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Heavy metal levels (Al, As and Ba) in the organs of herbivore fish species residing in aquatic ecosystem of the River Ravi

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Abstract
Heavy metals were analyzed in the samples of herbivorous fishes, *Catla catla*, *Labeo rohita* and *Cirrhina mrigala* collected from the three public fishing sites, Shahdara bridge, Baloki headworks and Sidhnai barrage of the river Ravi during the sampling year, 2009-2010. All the three fish species exhibited significantly different abilities to accumulate metals in their body organs with the order: Al> As> Ba. The concentrations of heavy metals showed significant amassing of aluminium and arsenic in all the body organs of herbivore fishes while barium accumulations were significantly least in fish body at all the sampling stations. The three species of fish had the mean metallic toxicity levels followed the order: *Cirrhina mrigala*> *Labeo rohita*> *Catla catla*. The fish at Shahdara bridge were more contaminated with Al, followed by As and Ba with statistically significant differences.

Keywords: arsenic levels, aquatic food chain, biomagnification, liver, metallic ions toxicity, public fishing sites

1. Introduction

Water pollution is a major problem in many parts of Pakistan and is growing at an alarming rate around industrial and urban areas causing decline of water quality and reduction in freshwater fisheries. Urban and Industrial development in the developing countries has resulted in heavy metal pollution of river systems. Domestic wastewater and obnoxious chemicals of industrial effluents and products of heavy metals which find their way into water systems can produce toxic effects in receiving water bodies and fish inhabiting these waters (Allen and Moore, 2004) [1].

The contamination of freshwaters due to several harmful substances, like metals, through inputs from anthropogenic sources, industrial and agricultural activities, domestic sewage, groundwater leaching and runoffs from agriculture has devastating effects on animals (Donohue *et al*., 2006) [2]. Aluminium is widely used for making drinking bottles, foils, containers, bottle tops and machinery for transport industry. All these activities generated aluminium rich water resources for fishes and aquaculture.

Fish communities are excellent indicator of metal pollution and commercially important edible fish species have been widely investigated in order to assess for those hazards to human health (Begum *et al*., 2005) [3]. River Ravi is imperiled to severe pollution and dredging due to heavy discharge of enormous metallic compounds into the river systems of Pakistan (Jabeen and Javed, 2012) [4]. This has attributed to bio-accumulation and biological magnification even at low concentration exposures of heavy metals like aluminium, arsenic and barium due to discharge of surface runoffs and industrial effluents causing adverse effects on the indigenous fish fauna in the river Ravi. Recent studies conducted by different researchers have generally examined cadmium, copper, iron, manganese, cobalt and lead in the river Ravi aquatic ecosystem as far as the toxic and deleterious effects of heavy metals are concerned. However, the toxic effects of aluminium, arsenic and barium have not been previously reported in rivers of Pakistan. Therefore, the aim of current study was to evaluate the heavy metal toxicity gradient in commercially vital and edible herbivore fishes at three main public fishing sites, Shahdara Bridge, Baloki headworks and Sidhnai barrage and develop strategies to eliminate the toxic effect of metals and promotion of freshwater fisheries and aquaculture in Pakistan.

2. Materials and Methods

2.1 Collection of Experimental Fish

Fish samples were collected on monthly basis from the three public fishing sites, Shahdara bridge (Lahore), Baloki headworks and Sidhnai barrage (Figure I) with the help of Punjab Fisheries Department.

The research work was conducted for a period of one year (from June 2009 – May 2010). Five fish of each species belonging to major carps i.e. *Catla catla*, *Labo rohita* and *Cirrhina mrigala* were sampled randomly for bioaccumulation and metal level assessment.

2.2 Analysis of Fish and Determination of Heavy Metals

Sampled fish were dissected to obtain the fish organs, gills, liver, kidney, intestine, reproductive organs, skin, muscle, fins, scales, bones and fats for the bioaccumulation studies. After wet digestion, samples were analyzed for the selected heavy metals determinations by Atomic Absorption Spectrometry, (Perkin Elmer, A Analyst-400). The data on different variables were statistically analyzed by using SPSS 10.1 computer program. Analysis of variance and Tukey's/Student Newman-keul tests were performed to find-out statistically significant differences among various parameters under investigation.

