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Accumulation of heavy metals in the fish, *Oreochromis niloticus* and *Poecilia latipinna* and their concentration in water and sediment of dam lake of Wadi Namar, Saudi Arabia

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Abstract

The present study reports the accumulation of heavy metals like Cu, Hg, Cd, Pb and Cr in different tissues viz. liver, kidney, gills and muscles of *Oreochromis niloticus* and *Poecilia latipinna* from two sites in dam lake of Wadi Namar. Water and sediment samples were also collected from two sites for heavy metal analysis. Metal concentration in water and sediment samples of both the sites were observed in the followidng order : Cu>Cr>Pb>Cd>Hg; however, their concentration was found to be more at site 2 as compared to site 1. The order of metal accumulation in different tissues of *O. niloticus* and *P. latipinna* was in the following order: Cu>Cr>Pb>Cd>Hg at both the sites, while liver accumulated maximum amounts of metals followed by kidney, gills and muscles. The results showed the site 2 was more polluted by metals than Site 1 and *O. niloticus* accumulated greater amount of metals than *P. latipinna.*

Key words

Bioaccumulation, Heavy metals, *Oreochromis niloticus, Poecilia latipinna*

Introduction

Fish are an important part of human food because of high level of quality protein for proper growth and functioning of the body. *Oreochromis niloticus* and *Poecilia latipinna* inhabit freshwater of Saudi Arabia. These fishes are suitable species for aquaculture because of their faster growth and feeding habit. They feed on a large variety of agricultural by-products and can tolerate adverse water quality conditions. These fishes have been extensively used for freshwater fish culture practices throughout the world (Abdul-Baki, 2011: Alkahem Al-Balawi. 2013). Recently, Tilapia has become an important "aquaculture" fish in the Kingdom of Saudi Arabia.

The freshwater environment contaminated with a wide range of pollutants is a matter of concern worldwide (Dirilgen, 2001; Vutukuru, 2005; Malik, 2010). Occurence of heavy metals in aquatic system from both natural and anthropogenic sources has posed serious threat to the aquatic animals because of their toxic and long persisting nature, bioaccumulation, and biomagnifications via food chain (Eisler, 1988). Fish being situated at the top of food chain can accumulate large amount of toxicants (Yilmaz *et al.,* 2007). They have the potential to accumulate various types of toxic substances, including heavy metals either by diet and from water, and the concentrations of toxicants may be hundred times more than present in the water, sediment and food (Osman *et al.,* 2007). Since fish forms is one of the important part of human diet, the presence of trace elements in the aquatic ecosystem and its bioaccumulation in fish is a matter of great concern (Erdogrul and Erbilir, 2007)

Hg, Cd and Pb are toxic heavy metals even at a very low concentration and does not have any beneficial role to the aquatic organisms. Aquatic organisms develop a defense mechanism in response to the toxic effects of metals and other xenobiotics, that produces degenerative changes in the aquatic organisms including fish (Abou EL-Naga *et al.,* 2005). These activities alter the regulation, storage and excretion mechanisms. Strelli *et al.* (2006) reported that the bio accumulation rate of heavy metals in various tissues are different. Liver can accumulate a high level of metal as compared to other organs of fish (Uysal *et al.,* 2009). Gills can also accumulate high level of heavy metals and indicate contamination of water. The metal level in gills is affected by absorption through its surface, and by making mucus and metal complexion (Strelli *et al.,* 2006; Erdogrul and Erbilir, 2007). The production of healthy and enough aquatic foods to meet the ever increasing demands can be achieved by the management of the aquatic environment for toxicants and through corrective measures and implementation of environmental legislations.

Fish are widely used to evaluate the health of aquatic ecosystems because pollutants exert adverse effects on them and sometime the effects are so severe that they cause death of fish (Yousuf and El-Shahawi, 1999; Farkas *et al.,* 2002). These metals are finally assimilated by humans and cause several health problems (Agah *et al.,* 2009). As a consequence, fish are often used as indicators of heavy metals pollution in the aquatic ecosystem because they occupy high trophic levels and are an important food source (Agah *et al.,* 2009). The fish *Oreochromis niloticus and Poecilia latipinna* are introduced in many freshwater bodies of Saudi Arabia and the farmer species is cultured in ponds and irrigation canals by many fish farmers. The present study was conducted to determine the level of certain heavy metals in water, sediment and some organs of *Oreochromis niloticus and Poecilia latipinna* from dam lake of Wadi Namar, Riyadh, Saudi Arabia.

