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Heavy Metals Accumulation in Water, Sediment and Tissues of Different Edible Fishes in Upper Stretch of Gangetic West Bengal

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Abstract: Heavy metal pollution is a great concern to the environmental is widespread and non-degradable. It seems to be man's worst endeavor in his attempt to augment industrial development. Heavy metals are bioaccumulative and relatively stable as well as toxic/carcinogen and therefore require close monitoring. Concentration of zinc, chromium, copper, cadmium and lead were investigated in the gill, gonads, skin and muscle tissues of six commercially edible fishes from upper stretch of the Ganga River at West Bengal, India. The study area receives a wide variety of wastes generated by municipalities and the industries like paints and pigments, metal processing industries, thermal power plants, electro-processing industries etc. situated on the both side of the river Ganga. Simultaneous analysis of the metals was also carried out in the sediment and aquatic phases to monitor the degree of contamination. The results of this study indicated that the six commercially edible fishes through food, water and sediment leading thereby to bioaccumulation took the metals present in the river ecosystem. Heavy metal concentrations in the tissues tended to vary significantly among season and monsoon period showed particularly high metal concentration compared to pre-monsoon and post-monsoon. Muscle tissues and gill showed higher concentration of zinc, chromium, copper, cadmium and lead than gonads and skin ($p<0.05$). Highest concentration of zinc, chromium, copper, cadmium and lead were detected in gill tissues ($p<0.05$). Lowest concentration observed in gonads of fish sampled from upper course of the River Ganga. Further, metal accumulation showed high degree of species specificity, where the order of accumulation of heavy metals was zinc>copper>chromium>cadmium>lead.

Key words: Edible fish, heavy metals, bioaccumulation, ganga river, West Bengal, India

INTRODUCTION

The presence of heavy metals in the aquatic environment is a major concern because of their toxicity and threat to plant and animal life disturbing the natural ecological balance. The specific problem associated with the heavy metals in the environment is their accumulation through food chain and persistent in nature.

Uptake of heavy metals like zinc, copper and lead through food chain in human being may cause various physiological disorders like hypertension, sporadic fever, nausea, renal damage, cramps etc.

Bioaccumulation is the net accumulation of a substance from water into an aquatic organism resulting from simultaneous uptake and elimination of the substance. Tissues such as liver, kidney, muscle, viscera and whole organisms are analyzed to determine the concentration of metals (Dublin-Green *et al*., 1994).

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The Hooghly estuarine ecosystem is one of the most productive estuaries of the world (Nath, 1998) and the backbone of capture fishery. The study area, which is an important part of Hooghly estuarine ecosystem situated on the upper stretch of Gangetic West Bengal. The area receives a wide variety of industrial and municipal wastes from industries. The wastes generated from industries include fertilizer, paints and pigments, dye-manufacturing units, electroplating units, thermal power plants etc. These industrial effluents contaminated the river water with a variety of heavy metals acting as point sources.

With the advent of agricultural and industrial revolution, most of the water sources are becoming contaminated (Khare and Singh, 2002). Industrial discharges containing toxic and hazardous substances, including heavy metals (Gbem *et al*., 2001; Woodling *et al*., 2001) contribute tremendously to the pollution of aquatic ecosystems. Concentrations of both Mn and Co in gonads, Cr in bronchial hearts and Zn in both gills and mantle increased linearly with animal weight (Nessim Ramzy and Rafik, 2003).

Many of the dissolved metals that enter rivers are adsorbed onto colloid particulates. Also at high alkalinity and pH, the metals, particularly lead and cadmium, precipitate by forming complexation dramatically influence metal toxicity (Van Aardt and Booysen, 2004; Van Aardt and Venter, 2004). Therefore, precipitation and sedimentation of cadmium and lead and, to a lesser extent, copper and zinc in alkaline water bodies could be greater at the dam inlet where sedimentation processes act as a sink for metals (Harding and Whitton, 1978). Heavy metal such as lead, copper, nickel and zinc are usually deposited in sediments not deeper than 15 cm (Ochsen Bein *at al*., 1983; Santos Bermejo *et al*., 2003).