3. Results and Discussion

The toxic levels of different metals found in herbivorous fish species were directly dependent upon the metallic eco-toxicity of the river Ravi, the ecological needs, metabolism and feeding patterns of various fish species sampled during this study period. However, significant variations in metallic ion concentrations in various organs are due to the differences in physiological functions of various organ in fish body. Fish liver appeared as a target tissue/organ while monitoring metallic toxicity in the river Ravi aquatic ecosystem (Storelli *et al.*, 2006) [5]. The present investigation revealed that all the organs of herbivorous fish species showed significantly variable accumulation of metals with the sequence of liver > kidney > gills > intestine > reproductive organ > scales > fins > bones > muscle > fats (Table I; Figure II). In herbivore fish, the liver showed the mean maximum aluminium concentration of 152.66±19.66 μgg^{-1}, followed by that in kidney and gills. The herbivore species exhibited significantly lowest aluminium contents of 79.98±12.05 and 58.02±17.43 μgg^{-1}, respectively in their muscles and fats. Rajkowska and Protasowicki, 2000 [6] and Dural *et al.* (2007) [7] reported liver, kidney and gills as metabolically active organs to accumulate more amounts of heavy metals than the other tissue like muscle and fats. Fish liver and gills were reported as target organs for assessing metal accumulation. The amounts of metals in gills reflect the concentration of metallic ions in waters in which the fish live. Arsenic exerts toxic and deleterious effects to fish even at non-lethal concentrations (Ghosh *et al*., 2006; Farombi *et al*., 2007) [8, 9]. Culioli *et al.* (2009) [10] studied the impact of arsenic in the brown trout, *Salmo trutta*, of contaminated river of Corsica, France. Fish organs, liver and gills showed the highest concentrations of arsenic whereas concentrations in muscle were lower. Among the fish tissues, liver was the main storage compartment of arsenic (6.52 μgg^{-1}), followed by gills (4.83 μgg^{-1}) and muscle (1.45 μgg^{-1}). In the present study, herbivore fish species accumulated significantly higher arsenic in their liver as 3.22±0.58 $\mu g\ g^{-1}$, closely followed by the accumulations in kidney and gills with the mean arsenic concentrations of 3.17±0.64 μgg^{-1} and 2.79±0.66 μgg^{-1}, respectively. The accumulation of arsenic was lowest in the muscles (1.82±0.49 μgg^{-1}) and fats (1.13±0.56 μgg^{-1}). Significantly higher accumulation of heavy metals in fish liver than in the muscle was observed in studies conducted by Storelli *et al.* (2006) [11]. All the fish species exhibited significantly different abilities to accumulate metals in their body organs with the order: Al> As> Ba. (Table I). Uysal *et al.* (2008) [12] reported the mean concentrations of heavy metals in fish tissues were significantly different among species. Many researchers reported that accumulation of heavy metals in various tissues of different fish species living in the same habitat varied significantly (Canli and Atli, 2003 [13]; Mendil and Uluozlu, 2007) [14]. Heavy metal accumulation is dependent upon the type of fish species, life style and feeding habits of fish (Karaded and Unlu 2000 [15]; Karadede *et al*., 2004) [16]. In the present study, the three species of fish showed statistically different abilities to accumulate metals and the mean metallic toxicity levels followed the order: *Cirrhina mrigala*> *Labeo rohita*> *Catla catla*. The herbivore fish at Shahdara bridge were more contaminated with Al (121.35±7.65 $\mu g\ g^{-1}$), followed by As (3.11±0.49 $\mu g\ g^{-1}$) and Ba (0.25±0.04 $\mu g\ g^{-1}$) with statistically significant differences (Table 2). The water at sampling stations viz. Baloki headworks and Sidhnai barrage caused significant amassing of Al in the body organs of herbivore fishes while barium accumulations were significantly least in fish body at all the sampling stations. The differences in various tissues for the accumulations of Al, As and Ba might be the result of their capacity to induce metal-binding proteins such as metallothioneins as described by Canli and Atli, 2003 [13].

