Accumulation Variations of selected heavy metals in *Barbus xanthopterus* in Karoon and Dez Rivers of Khuzestan, Iran

Mohammadi M.[1*]; Askary Sary A.[2]; Khodadadi M.[2]

Received: March 2011 Accepted: August 2011

Abstract

The concentrations of Cd, Pb, Ni and Hg were determined in gill, liver and muscle of *Barbus xanthopterus* in down streams of Karoon and Dez Rivers during summer 2009. Heavy metal concentrations varied significantly, depending on the types of the tissue in fish species. The levels of heavy metals such as Cd, Pb, Ni and Hg in the *Barbus xanthopterus* of Karoon River were higher than in *Barbus xanthopterus* of Dez River ($P<0.05$). In Karoon and Dez Rivers, the concentrations of Cd, Pb and Ni were in the sequence gill>liver>muscle. The concentration of Hg in Karoon River was in the sequence liver> gill> muscle but, in Dez River, it was in the sequence liver> muscle > gill. Among heavy metals (Cd, Pb, Ni and Hg), the accumulation of Pb was more than other heavy metals in fish ($P<0.05$). In both rivers, the accumulation of heavy metals in muscle of fish was higher than the world health organization (WHO) standard.

Keywords: Heavy metal, *Barbus xanthopterus*, Karoon, Dez, Khuzestan, Iran

1- Department of Fisheries, Science and Research Branch, Islamic Azad University, khuzestan-Iran.
2- Department of Fisheries, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran.
*Corresponding author's email: M40.Mohammadi@gmail.com

Introduction

The river systems may be excessively contaminated with heavy metals released from domestic, industrial, mining and agricultural effluents (Leland et al., 1978; Langston, 1990). The contamination of fresh waters with a wide range of pollutants has become a matter of great concern over the last few decades (Canli et al., 1998). Contamination of rivers with heavy metals may have devastating effects on the ecological balance of the aquatic environment, and the diversity of aquatic organisms becomes limited with the extent of contamination (Suziki et al., 1988). In fresh water systems, fish is one of the aquatic products that is consumed by humans and also provides a good indicator of trace element pollution (Rashed, 2001). The determination of trace metal concentration in natural water systems has received increasing attention for monitoring environmental pollution. Due to the fact that some metals are not biodegradable, their way in food chain through a number of path ways and they may accumulate in different organs of human beings or animals (Birge et al., 2000). Fish are the major part of the human diet and it is not surprising that numerous studies have been carried out on metal accumulation in different species (Lewis et al., 2002). Heavy metals like cadmium, lead, nickel and mercury are some of the major components of the industrial waters, which along with other products from industrial operations are discharged into the aquatic environment. These substances are toxic to aquatic life (Frostner and Wittman, 1983; Ibok et al., 1991). Cadmium, lead, nickel and mercury are among the most harmful metallic pollutants. Bioaccumulation of these metals is known to adversely affect liver, muscle, kidney, gill and other tissues of fish, disturb metabolism and hamper development and growth of fish (Korai et al., 2008; Dallinger et al., 1987). The gills are the first organs to be exposed to resuspended sediment particles, so they can be significant sites of interaction with metal ions (Pawert et al., 1998). Gills are the uptake site of waterborne ions, where metal concentrations increase especially at the beginning of exposure, before the metal enters other parts of the organism (Kamaruzzaman et al., 2010). In contrast, the muscle tissues are not considered an active site for metal accumulation but it plays an important role in human's feeding (Romeo et al., 1999). Fish which generally accumulate contaminants from aquatic environments have been largely used in food safety studies. The commercial and edible species have been investigated in order to check for those hazardous to human health. Metals can be taken up by fish from water, food, sediments and suspended particulate material (Agusa et al., 2005). Karoon-Dez River basin, (10° 48´- 30° 52´E, 20° 30´- 05° 34´N), is located in the southern part of Iran. Karoon River is one of the largest rivers in Iran and has an area of 60500 Km^2 and an average annual discharge of 18700 million m^3, also Dez River is one of the constant rivers in Iran and has an area of 21100 Km^2 and an average annual discharge of 7396 million m^3. They play an important role in water and fish supply. *Barbus* *xanthopterus* has high market value and is one of the main fish products in Karoon and Dez Rivers. Considering the complexity of heavy metal bioaccumulation of fishes, it was important to study the heavy metal accumulation in different commercial fishes such as *B. xanthopterus* in Karoon and Dez Rivers for the food safety. The main objective of this study was to determine the contents of heavy metals in different tissues of *B. xanthopterus* which were collected from down streams of Karoon and Dez Rivers. This could help us understand the enrichment behavior of heavy metals in down streams of Karoon and Dez Rivers and emphasize the need to discard the most polluted tissues of the fish.