Heavy metal levels were found generally higher in the liver and gill than the gonad and muscle tissues in three species *Dicentrarchus lbrax* L. *Sparus arata* L.and *Mugli cphalus* L., the levels of all metals in a given tissue were generally higher in Mugil Cephalus (Dural *et al*., 2005). The muller fish, *Liza klunzingeri*, commercially important and widely relished by Kumaiti residents and the stressed ecosystem in Kuwait Bay instigated us to conduct toxicity and bioaccumulation tests on heavy metals (Pb, Ni, V, Cu and Fe). Among five metals, Pb had the lowest observed effect concentration at 1 $\mu g\ L^{-1}$ (Bu-Olayan *et al*., 2005). The pattern of accumulation of cadmium and its affinity to selected tissues-gills, kidneys, liver, skin and muscle- of Clarias batrachus exposed to sub lethal concentration (7 ppm) of cadmium chloride was investigated and the mean rate of accumulation of exposure was in order gills> kidneys> liver> skin> muscle (Jayakumar and Paul, 2006). Bhattacharya *et al*. (2006) observed that chromium and cadmium in the muscles tissues and gill of six commercially edible fishes is higher than gonads and skin in upper course of gangetic West Bengal, India.

In the present study, an attempt has been made to study the seasonal bioaccumulation of zinc, chromium, copper, cadmium and lead in gills, gonads, skin and the muscle tissues of commercially edible six different fishes *Apocryptes bato*, *Glossogobius guris*, *Gudusia chapra*, *Mastacembelus armatusy*, *Eutropiichthys vacha*, *Cynoglossus punticeps* of pre-monsoon, monsoon and post-monsoon seasons from sampled from upper stretch of Gangetic West Bengal which flows through important town and industrial agglomerations. Heavy metals concentrations in water and sediment phase were also investigated simultaneously to assess the degree of bioaccumulation. The pH, alkalinity and temperature of the ambient aquatic medium were determined to find out if they influenced the zinc, copper and lead concentrations in the gills, gonads, skin and the muscle tissues of selected fish species.

MATERIALS AND METHODS

The study was carried out at Rishra-Konnagar region situated at the upper stretch of Gangetic West Bengal during 2006-2007. The entire network comprised the seasonal sampling of water, sediment and fish samples for detecting the concentration of zinc, chromium, copper, cadmium and lead in water sediment and muscle tissues of fish samples. The seasonal sampling was carried out during the time of pre-monsoon (March, 2006-Mid May, 2006), monsoon (August, 2006-September, 2006) and post-monsoon (December, 2006-January, 2007).

Water samples were collected in TARSON makes PVC bottles and passed through 0.45-micron Millipore membrane. The filtered sample was treated with diethyl-dithio-carbamate and extracted in carbon tetrachloride. The extract was evaporated to dryness and the residue was mineralized with 0.1 mL of concentrated HNO_3 as outlined by Chakraborty *et al*. (1987). Analytical blanks were prepared and treated with same reagents. All analysis was done in triplicate by direct aspiration to German make GBC-Atomic Absorption Spectrophotometer Model 902 fitted with a deuterium background corrector. The result obtained for dissolved heavy metals were expressed in $\mu g\ L^{-1}$.

The analytical procedure for the metal analysis in the sediment sample was the dilute (0.5 N HCl) acid treatment of Malo (1996) for the determination of biological fraction of total trace elements and the concentrated HNO_3, $HClO_4$ and HF digestion, Ageman and Chau (1976) for the determination of total metal concentrations. All analysis was done in triplicate by direct aspiration into air-acetylene flame of GBC Atomic Absorption Spectrophotometer Model 902 equipped with a simultaneous background corrector. The results obtained were expressed in $\mu g\ g^{-1}$. For all fish samples, specimens of uniform size were collected each season in order to avoid the possible error due to size differences soft parts was carefully dissected after rinsing with double distilled water and oven dried at 110°C. The heavy metal concentrations in the dried samples were estimated after acid digestion following standard method as laid down in APHA, AWWA (1998). Harper *et al*. (1989) using the same Atomic Absorption Spectrophotometer as used for water and sediment analysis. The results were expressed in $\mu g\ g^{-1}$ metal per dry weight.

The physico-chemical parameters (Table 2), pH and temperature were recorded at site with a pre calibrated portable pH meter (sensitivity±0.01) of Cyberscan pH 110 and a standard RTD thermometer, Eutech, Singapore make. Turbidity and total dissolved solids were determined at site with a pre-calibrated portable Nephelometric turbidity meter of waterproof TN 110 and Ecoscan Palmtop TDS meter, Eutech, Singapore make. The total alkalinity was determined by standard method as laid down in APHA, AWWA (1998). All analysis was carried in duplicate to avoid any conspiracy in experimental results.