Table 1: Metal concentrations (μgg^{-1}) in the organs of fish collected from the river Ravi

Organ × Metals	Metal concentrations (μgg^{-1})			
Organs	**Aluminium**	**Arsenic**	**Barium**	**Means**
Gills	128.14± 18.42a	2.79±0.66 b	0.24±0.06 c	43.72±73.12 c
Liver	152.66±19.86 a	3.22±0.58 b	0.29±0.09 c	52.06±87.14 a
Kidney	145.58±16.01 a	3.17±0.64 b	0.27±0.09 c	49.67±83.07 b
Intestine	126.70±12.61 a	2.92±0.59 b	0.24±0.08 c	46.17±77.25 bc
Reproductive organs	116.36± 14.00a	2.82±0.58 b	0.21±0.07 c	39.80±66.32 d
Skin	105.20± 12.79a	2.62±0.67 b	0.18±0.07 c	36.00±59.94 e
Muscle	79.98±12.05 a	1.82±0.49 b	0.11±0.07 c	27.30±45.63 g
Fins	100.04±5.81 a	2.44±0.62 b	0.16±0.06 c	34.21±57.02 e
Scales	105.20±6.33 a	2.57±0.61 b	0.19±0.06 c	35.99±59.95 e
Bones	90.71±10.63 a	2.14±0.44 b	0.14±0.05 c	31.00±51.72 f
Fats	58.07±14.17 a	1.13±0.56 b	0.06±0.03 c	19.75±33.19 h
Means	109.87±28.82 a	2.51±0.62 b	0.19±0.07 c	
Species × Metals				
Catla catla	101.51±2.13 a	2.12±0.03 b	0.13±0.01 c	25.08±40.80 b
Labeo rohita	110.86±1.17 a	2.49±0.02 b	0.20±0.03 c	27.66±44.56 b
Cirrhina mrigala	117.26±2.78 a	2.93±0.01 b	0.24±0.03 c	32.09±48.67 a
Means	109.87±7.94 a	2.51±0.41 b	0.19±0.05 c	
Station × Metals				
Shahdara bridge	121.61±21.04 a	3.15±0.12 b	0.24±0.02 c	41.67±69.25 a
Baloki headworks	111.38± 30.50 a	2.33±0.07 b	0.21±0.02 c	33.06±55.07 c
Sidhnai Barrage	96.64±26.60 a	2.05±0.08 b	0.12±0.01 c	37.85±63.69 b
Means	109.87±12.55 a	2.51±0.57 b	0.19±0.06 c	

(Single row means are nonsignificant at $p < 0.05$)

Table 2: Metal concentrations ($\mu g\ g^{-1}$) in the bodies of herbivorous fish collected from three sampling stations of the river Ravi.

Metals	Fish species	Sampling Stations			Means
		Shahdera bridge	**Baloki headworks**	**Sidhnai barrage**	
Aluminium	Herbivore	121.35±7.65 a	112.03±10.65 b	96.29±5.57 c	109.89±12.67 b
Arsenic	Herbivore	3.11±0.49 a	2.46±0.66 b	1.98±0.75 c	2.52±0.57 b
Barium	Herbivore	0.25±0.04 a	0.21±0.03 b	0.11±0.05 c	0.19±0.07 b
	Means	0.29±0.06 a	0.26±0.08 a	0.14±0.05 b	

(Single row means are nonsignificant at $p < 0.05$)

4. Conclusion

The present extent of heavy metal pollution in the river Ravi is a more serious issue for public health due to the ability of these metals to persist, bio-accumulate and bio-magnify in the fish body organs and ultimately in humans consuming this fish. It also provokes a need for mitigation measures and proper management to lessen the toxic effects of metals on aquatic biota and public health.

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