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A Study on the Concentration of Heavy Metals in Water and Sediments of Natural Water Reservoir in Wadi Hanefah, Saudi Arabia and Uptake of Metals by a Fish, *Poecilia latipinna*

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Abstract. - The study was carried out to assess the concentration of heavy metals in the water and sediments of a natural water reservoir in Wadi Hanefah, Saudi Arabia receiving heavy metal contaminated industrial waste. The overall concentration of heavy metals (Cu, Ni, Zn, Cr, Cd, As) in the organs of *Poecilia latipinna* was found to be 0.7-4.6 ppm in heart, 1.2-4.4 ppm in liver, 0.9-5.3 ppm in kidney, 0.8-4.6 ppm in gills, 0.5-3.1 ppm in muscles and 0.6-3.3 ppm in skin. The concentration of the heavy metals was higher in muscles and skin of fish from the Wadi Hanefah as compared with that of the control site. It has been found that the level of a few metals (Ni, As, Cu and Cr) in the various tissues of *P. latipinna* from Wadi Hanefah was higher than the acceptable limit for consumption by international standards.

Key words: Aquatic pollution, heavy metals, metal contaminated water, sediments of polluted water reservoir, metal uptake by fish organs

INTRODUCTION

Fish, because of high protein and essential amino acids contents promotes growth and functioning of body muscles and other tissues. Fish have the potential to accumulate toxic substances such as trace metals, pesticide residues through diet and from water, and the concentrations of these toxicants may be hundred times more than present in the water, sediment and food (Osman *et al.*, 2007). Since the fish meat is one of the major components of the human diet, the presence of trace metals in the aquatic ecosystem and its bioaccumulation in fish is a matter of grave concern (Erdogrul and Erbilir, 2007; Yilmaz *et al.*, 2007)

Among the various toxic pollutants in the aquatic habitat, heavy metals are particularly more dangerous due to their action and persistence in biological amplification through the food chain (Waqar, 2006; Vutukuru, 2005; Erdogrul and Erbilir, 2007; Honggang *et al.*, 2010; Farombi *et al.*, 2007; Babatunde *et al.*, 2012). Some of these heavy metals like Hg, Cd and Pb are toxic to many organisms even at very low concentrations. The main sources of heavy metal pollution are industrial effluents, domestic sewage, hospital wastes, agriculture, mining and human activities (Kumar *et al.*, 2007).

Poecilia latipinna is one of the common freshwater fishes and is found in natural water bodies in Saudi Arabia. In this study it has been used as a model organism to assess the impact of heavy metal concentration as a result of discharge of industrial wastes like released unprocessed in natural water reservoirs Wadi Hanefah, Saudi Arabia.

MATERIALS AND METHODS

Study area

Wadi Hanefah (WH) is one of the major natural landmarks in the middle part of Najd plateau. It is one of the representative natural drains of surface water consisting of wide areas. The Wadi

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passes through the city of Riyadh and approximately 70% of the city is situated within its catchment area. It extends from north of Al-Uyaynah to the south of the Al-Hair city. The watershed area of WH was estimated to be about 4400 km^2 (AlGhanim, 2012). It flows towards south from its source near Al-Uyaynah and it ends into Wadi Sahba (Fig. 1). The main Wadi flood-channel is situated slightly east of the center of the catchment area and flows northwest to the Southeast. The population of Riyadh city is more than 4 million and it is located in the WH catchment area.

