Trends in Applied Sciences Research

ISSN 1819-3579

Academic Journals Inc.

www.academicjournals.com

Trends in Applied Sciences Research 1 (5): 511-517, 2006
ISSN 1819-3579

Bioaccumulation of Chromium and Cadmium in Commercially Edible Fishes of Gangetic West Bengal

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Abstract: Concentration of chromium and cadmium were investigated in the gill, gonads, skin and muscle tissues of six commercially edible fishes sampled from upper course of gangetic West Bengal. Heavy metal concentrations in the tissues tended to vary significantly among seasons and monsoon period showed particularly high metal concentration compared to pre-monsoon and post-monsoon period. Muscle tissues and gill showed higher concentration of chromium and cadmium than the gonads and skin. Highest concentration of chromium and cadmium was detected in gill tissues. Lowest concentration observed in gonads of fish sampled from upper course of the River Ganga. Analysis of the above two metals were also carried out in ambient aquatic and sediment phases to monitor the degree of pollution. Higher values of chromium and cadmium were observed in sediment phases in comparison to water and fish. Further metals were observed to become bio-accumulated. High degree of species-specificity was also observed for metal accumulation and in case of chromium accumulation rate was higher than that of cadmium. During study, influence of physico-chemical parameters like pH, Alkalinity and temperature were also investigated to find out if they have any influence on accumulation phenomenon of chromium and cadmium in the muscle tissue of the selected fish species.

Key words: Heavy metals, accumulation, edible fish, tissues, species-specificity, bioaccumulation, Ganga river, West Bengal, India

Introduction

Heavy metals are known toxicants and their presence in fish is of worldwide concern because these can affect the health and productivity of the fish and can accumulate in human if contaminated fishes are consumed (Krogh and Scanes, 1996). In an aquatic life, they also affect the metabolic activity of the flora and fauna, disturbing the natural activity of the environment. Contaminated fish by heavy metals, if consumed by human being may cause various physiological disorders like hypertension, sporadic fever, renal damage, anemia, cramps. Fish contaminated with heavy metals it consumed by human being may cause various physiological disorders like hypertension, sporadic fever, renal damage, cramps, kidney damage etc. (Pani *et al*., 2002) among the heavy metals, chromium and cadmium specifically were reported to be highly toxic to the aquatic environment.

Uptake of chromium and cadmium through food chain in human being may lead to destruction of testicular tissues and red blood cells, kidney damage etc. Spurny *et al*. (2002) observed it is essential to ensure the restoration and protection of the fish communities, negatively affected for a very long time, where heavy metals contamination cause chronic stress leading to reproductive, immune, growth and other disorders, which could finally lead to the extinction and disappearances of the more

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sensitive species from their natural ichthyocenoses. Ansari *et al.* (2004) explained the basic concepts, sources, speciation and mode of action, levels, analytical measurements, bioavailability, bioaccumulation, biological role and toxicity of heavy metals in the marine environment. In the 1950's, chronic cadmium poisoning through food chain caused epidemic of kidney damage and a painful skeletal disease among middle-aged women in Japan, called Itai-itai disease. Further chromium (VI) was reported to be possible carcinogenic. Availability of heavy metals in aquatic ecosystem and its impact in flora and fauna has been reported by various workers (Mann and Ajani, 1991; Nayak, 1999; Shrinivas and Rao, 1999; Kannan *et al*., 1999; Mitra *et al*., 2000). Heavy metals in the aquatic ecosystem may be of anthropogenic or natural origin. Heavy metals residues in fish tissues sampled from uncontaminated waters may reflect local geo-chemical characteristics, which can be highly variable (Harms and Kerkhoff). However, fish samples collected from contaminated waters can indicate the magnitude of contamination in the surroundings water through accumulated heavy metal concentration in their body tissues (Korgh and Scanes, 1996). The study area is situated on the upper stretch of Gangetic West Bengal. The fishery resources of this important revering ecosystem have tremendous economical as well as nutritional importance (Hassan *et al*., 1998). But the declining trend of the commercial fishes in the recent past is a matter of concern of the fishery scientists. The area receives wide varieties of wastes generated by municipalities and industries, which might have toxic effects to the aquatic habitat of the estuary. The industries like paints and pigments, metal processing industries, thermal power plants, tanneries, chemical process industry and electroplating industries generated wastes which act as a point source of heavy metal pollution to this estuary. The wastes generated by tanneries are the major source of chromium pollution. In fact, global budgets of metal discharge to the aquatic environment show that domestic wastewater is a major source of heavy metals into rivers, lakes and oceans. Other major sources include coal burning power plants and the metal industries. The ground water contamination by aforesaid sources and their persistence in food chain has been of major concern as it posing a serious threat to aquatic cultures including fisheries (Gupta *et al*., 2002). Heavy metal has been man's worst endeavor in his attempt to augment industrial development. Today, the heavy metals are termed as devils and disguise and the economic reason impels us to keep them using.