RESULTS AND DISCUSSION

The concentration of zinc, chromium, copper, cadmium and lead in the ambient media (sediment and water) as well as in commercially edible fish samples at the sampling station exhibited a unique seasonal oscillation. The concentration of heavy metals follow the trend: zinc> chromium> copper> cadmium> lead. The seasonal variation of different metals considered for the study in water and sediment phase at sampling station Rishra-Konnagar, West Bengal in the upper stretch of Ganga River is shown in the Table 1. The concentrations of zinc, chromium, copper, cadmium and lead in water phase were found to be maximum during monsoon period ($p<0.05$) which may be characterized by extremely low alkalinity and pH of the aquatic medium (Table 2) During the pre-monsoon period the concentration of metals attained it's minimum value with high surface water temperature. The parameters like pH, alkalinity, TDS and turbidity value also reached to their highest values during the pre-monsoon period. The resulting effect was observed in sediment phase with highest heavy metal concentration in pre-monsoon period followed by post-monsoon and monsoon period. This might be due to heavy precipitation for high pH and alkalinity value in monsoon period and subsequent discharge of fresh water (run off) from the adjacent area during monsoon. Similar observations were also recorded by Mitra *et al*. (1999) while working on brackish water wet land ecosystem of West Bengal, India. The lowering of water pH and alkalinity due to increased precipitation switches on the

Table 1: Heavy metal distribution in water and sediment phase

		Water phase (μg L^{-1})				
Station	Season	Zn	Cr	Cu	Cd	Pb
Rishra-Konnagar, West Bengal, India	Pre-monsoon	0.545	0.281	0.322	0.043	0.041
	Monsoon	0.691	0.391	0.191	0.088	0.058
	Post-monsoon	0.622	0.288	0.155	0.049	0.046
		Sediment Total (μg g^{-1})				
Station	Season	Zn	Cr	Cu	Cd	Pb
Rishra-Konnagar, West Bengal, India	Pre-monsoon	11.771	5.816	5.671	0.791	0.109
	Monsoon	10.641	3.682	2.191	0.672	0.099
	Post-monsoon	10.925	3.816	3.318	0.739	0.106
		Sediments Biologically available (μg g^{-1})				
Station	Season	Zn	Cr	Cu	Cd	Pb
Rishra-Konnagar, West Bengal, India	Pre-monsoon	5.386	3.795	3.141	0.578	0.032
	Monsoon	4.816	2.734	1.419	0.429	0.027
	Post-monsoon	5.165	3.369	2.221	0.521	0.038

Table 2: Environmental characteristics of the investigated course of the Ganga River

Season	Temperature (°C)	pH	Total alkalinity ($CaCO_3$) (mg L^{-1})	Total dissolved solids (mg L^{-1})	Turbidity (NTU)
Pre-monsoon	31.5	8.0	146	274	37
Monsoon	24.2	7.4	87	189	362
Post-monsoon	15.8	8.1	124	242	27

Table 3: Concentrations of analyzed heavy metals (in μg g^{-1} dry weight) in the muscle of fishes of the Ganga River

Metal	*Apocryptes bato*	*Glossogobius guris*	*Gudusia chapra*	*Mastacembelus armatusy*	*Eutropiichthys vacha*	*Cynoglossus punticeps*
Pre-monsoon						
Zn	11.889	10.121	7.567	4.936	4.648	4.496
Cu	4.687	0.576	4.832	1.123	0.554	0.345
Cr	1.672	1.662	0.335	0.569	0.678	0.545
Cd	0.331	0.385	0.275	0.375	0.410	0.184
Pb	0.009	0.012	0.015	0.007	0.006	0.008
Monsoon						
Zn	12.213	11.421	7.998	5.569	5.014	4.887
Cu	5.421	1.895	4.758	1.121	1.054	1.089
Cr	1.934	1.945	0.554	3.687	2.108	1.124
Cd	0.754	0.719	0.689	0.909	0.968	0.435
Pb	0.010	0.014	0.017	0.008	0.010	0.012
Post-monsoon						
Zn	11.987	10.765	7.989	4.982	4.679	4.776
Cu	4.789	0.674	4.760	1.176	1.044	1.081
Cr	1.791	1.791	0.385	0.881	1.678	0.679
Cd	0.691	0.571	0.661	0.841	0.829	0.386
Pb	0.009	0.013	0.016	0.005	0.009	0.009

process of dissolution of metallic compounds from the sediment compartment to the aquatic column (Laksmann and Nambisan, 1983) resulting in the increase of dissolve heavy metals and decrease of biologically available heavy metals in the sediment compartment during monsoon.

