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Full Length Research Paper

Bioaccumulation of some heavy metals in tilapia fish relevant to their concentration in water and sediment of Wadi Hanifah, Saudi Arabia

Abdel-Baki, A. S.[1, 2*], Dkhil, M. A.[1,3] and Al-Quraishy, S.[1]

[1]Zoology Department, College of Science, King Saud University, P.O. Box: 2455, Riyadh- 11451, Saudi Arabia.
[2]Zoology Department, Faculty of Science, Beni-Suef University, Egypt.
[3]Department of Zoology and Entomology, Faculty of Science, Helwan University, Egypt.

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Concentrations of some heavy metals (Pb, Cd, Hg, Cu and Cr) were determined in water, sediment and tissues of tilapia fish collected from Wadi Hanifah during summer 2010. The concentrations of the heavy metal in water were within the international permissible level. Cu had the highest accumulating level in fish whilst Hg had the lowest. The transfer factors of all metals in fish from water were greater than those from sediments. This led to the conclusion that fish bioaccumulation with these metals was from water. Heavy metals under study in the edible parts of tilapia were within the safety permissible level for human use.

Key words: Heavy metals, bioaccumulation, tilapia, Wadi Hanifah.

INTRODUCTION

Anthropogenic activities continuously increase the amount of heavy metals in the environment, especially in aquatic ecosystem. Pollution of heavy metals in aquatic ecosystem is growing at an alarming rate and has become an important worldwide problem (Malik et al., 2010). Increase in population, urbanization, industrialization and agriculture practices have further aggravated the situation (Giguere et al., 2004; Gupta et al., 2009). As heavy metals cannot be degraded, they are deposited, assimilated or incorporated in water, sediment and aquatic animals (Linnik and Zubenko, 2000) and thus, causing heavy metal pollution in water bodies (Malik et al., 2010). Therefore, heavy metals can be bioaccumulated and biomagnified via the food chain and finally assimilated by human consumers resulting in health risks (Agah et al., 2009). As a consequence, fish are often used as indicators of heavy metals contamination in the aquatic ecosystem because they occupy high trophic levels and are important food source (Blasco et al., 1998; Agah et al., 2009). The objective of the present study was to determine the level of certain heavy metals in water, sediment and organs of *Tilapia nilotica* from Wadi Hanifah in Riyadh, Saudi Arabia.

*Corresponding author. E-mail: azema1@yahoo.com. Tel: 00966-14675754.

MATERIALS AND METHODS

Sampling site

Wadi Hanifah is one of the principal Wadis (valleys) draining the eastern slope of the Tuwaig Mountains. It extends from north of Al Uyaynah to south of Al-Hair city. Wadi Hanifah has always played a key role in the water management of Riyadh. In the past, it was used as a source of water and now as a convenient means for disposing of the city's wastewater. The industrial effluents as well as domestic sewage/wastes are disposed in Wadi Hanifah either with partial or no pretreatment and hence, increasing concentration of different kinds of pollutants including heavy metals especially at Al-Hair. Also, Al-Hair is located at the end of down stream and it is the main site for catching fish. Therefore, Al-Hair has been selected as a sampling site (Figure 1).

Collection of sample

Ten samples of water, sediments and *T. nilotica* were collected from Wadi Hanifah at Al-Hair during (May, June and July) summer 2010. Samples were collected once per month from the same site.

Figure 1. Map for Wadi Hanifah showing the main stream (arrows) and sampling site (red spot).

Then, result was pole to express summer season. The summer season was selected as no rain and the main water source is wastewater. The water was preserved in plastic bottles by the addition of few drops of nitric acid. Sediments were preserved in plastic bags. The collected fish were dissected and different organs (muscles, liver, kidney, intestine, gills) were obtained and frozen until ready for acid digestion.