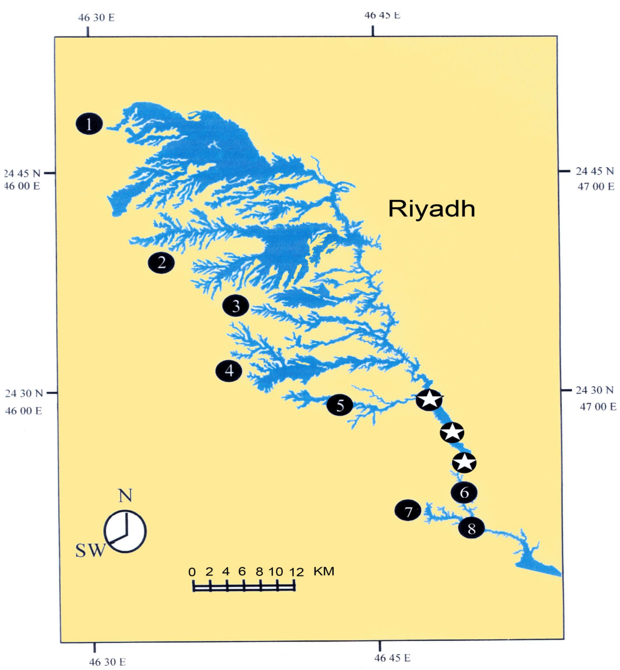

Fig. 1. Map of Wadi Hanefah, Saudi Arabia showing the main stream and the sampling sites (Stars).

Sample collection and preparation for analysis

Ten samples each of sediment and water were collected of from different locations WH and control site (CS). The sediment samples were collected 50 cm from the banks at a depth of 10 cm. Water samples were collected from the same points as sediment. The water samples were mixed together to make sample composite and the same was done with sediment.

Water samples were filtered through a 0.45 µm membrane, while the sediment samples were air dried for 7 days in aluminium plates. They were then refined through a 2 mm screen prior to digestion.

Fish, *Poecilia latipinna* (20-40g) were captured with a hand net from WH, brought to the laboratory in large aerated crates and kept alive for 24h to avoid stress. Control fishes were collected from unpolluted commercial fish farm.

Estimation of heavy metals in the tissues

Fish samples were prepared for heavy metal estimation by following standard procedure reported by Farombi *et al.* (2007).

The levels of Cu, Cd, Ni, Zn, As and Cr of different fish tissues (heart, liver, kidney, gills, muscles and skin) and water and sediment were determined with the help of Atomic Absorption Spectrophotometer (Shimadzu-12/574, 213).

Statistical analysis

The data thus obtained were subjected to appropriate statistical analysis through computer by using Minitab software. Significance of difference has been presented as the probability (P) values. Duncan's multiple range tests was applied to compare the means and to work out statistical differences.

RESULTS AND DISCUSSION

Table I shows the heavy metal level of Cu, Cd, Ni, Zn, As and Cr in water and sediments of WH, whereas Table II shows the level of trace metals in the various organs viz., heart, liver, kidney, gills, muscles and skin of *Poecilia latipinna* from WH and control site (CS). It has been found that these heavy metals were accumulated to varying extent in all the organs of the fish from the two locations. The mean concentrations of Cu in fish ranged from 2.2-5.3 mg/kg and 0.4-0.9 mg/kg in WH and CS, respectively. Likewise, Cd was recorded as 1.9-3.4 mg/kg and 0.4-0.8 mg/kg, Zn was recorded as 2.9-3.8 mg/kg and 0.7-1.5, Cr ranged from 2.9-4.6 mg/kg and 0.6-1.4 mg/kg in WH and CS, respectively. The overall level of heavy metals in various organs was recorded as 0.7-4.6, 1.2-4.4, 0.9-5.3, 0.8-4.6, 0.5-3.1and 0.6-3.3 mg/kg dry-wt basis in the heart, liver, kidney, gills,

Table I.- Mean (±SD) concentrations (ppm) of heavy metals in water and sediments from control fish farm and Wadi Hanefah.

Parameters	Cu	Cd	Ni	Zn	As	Cr
Water (WH)	4.8±0.04	3.3±0.01	4.7±0.05	4.1±0.07	1.4±0.02	4.9±0.06
Water (CS)	0.8±0.01	0.9±0.03	ND	1.4±0.05	ND	1.1±0.04
Sediments (WH)	5.7±0.09	3.7±0.05	5.2±0.06	4.6±0.08	1.8±0.03	5.2±0.08
Sediments (CS)	1.0±0.05	1.1±0.06	ND	1.6±0.04	ND	1.3±0.06

WH, Wadi Hanefah; CS, Control Site.