The concentrations of heavy metals in different tissues of fish samples from upper course of River Ganga were shown in Table 3-6, the monsoon period got the highest concentration of heavy metals followed by post-monsoon and pre-monsoon period. Muscle tissues and gill showed higher concentration of zinc, chromium, copper, cadmium and lead than gonads and skin ($p<0.05$). Zinc, copper and chromium accumulation are much higher than cadmium and lead of different fish species ($p<0.05$). Gonads showed the lowest concentration of heavy metals compare to the any other tissues of the fish samples studied at the sampling station during the period. The order of metal accumulation

Table 4: Concentrations of analyzed heavy metals (µg g^{-1} dry weight) in the gonads of fishes of the Ganga River

Metal	*Apocryptes bato*	*Glossogobius guris*	*Gudusia chapra*	*Mastacembelus armatusy*	*Eutropiichthys vacha*	*Cynoglossus punticeps*
Pre-monsoon						
Zn	6.423	5.501	3.424	2.391	2.301	2.201
Cu	2.271	0.244	2.271	0.590	0.254	BDL
Cr	0.861	0.702	0.172	0.314	0.351	0.301
Cd	0.289	0.391	0.289	0.361	0.401	0.169
Pb	0.004	0.006	0.006	0.004	0.003	0.004
Monsoon						
Zn	6.653	5.634	4.321	2.993	2.367	2.449
Cu	2.567	0.998	2.456	2.621	0.512	0.510
Cr	0.978	0.996	0.294	2.103	1.079	0.519
Cd	0.754	0.719	0.659	0.887	0.921	0.409
Pb	0.005	0.007	0.009	0.004	0.005	0.007
Post-monsoon						
Zn	6.432	5.389	3.996	2.442	2.319	2.321
Cu	2.343	0.315	2.301	2.521	0.321	0.240
Cr	0.829	0.709	0.221	0.429	0.844	0.351
Cd	0.691	0.542	0.621	0.819	0.829	0.359
Pb	0.004	0.006	0.007	0.005	0.005	0.005

BDL = Below Detection Limit

Table 5: Concentrations of analyzed heavy metals (in µg g^{-1} dry weight) in the skin of fishes of the Ganga River

Metal	*Apocryptes bato*	*Glossogobius guris*	*Gudusia chapra*	*Mastacembelus armatusy*	*Eutropiichthys vacha*	*Cynoglossus punticeps*
Pre-monsoon						
Zn	10.123	8.013	6.109	4.790	4.213	3.121
Cu	4.014	0.571	2.215	1.506	1.031	1.007
Cr	1.361	1.498	0.207	0.508	1.501	0.421
Cd	0.405	0.112	0.201	0.712	0.539	0.119
Pb	0.008	0.011	0.015	0.014	0.007	BDL
Monsoon						
Zn	11.999	10.024	7.017	5.070	4.449	4.389
Cu	4.969	1.145	3.900	1.018	1.045	1.079
Cr	4.969	1.145	1.420	1.676	2.008	1.120
Cd	0.623	0.389	0.227	0.789	0.792	0.165
Pb	0.010	0.013	0.017	0.007	0.009	0.010
Post-monsoon						
Zn	10.229	8.023	6.669	4.890	4.313	3.501
Cu	4.540	0.574	2.225	1.621	1.041	1.071
Cr	1.601	1.651	0.381	0.567	1.591	0.579
Cd	0.419	0.122	0.208	0.743	0.612	0.129
Pb	0.009	0.012	0.0016	0.005	0.008	0.009

BDL = Below Detection Limit

in the muscle tissues of this study was also supported by the present results. Combie (1975) also found considerable differences in mercury concentrations in the muscle of different fish from the Suwannee River in Georgia, indicating that metabolic activities of different fish species may be an important factor in mercury accumulation.

Gonads showed the lowest concentration of zinc, chromium, copper, cadmium and lead of *Mastacembelus armatusy*, *Eutropiichthys vacha* and *Cynoglossus punticeps* in the pre-monsoon and post-monsoon period from upper course of the Ganga River shown in Table 4. In the monsoon period, the highest concentration of chromium and cadmium were detected in gill of *Apocryptes bato* (Table 6) and the muscle tissues of *Apocryptes bato* (Table 3).

