.74 $\mu g\ g^{-1}$ in livers of stinging catfish (*Heteropneustesfossilis*), spotted snakehead (*Channapunctata*), wallago (*Wallagoattu*), andzig-zag eel (*Mastacembelusarmatus*), respectively (Table 2). According to FAO (Nauen, 1983), maximum legal limit of Mn for fish species is 10.00 $\mu g\ g^{-1}$. Considering this permissible limit, Mn level was far below the recommended limit in all fish species collected from the Buriganga and Turag rivers. The result indicated that Mn concentrations in liver were higher than that in muscle. Similar result was reported by Mendil et al. (2005) for fish species.

Lead. In the polluted river like Buriganga, the respective levels of Pb were 0.68, 0.61, 0.54, and 0.36 $\mu g\ g^{-1}$ in muscles and were also 0.91, 0.76, 0.71, and 0.48 $\mu g\ g^{-1}$ in livers of stinging catfish (*Heteropneustesfossilis*), spotted snakehead (*Channapunctata*), wallago (*Wallagoattu*), and zig-zag eel (*Mastacembelusarmatus*) as shown in Fig. 6. Considering the Turag river, the contents of Pb were 0.60, 0.58, 0.52, and 0.24 $\mu g\ g^{-1}$ in muscles and were also 0.82, 0.75, 0.63, and 0.38 $\mu g\ g^{-1}$ in livers of stinging catfish (*Heteropneustesfossilis*), spotted snakehead (*Channapunctata*), wallago (*Wallagoattu*), and zig-zag eel (*Mastacembelusarmatus*), respectively (Fig. 7). The concentration of Pb in all fish species except zig-zag eel (*Mastacembelusarmatus*) collected from the

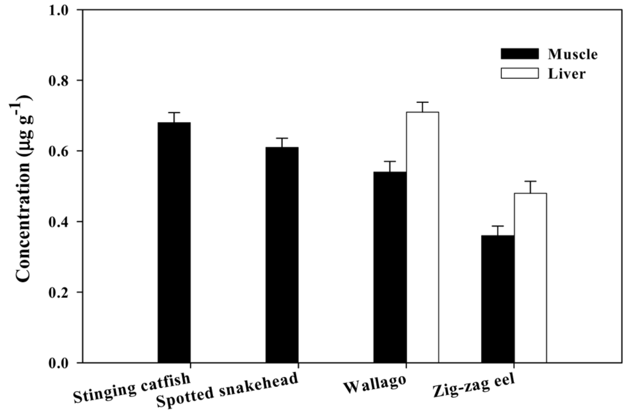

Fig. 6 Lead content in tissue of fishes in the Buriganga river. Error bars indicate standard deviation of mean (n =4).

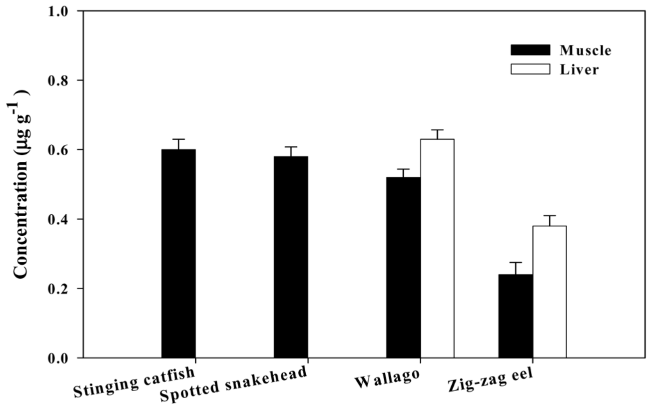

Fig. 7 Lead content in tissue of fishes in the Turag river. Error bars indicate standard deviation of mean (n =4).

Buriganga and Turag rivers under test exceeded the permissible limit (0.50 μg g^{-1}) as recommended by FAO (Nauen, 1983). As per this limit, Pb ion was considered as toxicant in tissues of fish species. As because, the level of Pb in water samples of these polluted rivers varied from 0.09 to 0.12 μg mL^{-1}. On the basis of this legal limit (0.02 μg mL^{-1}), river water samples under study were problematic for aquaculture purpose showing Pb toxicity (Meade, 1989). In the polluted rivers, the highest level of Pb might be due to the high discharge of surrounding city wastes including industrial effluents. Similar results were observed by Sharif et al. (1993); Aucoin et al.(1999) and Mendil et al.(2005). The present results showed that Pb level was higher in liver than that in muscle.The source of Pb in the aquatic organisms might be due to the discharge of industrial and municipal wastes, which contributed significantly to the level of this toxic metal. The observed variability of metal levels in different species depends on feeding habits (Amundsen et al., 1997; Romeoa et al., 1999; Mormede and Davies, 2001; Watanabe et al., 2003), ecological needs and metabolism (Canli and Furness, 1993; Canli and Kalay, 1998), age, size, and length of the fish (Linde et al., 1998; Al-Yousuf et al., 2000) and their habitats (Canli and Atli, 2003).

Zinc. In the Buriganga river, muscles of stinging catfish (*Heteropneustesfossilis*), spotted snakehead (*Channapunctata*), wallago (*Wallagoattu*), and zig-zag eel (*Mastacembelusarmatus*) fish species contained 3.34, 2.82, 1.78, and 0.86 μg g^{-1} Zn, respectively and livers of these four fishes also contained 4.66, 5.20, 3.43, and 2.96 μg g^{-1} Zn, respectively (Table 1). In the Turag river, the levels of Zn were 2.24, 1.72, 0.68, and 0.34 μg g^{-1} in muscles and were also 3.56, 3.82, 2.33, and 1.86 μg g^{-1} in livers of stinging catfish (*Heteropneustesfossilis*), spotted snakehead (*Channapunctata*), wallago (*Wallagoattu*), and zig-zag eel (*Mastacembelusarmatus*), respectively (Table 2). According to FAO (Nauen, 1983), the detected concentration of Zn in all fish species of the polluted rivers *viz*., Buriganga and Turag was far below the permissible limit (40.00 μg g^{-1}). Considering this metal ion, the fish species in these polluted rivers did not threat for fish consumers. Similar results were recorded in fish species from lakes of Turkey (Karadede et al., 2004; Mendil et al., 2005) and from Ataturk Dam Lake and Lake Kasumigaura (Karadede and Unlu, 2000; Alam et al., 2002).

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