Table II.- Concentration of heavy metals in the heart, liver, kidney, gills, muscles and skin of *Poecilia latipinna* from controlled fish farm and Wadi Henefah

Heavy metal (ppm)	Heart	Liver	Kidney	Gills	Muscles	Skin
Copper						
Fish (CS)	0.4±0.01	0.9±0.02	0.8±0.01	0.6±0.04	0.5±0.06	0.7±0.01
Fish (WH)	2.3*±0.2	4.4*±0.4	5.3*±0.2	3.9*±0.5	2.2*±0.1	2.6*±0.2
X fold increase	4.75	3.88	5.62	5.5	3.4	2.71
Cadmium						
Fish (CS)	0.5±0.01	0.7±0.01	0.5±0.02	0.8±0.02	0.4±0.01	0.6±0.01
Fish (WH)	1.9*±0.01	2.5*±0.02	2.8*±0.03	3.4*±0.04	2.4*±0.03	2.7*±0.03
X fold increase	2.80	2.57	4.40	3.25	4.00	3.66
Zinc						
Fish (CS)	0.7±0.01	1.1±0.03	1.5±0.02	0.6±0.01	1.2±0.02	1.1±0.02
Fish (WH)	3.4*±0.04	3.7*±0.05	3.6*±0.04	3.8*±0.02	3.1*±0.04	2.9*±0.03
X fold increase	3.85	2.36	1.40	5.5	1.58	1.63
Chromium						
Fish (CS)	0.6±0.01	0.9±0.02	1.4±0.02	1.1±0.02	0.8±0.02	0.9±0.01
Fish (WH)	4.6*±0.05	3.2*±0.07	3.7*±0.08	3.1*±0.05	2.9*±0.06	3.3*±0.08
X fold increase	6.66	2.55	1.62	1.82	2.63	2.66

The results are expressed as mean of 10 fishes + SD. *Significantly different from control, $p < 0.001$
The acceptable limits of consumption for the metals are as follows: Lead - 0.29 ppm, Zinc - 5.0 ppm, Arsenite - 0.01 ppm, Copper - 0.5 ppm and Cadmium - 0.05 ppm (FAO, 1983; WHO, 1985, 1992).