Materials and methods

The concentration of heavy metals such as cadmium, lead, nickel and mercury were measured in the muscle, gills and liver of *B. xanthopterus*, collected by gillnet from down streams of Karoon (Shekariyeh 3 village) and Dez (Ali abad village) Rivers in Khuzestan province during summer 2009. The number of samples was 48 fish in each river. After capture, fish were placed in plastic bags and transported to the laboratory in freezer bags with ice. The length and weight were measured which ranged from minimum and maximum value as 248.5 and 377.5mm for length and 173 and 561.3 g for weight of *B. Xanthopterus* in Karoon and Dez Rivers. After biometry, fish were immediately frozen at -20°C. All samples were cut into pieces and labeled, and then all sampling procedures were carried out according to internationally recognized guidelines (UNEP, 1991). Fish samples for heavy metals were put onto a dissection tray and thawed at room temperature. They were dissected using stainless steel scalpels and Teflon forceps using a laminar flow bench. In parallel gill, liver and a part of the muscle (dorsal muscle without skin) were removed and transferred in polypropylene vials. Subsequently, samples were put into an oven to dry at 90°C and reached constant weights in the oven. Before acid digestion, a porcelain mortar was employed to grind and homogenize the dry tissue samples. Aliquots of approximately 1g dried gill, liver and muscle were digested in Teflon beakers for 12 h at room temperature, and then for 4h at 100°C with 5 ml ultrapure nitric acid (65%, Merck).

Sample analysis

Heavy metals analysis: Cd, Ni and Pb were measured by graphite furnace atomic absorption spectrophotometry (Perkin-Elmer, 4100 ZL). Hg concentrations were determined with a Perkin–Elmer MHS-FIAS coupled to a Perkin–Elmer 4100 ZL spectrophotometer. Results are expressed as $mgkg^{-1}$ dry weight. The analytical procedure was checked using reference material [MESS-1, the National Center of Canada and CRM 277, the Community Bureau of Reference, Brussels, Belgium, and details were in (Robisch and Clark, 1993; Meador et al., 1994)]. For each matrix, analyses of three blank samples were performed along with the samples. Quality control was assured by the analysis of reagent blank and procedural blanks. Data statistics were performed using SPSS 17 software.

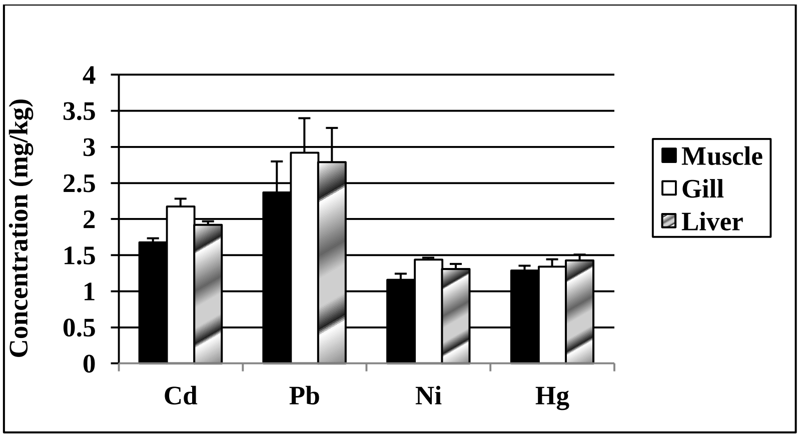

Figure 1: Heavy metal concentrations in muscle, gill and liver of *Barbus xanthopterus* in Karoon River