Materials and Methods

Sampling site and sample collection : Wadi Namar is one of the subsidiary Wadis (valleys) of Wadi Haneefah draining the western part of Riyadh. Wadi Namar has always played a key role in the water management of the western part of Riyadh. In the past, it was used as a source of water and now as a convenient means for disposing off city's wastewater. The agricultural runoff as well as domestic sewage/wastes are disposed in Wadi Namar. The dam lake is also used for bird and fish culture. This is also a place of recreation for the local community. Therefore, this reservoir has been selected for the study. Two different locations selected for collecting the samples were designated as site I and site II.

Five samples of water, sediments and *O. niloticus* and *P. latipinna* from two sites of the dam lake (Wadi Al-Namar at Al-Riyadh) were collected during the summer season (June, July, August and September, 2012). Samples were collected monthly from the same location. The mean values of the results obtained in the months of June, July, August and September were expressed as summer season. The collected water samples were preserved by adding few drops of nitric acid. The sediment samples were preserved in polyethylene bags. Different organs like muscles, liver, kidney and gills were collected by dissecting the fish and frozen for further study.

Metal estimation : Metal concentration in water and sediment samples were analyzed following the standard method of APHA (1992). Fish organs were dried at 100 ºC and then digested according to the method used by Alkahem Al-Balawi (2013). Pb, Cd, Hg, Cu and Cr concentration in the digested samples were estimated by atomic absorption spectrophotometer (Shimadzu) using different cathode lamps with air acetylene flame method. The cathode lamps had wave length ranging from 190 to 900 nm, respectively.

Results and Discussion

The average concentration of Pb, Cd, Hg, Cu and Cr in the water of samples were recorded as 1.91, 0.98, 0.32, 65.95 and 12.07 $\mu g\ l^{-1}$ at site I and 1.94, 1.35, 0.34, 69.57 and 10.79 at site II, respectively (Table 1). The order of heavy metal in water samples was found in the following order: Cu > Cr > Pb > Cd > Hg.

The mean concentration of Pb, Cd, Hg, Cu and Cr in the sediments samples were 105.12, 62.72, 12.91,10925 and 10712 $\mu g\ kg^{-1}$ at site I and 111.15, 78.81, 12.42, 12216, and 11045 $\mu g\ kg^{-1}$ at site II, respectively (Table 1). The concentration of heavy metal s in the sediment sample was in the following order : Cu > Cr > Pb > Cd > Hg.

The mean of concentration of heavy metals in different tissues of fish are presented in Table 2. Liver accumulated highest concentration of metals, while muscles accumulated the least. The mean Pb and Cr concentrations was (385.46 and 561.32 $\mu g\ kg^{-1}$, respectively) found to be high in kidney and low (52.33 and 155.39 $\mu g\ kg^{-1}$, respectively) in muscles (Table 2). Cu comparatively accumulated the highest concentrations among the studied heavy metals in all fish tissues and in both the fish species. The copper concentrations were, 12875, 8985, 3545 and 1279 $\mu g\ kg^{-1}$ in liver, kidney, gills and muscles, respectively.

The highest concentrations of Cr in different fish organs viz. liver, kidney, gills and muscles were determined as 381.09, 561.32, 255.71 and 164.35 $\mu g\ kg^{-1}$, respectively. The kidney accumulated the highest concentration of Cr whereas muscles accumulated the lowest concentration. The order of heavy metal concentration in different fish tissues was Cu > Cr > Pb > Cd > Hg. The mercury was found minimum to all metals determined in all the tissues of both the species.

The presence of different pollutants especially the heavy metals is more than the natural loads and has become a problem of concern. This condition has appeared as a result of uncontrolled growth of population, urban development, an expansion of industrial activities, increased exploration of natural resources, expansion of irrigation and other modern agricultural practices as well as the lack of environmental regulations (FAO, 1992).

The level of metals in water samples collected from site I and site II indicated relatively low concentration of all metals below to USEPA (1999) criterion of continuous concentration levels (CCC: Pb 2.5, Cd 2.2, Cr 11.0 and Zn 120.0 $\mu g\ l^{-1}$). Cadmium is considered to be toxic if its concentration exceeds 0.01 mg l^{-1} in both drinking and irrigation water (Taha, 2004). Cu

Table 1 : Concentration of heavy metals in water (µg l^{-1}) and sediment (µg kg^{-1}) samples of dam lake of Wadi Namar, Riyadh

Substance	Copper(Cu)		Mercury(Hg)		Cadmium(Cd)		Lead(Pb)		Chromium(Cr)	
	Site I	Site II	Site I	Site II	Site I	Site II	Site I	Site II	Site I	Site II
Water	65.95±1.65	69.57±1.65	0.32±0.005	0.34±0.006	0.98±0.03	1.35±0.07	1.91±0.06	1.94±0.06	12.07±0.73	10.79±0.66
Sediment	10925±382	12216±375	12.91±0.56	12.42±0.61	62.72±4.8	78.81±5.58	105.12±5.71	111.15±5.81	10712±252	11045±232