In the present study, an attempt was made to investigate the current heavy metal like chromium and cadmium contamination in gills, gonads, skin and muscle tissues of six commercially edible fishes *Apocryptes bato*, *Glossogobius guris*, *Gudusia chapra*, *Mastacembelus armatus*, *Eutropiichthys vacha* and *Cynoglossus punticeps* of pre-monsoon, monsoon and post-monsoon seasons of the upper stretch of gangetic West Bengal. Analysis of the above two metals were also carried out in ambient aquatic and sediment phases to monitor the degree of pollution. The pH, alkalinity and temperature of the ambient aquatic medium were determined to find out if they influenced the chromium and cadmium concentrations in the muscle tissues of selected fish species.

Materials and Methods

The study was carried out considering Uttarpara-Bally region as the sampling station situated at the upper stretch of Gangetic West Bengal during 2005-2006. The area received wide variety of wastes that arise due to various anthropogenic activities from both sides on the bank of river Ganga. The entire network comprised the seasonal sampling of water, sediment and fish samples for detecting the concentration of chromium and cadmium in water sediment and muscle tissues of fish samples. The seasonal sampling was carried out during the time of pre-monsoon (March, 2005-Mid May, 2005), monsoon (August, 2005-September, 2005), Post-monsoon (December, 2005-January, 2006).

Water samples were collected in TARSON bottle and passed through 0.45-micron millipore membrane filter paper. The filtered sample was then treated with diphenyl-dithio-carbamate and extracted in carbon tetra chloride. The extract was evaporated to dryness and the residue was mineralized with 0.1 of concentrated nitric acid as outlined by Chakraborty *et al*. (1987). Analytical blanks were prepared and treated with same reagents. Analysis was done in triplicate by direct aspiration to German make GBC atomic absorption spectrophotometer fitted with a deuterium background corrector. The results obtained for dissolved heavy metals were expressed in $\mu g\ L^{-1}$.

The analytical procedure for the metal analysis in the sediment sample was diluted (0.5 N HCl) treatment of Malo (1997) for the determination of biological fraction of the 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 carried out in duplicate by direct aspiration into air-acetylene flame of German make GBC Atomic Absorption Spectrophotometer Model 902 equipped with a simultaneous background corrector. The results obtained were expressed in micro-gram metal/gram dry weight.

Samples of the fish tissues for heavy metal analyses were taken in the laboratory immediately after returning from the field excursions. For the individual assessment of heavy metals, samples of the dorsal muscle without skin, gill tissue (cut off from the gill arch), gonads and skin without scales were taken. These tissue samples were immediately frozen and kept in the freezer in a temperature of -18°C together with the water and sediment samples until further assessment.

For all fish samples, specimens of uniform size were collected each season in order to avoid possible error due to size differences. The collected fish specimens were carefully dissected to obtain the muscle, skin, gills and gonads tissues, which were then oven dried at 110°C for overnight. The chromium and cadmium concentration of the dried sample were estimated after acid digestion following standard method (Harper *et al*., 1989) using the same Atomic Absorption Spectrophotometer as used for water and sediment analysis. The results were expressed in $\mu g\ g^{-1}$.