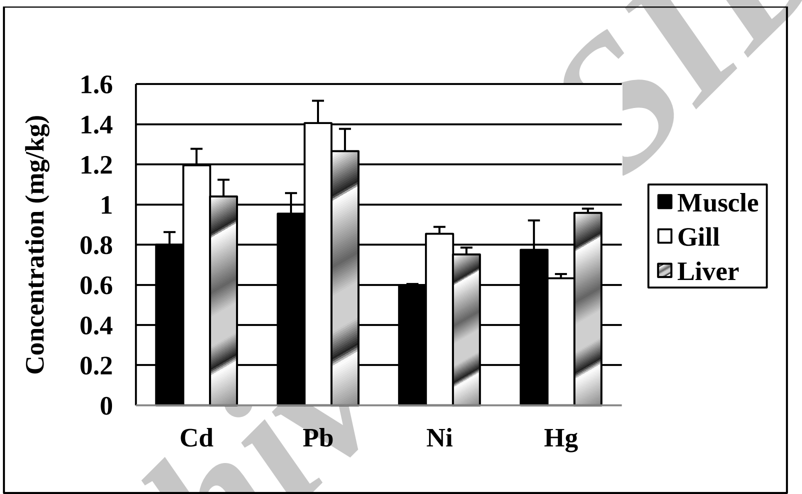

Figure 2: Heavy metal concentrations in muscle, gill and liver of *Barbus xanthopterus* in Dez River