Values are mean and ± is standard error

Table 2 : Concentrations (µg kg^{-1} d. wt.) of different heavy metals in various organs of *O. niloticus* and *P. latipinna* collected from dam lake of Wadi Namar, Riyadh

Organs	Fishes	Copper (Cu)		Mercury (Hg)		Cadmium (Cd)		Lead (Pb)		Chromium (Cr)	
		Site I	Site II	Site I	Site II	Site I	Site II	Site I	Site II	Site I	Site II
Liver	*O. niloticus*	12586^{a}	12875^{a}	7.21^{a}	7.35^{a}	22.97^{a}	23.95^{a}	79.32^{a}	82.30^{a}	371.12^{a}	381.09^{a}
		±736	±735	±0.29	±0.31	±1.78	±1.77	±4.35	±3.28	±10.24	±9.19
	P. latipinna	11312^{a}	11425^{a}	6.80^{a}	6.65^{a}	20.91^{a}	21.99^{a}	75.32^{a}	81.39^{a}	361.02^{a}	371.09^{a}
		±745	±745	±0.38	±0.25	±1.85	±1.76	±3.36	±4.26	±8.24	±11.21
Kidney	*O. niloticus*	8601^{b}	8985^{b}	10.21^{b}	11.02^{b}	14.12^{b}	15.14^{b}	376.48^{b}	385.46^{b}	551.25^{b}	561.32^{b}
		±125	±131	±0.62	±0.45	±1.35	±1.24	±4.42	±5.31	±13.36	±14.51
	P. latipinna	7861^{b}	7985^{b}	9.98^{b}	10.88^{b}	12.08^{b}	13.11^{b}	369.50^{b}	381.51^{b}	551.35^{b}	556.34^{b}
		±236	±231	±0.25	±0.62	±0.76	±0.85	±6.35	±7.38	±14.38	±15.61
Gills	*O. niloticus*	3475^{c}	3545^{c}	2.54^{c}	3.01^{c}	13.55^{c}	15.51^{c}	158.89^{c}	162.98^{c}	240.69^{c}	255.71^{c}
		±46	±56	±0.13	±0.21	±1.06	±1.04	±9.15	±11.21	±9.41	±13.051
	P. latipinna	3456^{c}	3511^{c}	2.94^{c}	2.96^{c}	13.49^{c}	14.58^{c}	158.87^{c}	159.88^{c}	235.67^{c}	238.65^{c}
		±45	±45	±0.41	±0.35	±1.06	±1.07	±11.18	±9.17	±11.38	±11.051
Muscle	*O. niloticus*	1279^{d}	1275^{d}	1.99^{d}	2.05^{d}	8.25^{d}	9.24^{d}	55.33^{d}	58.35^{d}	155.31^{d}	164.35^{d}
		±39	±30	±0.25	±0.34	±0.76	±0.92	±2.11	±2.08	±11.34	±9.32
	P. latipinna	1175^{d}	1170^{d}	1.77^{d}	1.78^{d}	8.24^{d}	8.19^{d}	52.33^{d}	55.35^{d}	155.39^{d}	162.36^{d}
		±25	±29	±0.28	±0.42	±0.65	±0.82	±2.08	±2.11	±9.25	±9.40

Values are mean and ± is standard error. Values in column with different letters are significantly ($P<0.05$) different

concentration in the water samples of Wadi was high to the CCC (CCC for Cu 9 µg l^{-1}). The results indicate that more Cu adding sources are present near the vicinity of Wadi Namar. The safety limits of metals recommended to protect the fish in intensive aquaculture are Pb < 20 µg l^{-1}, Cd < 0.5 µg l^{-1}, Cu < 0.6 µg l^{-1}, and Zn < 5.0 µg l^{-1} in soft water (Wedemeyer, 1996). The concentration of Pb, Cd, Cu and Zn in the water of Wadi Namar exceeded the above mentioned permissible limits. This situation may pose a health risk for the fish population in Wadi Namar and an ultimate threat to the human.

The concentration of different metals reported in sediment samples were much higher at site II as compared to site I is in confirmation with the previous reports of Abdel-Baki *et al.* (2011) and Alkahem *et al.* (2013) for the sediment of Wadi Haneefah, Riyadh. The results of present investigation showed that the levels of all the metals were much below the proposed probable effect concentrations of sediment. Although, the concentration of metals was low, but may affect the sediment dwelling organisms in the Wadi Namar.

Lead is a non-essential element that cause neurotoxicity, nephrotoxicity and other adverse effects on fish and other animals (Garcia-Leston *et al.*, 2010). In the present study Pb concentration in both the fish species was found to be less than the permissible limit (2 mg kg^{-1}) followed in Australia, UK, and Spain for human consumption.