Further, metal accumulation was not same in all finfishes rather species specificity was observed (Bhattacharya *et al*., 2001, 2006) and metal accumulation was found to be the function of their respective membrane permeability and enzyme system. This is why different degree of zinc, chromium, copper, cadmium and lead accumulation has been observed in different fishes.

Table 6: Concentrations of analyzed heavy metals (in µg g^{-1} dry weight) in the gill of fishes of the Ganga River

Metal	*Apocryptes bato*	*Glossogobius guris*	*Gudusia chapra*	*Mastacembelus armatusy*	*Eutropiichthys vacha*	*Cynoglossus punticeps*
Pre-monsoon						
Zn	12.218	10.312	9.301	7.839	6.245	5.300
Cu	7.337	1.024	7.209	2.022	1.324	0.901
Cr	3.392	3.279	1.279	1.541	1.919	1.528
Cd	0.962	1.015	0.570	0.755	0.839	0.412
Pb	0.017	0.021	0.023	0.013	0.012	BDL
Monsoon						
Zn	13.239	12.623	11.321	10.643	10.213	8.007
Cu	10.123	2.265	8.444	2.242	1.997	1.201
Cr	3.716	3.734	1.456	3.771	3.643	2.323
Cd	1.698	1.427	1.379	1.814	1.742	0.901
Pb	0.017	0.025	0.032	0.014	0.018	0.021
Post-monsoon						
Zn	12.292	10.432	9.669	7.931	6.332	5.529
Cu	7.589	1.198	7.739	2.220	1.469	0.949
Cr	3.432	3.698	1.369	2.525	3.213	2.212
Cd	1.458	1.177	1.280	1.771	1.629	0.719
Pb	0.017	0.024	0.024	0.013	0.015	0.014

BDL = Below Detection Limit

Therefore, it may be said that aquatic life is more prone to heavy metal contamination in monsoon period while comparing with the other two period of the season. In fact, the level of heavy metals in the body of the fish depending upon their chemical environment in which they exist (Yazdandoost and Katdare, 1999).

CONCLUSIONS

The degree of bio-magnification of heavy metals at different levels depends upon the bioaccumulation capacity of the flora and fauna. In water they occur as complex and diverse mixtures of soluble and insoluble forms such as ionic species, inorganic and organic complexes and /or associated with colloids and suspended particulate matter (Pani *et al*., 2002).

Today, fishes have become the major diet and there have been attempts to devise ways to enhance fish production. The present study bioaccumulation of zinc, chromium, copper, cadmium and lead in edible part of the fishes indicates the extent of stress posed on this highly productive ecosystem. Muscle tissues and gill showed higher concentration of zinc, chromium, copper, cadmium and lead than gonads and skin. In fact, lowest concentration of heavy metals was observed in tissue of gonads for all the different fish species from the upper course (Rishra-Konnagar region) of Ganga River. The metal accumulation trend was observed to zinc> copper>chromium>cadmium> lead.

In sediment phase, during monsoon and pre-monsoon periods heavy metal concentrations were observed minimum and maximum respectively. Apart from acute toxicity the aforesaid metals in water has proved dangerous and harmful due to their bioaccumulation and their impact on tissue degeneration, thus influencing growth, survival and reproductive potential of animals with special reference to fishes (Gupta *et al*., 2002). Carnivores at the top of the food chain including humans, obtain most of heir pollutant burden from aquatic ecosystem by way of their food specially fish (Mason, 1990; Milagros, 1996). The need of hour is to rationalize the use of industrial/domestic effluent on one hand and to minimize on the other hand their interference with other biotic components specially fishes for maintaining proper and right ecological balance.

The major findings of this study reveals that heavy metal concentrations in the muscle, gonads, skin and gill of *Apocryptes bato*, *Glossogobius guris*, *Gudusia chapra*, *Mastacembelus armatusy*, *Eutropiichthys vacha* and *Cynoglossus punticeps* from the river Ganga were significantly alarming and in general displaying significant variation from season to season. Efforts should however be concentrated on ensuring that these concentrations are not exceeded. Zinc, chromium, copper, cadmium and lead are essential in human diet. They all play significant role in metabolic processes. In view of the importance of fish to diet of man, it is recommended that biological monitoring of the water and fish meant for consumption should be done regularly to ensure continuous safety of food. Safe disposal of domestic sewage and industrial effluents should be practiced and where possible recycled to avoid these metals and other contaminants from going into the environment. Laws enacted to protect our environment should be enforced.

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