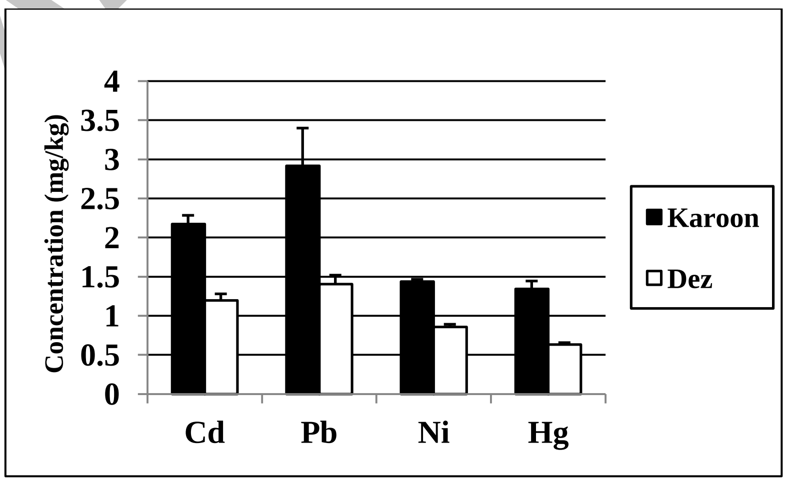

Figure 3: Heavy metal concentrations in gill of *Barbus xanthopterus*

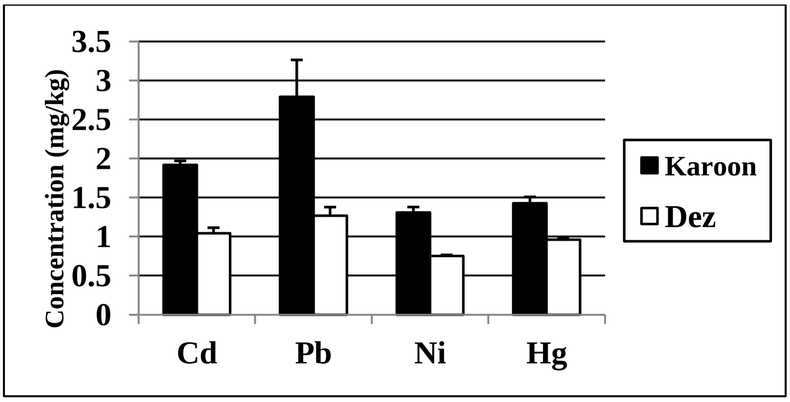

Figure 4: Heavy metal concentrations in liver of *Barbus xanthopterus*

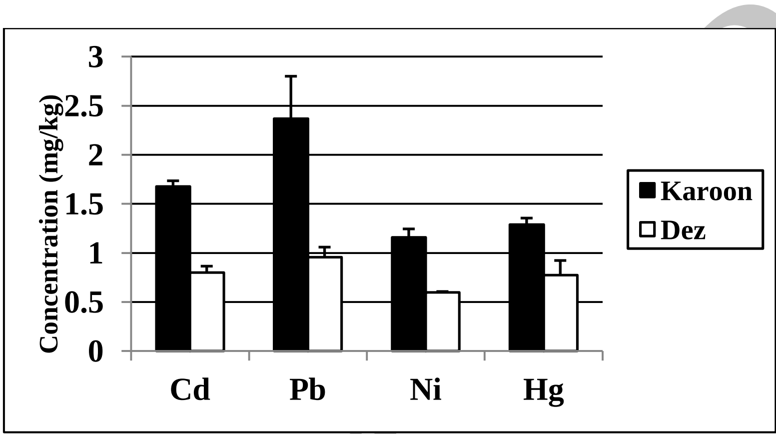

Figure 5: Heavy metal concentrations in muscle of *Barbus xanthopterus*

Table1: The concentrations of heavy metals (mgkg^{-1}dry weight) in various tissues of *Barbus xanthopterus* in Karoon and Dez Rivers, Khuzestan, Iran, summer 2009

Tissues	River	Cd	Pb	Ni	Hg
Gill	Karoon	2.1734± 0.1089[a]	2.918± 0.480[a]	1.4388± 0.0256[a]	1.3422± 0.1003[a]
	Dez	1.1947± 0.0833[b]	1.4063± 0.1110[b]	0.8550± 0.0342[b]	0.6331±0.0213[b]
Liver	Karoon	1.9197± 0.0491[a]	2.789± 0.474[a]	1.3078± 0.0704[a]	1.4269±0.0811[a]
	Dez	1.0406±0.0726[b]	1.2663± 0.1110[b]	0.75188± 0.01281[b]	0.9588±0.0256[b]
Muscle	Karoon	1.6781±0.0555[a]	2.370±0.429[a]	1.1597±0.0833[a]	1.2894±0.0640[a]
	Dez	0.7994±0.0640[b]	0.9550±0.1025[b]	0.59844±0.00640[b]	0.7741±0.1473[b]

Data are presented as means ± S.E. of Karoon and Dez Rivers: a, b: P<0.05, significantly different in each tissue between two rivers.

Table2: Comparison of heavy metals (mgkg^{-1}) in some studies with present study

Species	Tissues	Cd	Pb	Ni	Hg	References
Barbus xanthopterus	Gill	-	-	-	-	Alhas et al. (2009)
	Liver	-	-	-	-	
	Muscle	-	0.68	0.08	-	
Barbus rajanorum	Gill	-	-	-	-	Alhas et al. (2009)
	Liver	-	-	-	-	
	Muscle	-	0.66	0.04	-	
Tor grypus	Gill	-	2.57	0.35	-	Oymak et al. (2009)
	Liver	-	2.98	0.17	-	
	Muscle	-	1.23	0.16	-	
Labeo rohita	Gill	0.583	0.531	0.370	0.107	Malik et al. (2010)
	Liver	0.529	1.263	1.210	0.315	
	Muscle	0.427	0.393	0.207	0.077	
Ctenopharyngodon idella	Gill	0.393	1.63	1.11	0.16	Malik et al. (2010)
	Liver	0.343	1.47	0.71	0.16	
	Muscle	0.417	1.32	0.67	0.14	
Cyprinus carpio	Gill	-	-	-	-	Erdogrul (2007)
	Liver	-	-	-	-	
	Muscle	-	-	-	0.07	
Siluris glanis	Gill	-	-	-	-	Erdogrul (2007)
	Liver	-	-	-	-	
	Muscle	-	-	-	0.26	
Elops lacerta	Gill	-	-	-	-	Ekpo &Ibok (1999)
	Liver	-	-	-	-	
	Muscle	0.01	0.02	-	-	
Psettias sebae	Gill	-	-	-	-	Ekpo &Ibok (1999)
	Liver	-	-	-	-	
	Muscle	0.03	0.01	-	-	
Liza parsia	Gill	-	-	-	0.54	Saha et al. (2006)
	Liver	-	-	-	0.65	
	Muscle	-	-	-	0.12	
Barbus xanthopterus (Karoon)	Gill	2.1734	2.918	1.4388	1.3422	Present study (2009)
	Liver	1.9197	2.789	1.3078	1.4269	
	Muscle	1.6781	2.370	1.1597	1.2894	
Barbus xanthopterus (Dez)	Gill	1.1947	1.4063	0.8550	0.6331	Present study (2009)
	Liver	1.0406	1.2663	0.75188	0.9588	
	Muscle	0.7994	0.9550	0.59844	0.7741	