Cd concentration was low in all the organs of fish when compared to maximum permissible limit (1mg kg^{-1} to 5.5mg kg^{-1}) proposed by the Australian National Health and Medical Research Council (ANHMRC), Western Australian Authorities and Spanish Legislation, but prolonged accumulation of Cd may pose health hazards. Higher values of cadmium recorded in liver, kidney and gills are in agreement with the findings of other workers (El-Nemr, 2003, Khaled, 2004, Javed and Usmani 2011, and Rahman *et al.,* 2012) which reported that Cd is stored in the body in various tissues, but the main site of accumulation in aquatic organism is liver, kidney and gills. It was also reported that Cd level in gills was higher than the values reported in liver of *Cyprinus carpio* and some other fish species (Canli *et al.*, 1998, Khaled, 2004). Muscles showed the lowest Cd level in both the species of fish. The metal concentration remained less than the permissible value of Cd (0.5mg kg^{-1}) proposed by the Food and Agricultural Organizations (FAO, 1983) safe human consumption.

Bio accumulation of Cr in the tissues was low as compared to proposed limit 5.5 mg kg^{-1} by the Western Australian Food and Drug regulation. Normally chromium does not accumulate in fish and hence low concentration of Cr has been reported from the industrialized part of world (Rahman *et al.*, 2012). The rate of uptake may be higher in young fish which decline with age, causing reduction in chromium level in tissues (Dara, 1995). High accumulation of Cr was related to wastewater coming from various industries such as dying and tanning industries, photography, textile, manufacturing green varnish, paints and inks and river run-off from agricultural field (Rahman *et al.*, 2012).

Copper is an essential part of several enzymes and is necessary for hemoglobin synthesis (Sivaperumal *et al.*, 2007). Moreover, high intake of Cu would undoubtedly cause health hazard. Copper minerals are mostly insoluble hence concentration of copper is usually low in natural water. Copper availability in surface water and ground water is also due to extensive use of pesticides containing copper compounds for agricultural purpose (Al-Weher, 2008). Copper is an essential element in human metabolism however, causes anemia, disorders of bone, and connective tissues and liver damage at excessive level. Cu toxicity depends upon hardness and pH of water and therefore, it is more toxic in soft water and in water with low alkalinity (Taha, 2004). The permissible limits of Cu proposed by Australian National Health and Medical Research Council (ANHMRC) and FAO, UK Food Standard Committee, and Turkish legislation and Spanish legislation is 30, 20 and 5mg kg^{-1}, respectively (Cronin *et al.*, 1998, Demirak *et al.*, 2006 and Dural *et al.*, 2007). Metal content in the present study did not exceed aim of the proposed limits in test species studied. Therefore, the fish were suitable for the human consumption.

Fish is supposed to be the main source of Hg in human diet (Malik *et al.*, 2010). The results of present study showed that Hg is the least accumulated metal in all the organs of two fish species. Similar findings were reported by Malik *et al.* (2010) and Abdel-Baki *et al.* (2011). Rosenberg *et al.* (1995) reported that temperate reservoir fish tend to have relatively high Hg level (up to 0.5 mg kg^{-1} wet wt.). In contrast to this, low concentration of Hg was registered in various fish species collected from reservoirs in Thailand (Yingcharoen and Bodlay, 1993) and Sri Lanka (Allinson *et al.*, 2002).

The present study revealed that accumulation of different metals in liver, kidney and gills were higher than the concentration found in muscle. Muscle tissue is of the major interest for routine monitoring of metal levels as it is consumed by humans. The metal level in muscles reflect their lower metal storage capacity. High accumulation of metals in liver, kidney and gills of food fishes do not directly affect human health because these are non-edible. Nevertheless, the predatory fish, birds and other animals who consume whole fish from the habitat are at risk of bio accumulation of metal (Senarathne *et al.,* 2007). It is quite obvious that metal concentrations in fish muscle varied widely depending on the source and the species caught. Concentration of metal in the muscles of fish was similar in the present investigation to the values reported earlier by Abdel-Baki *et al.* (2011) and Lakshmanan *et al.* (2009).

Difference in the pattern of heavy metal distribution in both fish species might be due to difference in their feeding habits, ecological needs, metabolism, biology and physiology (Ali and Fishar, 2005; Al-Weher, 2008). Pb, Cd, Cu and Zn concentration in the water of Wadi Namar exceeded the permissible limits. This situation may pose health risk to the fish population in Wadi Namar and an ultimate threat to humans. However, in the present study level of heavy metal in muscle was at acceptable level in both the species of fish, as suggested by various international agencies.

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