The physico-chemical parameters (Table 1) like pH, turbidity, total dissolved solids 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 meter of waterproof TN110 and Ecoscan Palmtop TDS meter, Eutech, Singapore make. The alkalinity was determined by standard method as laid down in APHA and AWWA (1998).

Results and Discussion

The concentration of chromium and cadmium in the ambient media (sediment and water) as well as in commercially edible fish samples at the sampling station exhibited a unique seasonal oscillation.

Table 1 showed the seasonal variation of chromium and cadmium concentrations in water phase and sediment phase at the sampling station Bally Uttarpara, West Bengal in the upper stretch of Ganga River. The concentrations of chromium and cadmium in the water phase were found maximum during the monsoon period. Monsoon period characterized by extremely low alkalinity and pH of the aquatic medium and during the pre monsoon period the concentration of metals reached to a minimum value with high surface water temperature. This may be the effect of high water alkalinity and high pH during pre-monsoon period, which play a significant role in the process of compartmentation of heavy metals in this riverine ecosystem (Mitra *et al*., 1994). The surface water alkalinity and pH were observed to be highest in pre-monsoon period. In sediment phase, during monsoon and pre-monsoon periods heavy metal concentrations were observed minimum and maximum, respectively. The fact may be explained by surface water alkalinity and pH, which observed to be highest during pre-monsoon months and lowest during the monsoon season shown in Table 2. 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

Table 1: Heavy metal distribution in water and sediment phase

		Water phase ($\mu g\ L^{-1}$)		Sediment (total) ($\mu g\ g^{-1}$)		Sediments (biologically available) ($\mu g\ g^{-1}$)	
Station	Season	Cr	Cd	Cr	Cd	Cr	Cd
Bally, Uttar	Pre-monsoon	0.275	0.04	4.5	0.78	3.8	0.57
Para,West	Monsoon	0.32	0.08	3.76	0.66	2.74	0.42
Bengal,India	Post-monsoon	0.29	0.05	3.78	0.74	3.32	0.51

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

Season	Temperature (°C)	pH	Total alkalinity (as $CaCO_3$) (mg L^{-1})	Total dissolved solids (mg L^{-1})	Turbidity (NTU)
Pre-monsoon	30	8.1	142	270	38
Monsoon	25	7.2	90	193	346
Post-monsoon	17	7.9	120	238	29

Table 3: Concentrations of analyzed heavy metals (in $\mu g\ g^{-1}$ dry weight) in the muscle of fishs of the Ganga River

Fish metal	*Apocryptes bato*	*Glossogobius guris*	*Gudusia chapra*	*Mastacembelus armatus*	*Eutropiichthys vacha*	*Cynoglossus punticeps*
Pre-monsoon						
Cr	1.63	1.6	0.32	0.56	0.65	0.54
Cd	0.32	0.39	0.27	0.37	0.40	0.18
Monsoon						
Cr	1.93	1.94	0.54	3.73	2.08	1.10
Cd	0.75	0.72	0.69	0.91	0.93	0.43
Post-monsoon						
Cr	1.65	1.78	BDL	0.85	1.66	0.67
Cd	0.68	0.56	0.65	0.83	0.82	0.38

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

Chromium and cadmium concentration in the muscle, gonads, skin and gill of *Apocryptes bato*, *Glossogobius guris*, *Gudusia chapra*, *Mastacembelus armatus*, *Eutropiichthys vacha* and *Cynoglossus punticeps* of pre-monsoon, monsoon and post-monsoon seasons are shown in the Table 3-6.

Unique seasonal variation was observed also in case of heavy metal accumulation in the muscle tissues of fishes sampled from upper stretch of Gangetic region of West Bengal. Maximum accumulation was found during monsoon period and minimum during the pre-monsoon period in all fishes. This might be attributed to maximum run off that brings huge load of heavy metals like chromium and cadmium from electroplating industries, tanneries and metal processing units situated in the both sides of the River Ganga. The second cause behind high concentration of heavy metals in the muscle tissues during monsoon period may be related to the lowering of alkalinity and pH which might facilitate the dissolution of metal from sediment phase and increase the amount of metallic ions availability in water phase (Laksmann and Nambisan, 1983). The concentration of heavy metals in skin and muscle tissues showed in Table 5 and 3. The monsoon period generally showed the highest concentration of chromium and cadmium in the muscle tissues of *Mastacembelus armatus* and *Eutropiichthys vacha*, respectively (Table 3). The order of metal accumulation in the muscle tissues of this study was also supported by the present results. Cumbie (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.