Table3: Comparison of heavy metals (mgkg^{-1}dry weight) in muscle of *Barbus xanthopterus* with WHO standard in Karoon and Dez Rivers, Khuzestan, Iran

Tissue	River	Cd	Pb	Ni	Hg
Muscle	Karoon	1.6781±0.0555 [a]	2.370±0.429 [a]	1.1597±0.0833 [a]	1.2894±0.0640 [a]
	Dez	0.7994±0.0640 [b]	0.9550±0.1025 [b]	0.59844±0.00640 [b]	0.7741±0.1473 [b]
WHO		0.2[c]	0.3[c]	0.3[c]	0.1[c]

a, b, c: P<0.05, significantly different in muscle of *Barbus xanthopterus* with WHO standard.
References: WHO, 1985; WHO, 1994 ; Czarnezki, 1985.

Paired samples T-Test were used to compare differences between samples. A P-value ($p < 0.05$) was considered statistically significant (Zhang et al., 2007).

Results

Heavy metal concentrations in various tissues of *B. xanthopterus* in Karoon and Dez Rivers decreased in the sequence of Pb> Cd> Hg> Ni, but heavy metal concentrations in gill of *B. xanthopterus* in Karoon and Dez Rivers decreased in the sequence of Pb> Cd> Ni> Hg (Fig.1 and 2).

The comparison of heavy metal levels (Cd, Pb, Ni, Hg) in various tissues of *B. xanthopterus* between Karoon and Dez Rivers showed that heavy metal levels in *B. xanthopterus* of Karoon River were higher than in *B. xanthopterus* in Dez River (P<0.05) (Fig.3-5). The levels of Cd, Pb, Ni and Hg in various tissues of *B. xanthopterus* in Karoon and Dez Rivers are given in Table 1.