muscles and skin, respectively. Copper was the metal which accumulated with highest concentration (5.3±0.2 mg/kg) in the kidney of fish from WH, whereas, Cd was accumulated the least (1.9±0.01 mg/kg) in the heart of the fish from WH. The concentration of metals in all organs, muscles and skin of fish from WAH were higher than those in fish collected from CS (Table II). It was found that the level of Ni, As, Cu and Cr in various tissues of *P. latipinna* (Table II) were higher than the acceptable limit for consumption by international standards (FAO, 1983; WHO, 1985, 1992). Gosselin *et al.* (1984) reported higher accumulation of Cd in the liver and kidney. McCracken (1987) reported higher accumulation of Cd in the kidney compared with liver. In the present study the accumulation of Cd was more in gills followed by liver and kidney which was contradictory with the findings of Babatunde *et al.* (2012). They recorded higher concentration of Cd in kidney and heart of *C. garipenus*. Odoemelan (2005) reported the varying level of Cd in *Alestes nurse* (1.50 ppm) and *Synodontis nigritis* (1.23 ppm) from the same lake. Ishaq *et al.* (2011) reported 0.927 and 0.994 ppm of Cd in *Clarias gariepinus* and *Tilapia zillii*, respectively from the same river. Our results are more in line with the findings of Odoemelan (2005) but comparatively higher concentrations were probably due to higher pollution in WAH water received from the discharge of Riyadh city. The levels of Cd (3.4 ppm) in the gills of fish from WAH remained higher than the maximum safe limit of 2.00 ppm as recommended by WHO (1985) in fish. The highest copper accumulation in kidney of *P. latipinna* may be due to the fact that fish kidney is rich in cystine, a copper binding protein which probably has a detoxifying or storage function. The higher concentration of copper in the liver compared to the gills and heart can be related to the binding of Cu to metallothionein in the liver, which serves as a detoxification mechanism. Although copper is essential in the diet of fish but can be harmful when large intake occurs. The harmful toxicity is largely attributed to its cupric (Cu^{2+}) form, which is commonly found in various fish species due to water pollution (Olaifa *et al.*, 2004). In the present study the level of Ni ranged between 2.7 – 4.6 ppm in the fish from WAH which was higher than the recommended safe limits (0.5-0.6 ppm) reported by WHO (1985) for fish. The level of Ni recorded was in line with the findings of Babatunde *et al.* (2012). Obasohan (2007) reported varied accumulation of Cr in *Parachanna obscura* (0.40-5.61 ppm), and in *T. zillii* (29.8 – 31.6 ppm) and in *Clarias gariepinus* (28.1 – 32.2ppm). On the other hand, Nwani *et al.* (2010) estimated the level of Cr in *C. nigrodigitatus* as 1.19 ppm. In the present study Cr ranged between 2.1-3.6 ppm in *P. latipinna* from WH which was in line with findings of Nwani *et al.* (2010). The levels of Cr recorded in fish samples from WH were higher than the maximum recommended safe limits (0.15–1.0 ppm) for fish food. Our results indicate that the total concentration of Ni in all the organs of the fish was higher compared with that of Cd. The accumulation of metals (Cu, Cd, Ni, Zn, As and Cr) was generally higher in the gills, liver and kidney compared with muscle of *P. latipinna*. These findings were substantiated by the findings of Nwani *et al.* (2010). The concentrations of As in the liver and kidney samples of fish ranged between 0.5 ppm to 1.2 ppm. The two organs contained highest concentrations of these metals compared to other organs. It has been observed that both the liver and the kidneys have more ability to concentrate arsenite as compared with other organs presumably due to the metal binding proteins in fish (Kargin *et al*., 1999). Other studies have reported similar concentrations of these metals in the two organs in various fish samples (Olaifa *et al.*, 2004). In fish gill tissues are interfaced with the environment and responsible for gas exchange, acid balance, ion regulation and excretion of waste products. However, muscle is not active tissue for bioaccumulation of heavy metals as reported by Baje *et al.* (2005). Gills have been considered as metabolically active site and have the ability to accumulate higher concentration of heavy metals as compared with other tissues in fish (Shukla *et al.*, 2007). We found no relationship in the accumulation pattern of these trace metals in various tissues in *P. latipinna*. Thus the difference in accumulation pattern of metals in different tissues in the present study was presumably due to the differences in their physiological roles in maintaining homeostasis and regulatory ability of each organ in the fish. The organisms have the ability to develop a defense mechanism against the harmful effects of metals and other xenobiotics that produces degenerative changes in the aquatic organisms including fish (Abou EL-Naga *et al.*, 2005). It has been noticed that the muscle has the least concentration of the heavy metals compared with gills in the *P. latipinna* which confirms the findings of Ishaq *et al.* (2011) that muscle is not an active tissue for bioaccumulation of metals. We are of the view that the presence of metallothionine has facilitated the kidney for accumulation of higher level of some of the metals in the present study in *P. latipinna*.

CONCLUSIONS

The levels of most of the heavy metals in water, sediment and fish from Wadi Hanefah is higher than the recommended safe limits. The findings may be used as baseline information to monitor anthropogenic activities in freshwater and coastal areas of Saudi Arabia. Keeping in view the importance of fish as an important source of animal protein for human consumption, it is desired to develop the strategies for regular monitoring of the freshwater and marine water resources and fish to ensure regular supply of safe food for consumption in the Kingdom. The Government shall devise strategies for the safe disposal of industrial waste and domestic sewage. Efforts shall be made to recycle the waste in order to avoid contamination of water bodies. The Environmental Protection Agency shall regularly monitor the implementation of rules for the well being of human population and to protect our environment.

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