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

Fish metal	*Apocryptes bato*	*Glossogobius guris*	*Gudusia chapra*	*Mastacembelus armatus*	*Eutropiichthys vacha*	*Cynoglossus punticeps*
Pre-monsoon						
Cr	0.85	0.81	0.15	0.29	0.33	0.28
Cd	0.28	0.38	0.27	0.35	0.39	0.17
Monsoon						
Cr	0.97	0.98	0.28	2.10	1.08	0.52
Cd	0.74	0.71	0.65	0.88	0.92	0.42
Post-monsoon						
Cr	0.83	0.71	BDL	0.43	0.84	0.35
Cd	0.69	0.54	0.61	0.82	0.83	0.36

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

Fish metal	*Apocryptes bato*	*Glossogobius guris*	*Gudusia Chapra*	*Mastacembelus armatus*	*Eutropiichthys vacha*	*Cynoglossus punticeps*
Pre-monsoon						
Cr	3.35	3.41	0.98	1.67	1.96	1.63
Cd	0.64	0.77	0.53	0.71	0.81	0.37
Monsoon						
Cr	3.61	3.68	1.62	3.72	3.65	2.30
Cd	1.61	1.39	1.22	1.78	1.71	0.86
Post-monsoon						
Cr	3.69	3.56	0.51	2.55	3.59	2.21
Cd	1.41	1.12	1.23	1.72	1.61	0.67

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

Fish metal	*Apocryptes bato*	*Glossogobius guris*	*Gudusia chapra*	*Mastacembelus armatus*	*Eutropiichthys vacha*	*Cynoglossus punticeps*
Pre-monsoon						
Cr	3.59	3.98	0.96	1.53	1.92	1.53
Cd	0.96	1.01	0.57	0.75	0.83	0.41
Monsoon						
Cr	3.71	3.73	1.43	3.75	3.36	2.10
Cd	1.69	1.42	1.27	1.81	1.73	0.90
Post-monsoon						
Cr	3.34	3.64	0.48	2.51	3.21	2.11
Cd	1.45	1.17	1.27	1.75	1.63	1.72

Gonads showed the lowest concentration of chromium and cadmium of *Cynoglossus punticeps* and *Gudusia chapra* 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 *Gudusia chapra* (Table 6) and the muscle tissues of *Eutropiichthys vacha* (Table 3). Muscle tissues and gill showed higher concentration of chromium and cadmium than gonads and skin.

Chromium accumulation is much higher than cadmium of different fish species. Further, metal accumulation was not same in all finfishes rather species specificity was observed and metal accumulation was found to be the function of their respective membrane permeability and enzyme system. This is why different degree of chromium and cadmium accumulation has been observed in different fishes.

Conclusions

The phenomenon of bioaccumulation and bio-magnification intensified with concentration of heavy metals at different tropic levels. In aquatic ecosystem the primary producers absorb the metallic ions, which in turn pass to the consumer level through predictions. 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 bioaccumulation of chromium and cadmium in edible part of the fishes indicate the extent of stress posed on this highly productive ecosystem.

Muscle tissues and gill showed higher concentration of chromium and cadmium than gonads and skin. In sediment phase, values of chromium and cadmium were observed higher in comparison to water and fish. Monsoon period showed higher metal concentration in aqueous medium and fishes compare to pre-monsoon and post-monsoon period. 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 armatus*, *Eutropiichthys vacha* and *Cynoglossus punticeps* from the river Ganga were significantly alarming and in general displaying significant variation from season to season. As such proper monitoring and control is quite essential to keep the health of these components of food chain with a view to maintain highly productive ecosystem intact

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