Discussion

In this study, the concentration of heavy metals in gill were higher than those in other tissues, except for Hg which was high in liver (P<0.05). The concentration of heavy metals in muscle were lower than in other tissues, except for Hg in *B. xanthopterus*in Dez River which was the least in gill (P<0.05). In this research, heavy metal concentrations (Cd, Pb, Ni and Hg) in various tissues of *B. xanthopterus* in Karoon River was higher than in *B. xanthopterus* in Dez River (P<0.05) and the concentration of heavy metals, differed significantly in each tissue of *B. xanthopterus* between Karoon and Dez Rivers (P<0.05), (Table 1). Heavy metal concentrations varied significantly depending upon the type of fish tissues and locations. Alhas et al. (2009) reported that in *Barbus xanthopterus* and *Barbus rajanorum mystaceus* in Ataturk Dam Lake, Turkey, heavy metal concentrations in gill and liver were maximum, while these concentrations were the least in muscle. Oymak et al. (2009) has reported the concentrations of Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn in gill, liver, muscle and kidney of *Tor grypus* in Ataturk Dam Lake, Turkey. Malik et al. (2010) determined the concentrations of Pb, Cd, Zn, Ni, Cu, Cr and Hg in gill, liver and muscle of *Labeo rohita* and *Ctenopharyngodon idella* in the Lake of Bhopal, India. In different reports it was showed that the concentrations of heavy metals in liver and gill were higher than muscle. The results of this study were similar to the above studies (Table 2). Thus, heavy metals when discharged into the rivers enter the food chain and accumulate in the fish body as determined during this investigation. In this study the obtained results showed that heavy metal concentrations in *B. xanthopterus* in two rivers were more than the WHO (World Health Organization, 1985, 1994) standard. The concentrations of heavy metals have significant differences ($P<0.05$) in muscle of *B. xanthopterus* with WHO standard in Karoon and Dez Rivers (Table 3). In Sir Dam Lake in Turkey, the mean Hg concentration in the muscle of *Cyprinus carpio* and *Siluris glanis* was reported as: 0.07μgg^{-1} and 0.26 μgg^{-1}, respectively (Erdogrul, 2007). The values recorded for Cd and Pb in the muscles of *Elops lacerta* and *Psettias sebae* in Calabar River of Nigeria, were 0.01, 0.02 μgg^{-1}; and 0.03, 0.01 μgg^{-1} respectively (Ekpo and Ibok, 1999). The mean of Ni and Pb concentrations in the muscles of *Barbus xanthopterus* and *Barbus rajanorum* in Ataturk Dam Lake of Turkey, were reported as: 0.08, 0.68 μgg^{-1}; 0.04, 0.66 μgg^{-1}, respectively (Alhas et al., 2009) and in Sunderban mangrove wetland of northeast India, the mean Hg concentration in the muscle, liver and gill of *Liza parsia* was reported as: 0.12, 0.65 and 0.54 μgg^{-1} respectively (Saha et al., 2006), a comparison of these concentrations with our data clearly shows higher values in *B. xanthopterus* in Karoon and Dez Rivers (Table 2). Differences in ecological needs, metabolism and feeding patterns of fish and also the season in which studies were carried out. In the river, fish are often at the top of the food chain and have the tendency to concentrate heavy metals from water (Mansour and Sidky, 2002). The results from this research indicated that metal accumulation depended on the tissues probably as a consequence of metabolic needs, physiochemical properties, and detoxification processes specific for each element. The results of this study showed that Pb was the highest accumulating metal compared to other metals ($P<0.05$), Ahmad et al. (2010) reported that among the five metals (Pb, Cd, Ni, Cu and Cr) studied, Pb concentration was the highest in *Gudusia chapra* of Buriganga River, Bangladesh. So, the result of our study was similar to the above result. The Pb finds its way in rivers through the discharge of industrial waste waters, such as from painting, dyeing, battery manufacturing units and oil refineries etc. Pb also enters the rivers both from terrestrial sources and atmosphere and the atmospheric input of Pb aerosols can be substantial (Mitra et al., 2010). The high levels of Pb in the Karoon and Dez Rivers have toxic effects on fish metabolism and it is important to consider the biological effects of contamination on fish health in Karoon and Dez Rivers.

This study was carried out to provide information on heavy metal concentrations in *B. xanthopterus*in Karoon and Dez Rivers in Khuzestan, Iran. All results were higher than the limits for fish proposed by the WHO (Table 3). High levels of heavy metals were found in the gill and liver of *B. xanthopterus* in Karoon and Dez Rivers while the lowest levels of *B. xanthopterus* in Karoon River were found in the muscle and in the Dez River they were found in the gill. The concentrations of heavy metals in *B. xanthopterus* in Karoon River were higher than in *B. xanthopterus* in Dez River (P<0.05). Research conducted by this paper found high levels of Pb in *B. xanthopterus* in Karoon and Dez Rivers (P<0.05), that could be traced to urban and industrial places near the Karoon and Dez Rivers and their wastes that are discharged into these rivers.

Acknowledgements

We would like to thank Islamic Azad University, Khuzestan Science and Research Branch that have supported us through the process of developing my thesis.

References

Agusa, T., Takashi, K., Genta, Y., Hisato, I. and Annamalai, S., 2005. Concentrations of trace elements in marine fish and its risk assessment in Malaysia. *Marine Pollution Bulletin*, 51, 896- 911.

Ahmad, M. K., Islam, S., Rahman, S., Haque, M. R. and Islam, M. M., 2010. Heavy Metals in Water, Sediment and Some Fishes of Buriganga River, Bangladesh. *Journal of Environment*, 4(**2**), 321-332.

Alhas, E., Oymak, S. A. and Akin, H. K., 2009. Heavy metal concentrations in two barb, *Barbusxanthopterus* and *Barbusrajanorummystaceus* from Ataturk Dam Lake, Turkey. *Journal of Environmental Monitoring and Assessment*, 148(**4**), 11-18.

Korai, A. L., Sahato, G. A., Kazi, T. G. and Lashari, K. H., 2008. Lead Concentrations in Fresh Water, Muscle, Gill and Liver of *Catla Catla* (Hamilton) from Keenjhar Lake. *Pakistan Journal of Analytical & Environmental Chemistry*, 9(**1**), 11-19.

Birge, W. J., Price, J. R., Shaw, J. A., Wigginton, A. J. and Hogstrand, C., 2000. Metal body burden and biological sensors as ecological indicators. *Environmental Toxicology & Chemistry*, 19,1199-1212.

Canli, M., Ay, O. and Kalay, M., 1998. Levels of heavy metals (Cd, Pb, Cu, Cr and Ni) in tissue of *Cyprinus carpio*, *Barbus capito*and *Chondrostoma regium* from the Seyhan River, Turkey. *Journal of Zoology*, 22, 149- 157.

Czarnezki, J. M., 1985. Accumulation of lead in fish from Missouri streams impacted by lead mining. *Bulletin of Environm Toxicology*, 34,736-745.

Dallinger, R., Prosi, F., Senger, H. and Back, H., 1987. Contaminated food and uptake of heavy metals by fish: A review and proposal for further research. *Oecologia*, 73, 91-98.

Ekpo, B. O. and Ibok, U. J., 1999. Temporal variation and distribution of trace metals in freshwater and fish from Calabar River, S.E. Nigeria. *Environmental Geochemistry and Health*, 21, 51-66.

Erdogrul, O., 2007. Determination of Mercury Levels in Edible Tissues of Various Fish Samples from Sir Dam Lake. *Turkish Journal of Biology*, 31, 197-201.

Evans, D. W., Dodoo, D. K. and Hanson, P. J., 1993. Trace- element concentrations in fish livers: implications of variations with fish size in pollution monitoring. *Marine Pollution Bulletin*,26, 329-334.

Forstner, U. and Wittman, G. T. W., 1983. Metal pollution in the aquatic environment. 2nd edition, *Springer - Verlag, Berlin, Heidelberg, New York*. 486p.

Ibok, U. J., Udosen, E. D. and Udoidong, O. M., 1991. Heavy metal levels in water and fish from streams in Ikot Ekpene in relation to industrial and municipal discharges. *Transactions of the Nigerian Society for Biological Conservation*, 2, 130–143.

Kamaruzzaman, B. Y., Ong, M. C. and Rina, S. Z., 2010. Concentration of Zn, Cu and Pb in some selected marine fishes of the Pahang Coastal Waters, Malaysia. *American Journal of Applied Sciences*, 7 (**3**), 309- 314.

Langston, W. J., 1990. Toxic effects of metals and the incidence of marine ecosystems. In: Furness, R.W. and Rainbow, P.S., editors. *Heavy Metals in the Marine Environment. CRC Press, New York*. 256 p.

Leland, H. V., Luoma, S. N. and Wilkes, D. J., 1978. Heavy metals and related trace elements.*Water Pollution Control Federation*, 50, 1469-1514.

Lewis, M. A., Scott, G. I., Bearden, D. W., Quarles, R. L. and James, M., 2002. Fish tissue quality in near- coastal areas of the gulf of Mexico receiving point source discharges. *Science of the Total Environment*, 284, 249-261.

Malik, N., Biswas, A. K., Qureshi, T. A., Borana, K. and Virha, R., 2010. Bioaccumulation of heavy metals in fish tissues of a freshwater lake of Bhopal. *Journal of Environmental Monitoring and Assessment*, 160(**4**), 267-276.

Mansour, S. A. and Sidky, M. M., 2002. Ecotoxicological studies. 3. Heavy metals contaminating water and fish from Fayoum Governorate, Egypt. *Food Chemistry*, 78, 15-22.

Meador, J. P., Clark Jr, R. C., Robisch, P. A., Ernest, D. W., Landahl, J. T. and Varanasi, U., 1994. National Benthic Surveillance Project: Pacific Coast. Trace element analyses for cycles I to V (1984–1988).National Oceanic and Atmospheric Administration, *National Marine Fisheries Service Technical Memorandum NMFSNW FSC-16*, 206p.

Mitra, A., Mondal, K. and Banerjee, K., 2010. Concentration of Heavy Metals in Fish Juveniles of Gangetic Delta of West Bengal, India. *Journal of Fisheries and Hydrobiology*, 5(**1**), 21-26.

Oymak, S. A., Karadede-Akin, H. and Dogan, N., 2009. Heavy metal in tissues of *Tor grypus* from Atatürk Dam Lake, Euphrates River-Turkey. *Journal of Biologia*, 64(**1**), 151-155.

Pawert, M., Muller, E. and Triebskorn, R., 1998. Ultra structural changes in fish gills as biomarker to assess small stream pollution.*Tissue and Cell*, 30, 617- 626.

Rashed, M. N., 2001. Monitoring of environmental heavy metals in fish from Nasser lake. *Environmental International*, 27, 27-33.

Robisch, P. A. and Clark, R. C., 1993. Sample preparation and analyses of trace metals by atomic absorption spectroscopy. In: LauensteinGG ,Cantillo AY , editors. Sampling and Analytical Methods of the National

Status and Trends Program, National Benthic Surveillance and Mussel Watch Project 1984–1992, vol. III.Comprehensive Descriptions of Elemental Analytical Methods.US Department of Commerce, National Oceanic and Atmospheric Administration. *Technical Memorandum NOS ORCA* 71, 111–150.

Romeo, M., Siau, Y., Sidoumou, Z. and Gnassia- Barelli, M., 1999. Heavy metal distribution in different fish species from the Mauritania coast. *Science of the Total Environment*, 232, 169-175.

Saha, M., Sarkar, S. K. and Bhattacharya, B., 2006. Interspecific variation in heavy metal body concentrations in biota of Sunderban mangrove wetland, northeast India. *Environment International*, 32, 203-207.

Suziki, K. T., Sunaga, H., Aoki, Y., Hatakeyama, S., Sumi, Y. and Suziki, T., 1988. Binding of cadmium and copper in the mayfly Baetisthermicus larvae that inhabit in a river polluted with heavy metals. *Comparative Biochemistry and Physiology - Part C: Toxicology & Pharmacology, An International Journal*, 91, 487- 492.

UNEP.Sampling of selected marine organisms and sample preparation for the analysis of chlorinated hydrocarbons, 1991. *Reference Methods for Marine Pollution Studies No.12, Rev. 2.UNEP. Nairobi*. 17.

WHO. 1985. Review of potentially harmful substances - cadmium, lead and tin. *WHO, Geneva. (Reports and Studies No. 22. MO /FAO /UNESCO /WMO /WHO /IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Pollution)*.

World Health Organization, 1994. Quality Directive of Potable Water, 2nd ed. *WHO*, 197P.

Zhang, Z., He, L., Li, J. and Wu, Z. B., 2007. Analysis of Heavy Metals of Muscle and Intestine Tissue in Fish – in Banan Section of Chongqing from Three Gorges Reservoir, China. *Polish Journal of Environmental*, 16(**6**), 949-958.