Procedure

Water samples were digested according to the method described in APHA (1992), while sediments were digested after drying according to Kouadia and Trefry (1987) method. Different fish organs were digested after drying according to AOAC (1995) methods. The levels of Pb, Cd, Hg, Cu and Cr in digests were determined by Shimadzu atomic absorption spectrophotometer using different cathode lamps with air acetylene flame method. The cathode lamps had wave length range from 190 to 900 nm.

Transfer factor (TF)

The transfer factor in fish tissues from the aquatic ecosystem, which include water and sediments, was calculated according to Kalfakakour and Akrida-Demertzi (2000) and Rashed (2001) as follows

$$TF = M_{tissue} / M_{sediment\ or\ water}$$

Where, M_{tissue} is the metal concentration in fish tissue; $M_{sediment}$, metal concentration in sediment.

RESULTS

Heavy metals in water

In the water samples, the average concentration of heavy metals, Pb, Cd, Hg, Cu and Cr, were 0.95, 0.87, 0.26, 43.7 and 6.4 ppb, respectively (Table 1). Cu content was the highest and that of Cd was the lowest in water. The order of heavy metal accumulation in water was Cu > Cr > Pb > Cd > Hg.

Heavy metals in sediment

The mean values of Pb, Cd, Hg, Cu and Cr were 2455, 71.7, 14.7, 9856 and 9500 ppb, respectively (Table 2). The order of heavy metal concentrations in sediment was Cu > Cr > Pb > Cd > Hg. The data indicated that Cu was

Table 1. Mean heavy metals concentrations (ppb) in water of Wadi Hanifah compared to the international permissible limits.

Parameter	Lead	Cadmium	Mercury	Copper	Chromium
Mean	0.95	0.87	0.26	43.7	6.4
St.Dv.	0.03	0.01	0.01	1.5	0.15
S.E.	0.02	0.006	0.007	0.88	0.08
USEPA (1986)	5	5	2	1000	100
WHO (1985)	10	3	1	1000	50

St.Dv. Standard deviation; S.E., relative error.

Table 2. Mean heavy metals concentrations (ppb) in sediments of Wadi Hanifah.

Parameter	Lead	Cadmium	Mercury	Copper	Chromium
Mean	2455	71.7	14.7	9856	9500
St.Dv.	222	6.1	0.58	313	70
S.E.	128	3.5	0.33	181	43.5

St.Dv., Standard deviation; S.E., relative error.

Table 3. Mean heavy metals concentrations (ppb) in different tissues of *Tilapia* nit.

Parameter	Lead	Cadmium	Mercury	Copper	Chromium
Liver					
Mean	60.7	15.1	6.2	11533	328
St.Dv.	3.1	0.9	0.67	611	2
S.E.	1.7	0.52	0.38	352	1.2
Gills					
Mean	141.7	9.9	0.72	2060	386
St.Dv.	9.7	1.4	0.07	36	5.3
S.E.	5.6	0.9	0.04	20.8	3.05
Muscles					
Mean	39.7	7.5	3.1	1080	230
St.Dv.	4.5	0.98	0.34	79.3	2
S.E.	2.6	0.57	1.9	45.8	1.2
Kidney					
Mean	276	7.8	12.3	7990	512
St.Dv.	5.3	0.44	1.5	115	10.8
S.E.	3	0.25	0.88	66.5	6.2

St.Dv., Standard deviation; S.E., relative error.

maximally accumulated in the sediment whereas Hg got the least concentration.

Heavy metals in fish

The mean concentrations of heavy metals in different fish tissues are presented in Table 3 and Figures 2, 3, 4, 5 and 6. The average concentration of Pb in different fish organs, liver, gills, muscles and kidney, was 60.7; 141.7; 39.7 and 276 ppb, respectively. The data showed that, kidney accumulated the highest concentration while muscles accumulated the lowest. The mean Cd concentrations were 15.1 ppb in liver, 9.9 ppb in gills, 7.5 ppb in muscles and 7.8 ppb in kidney. The data revealed that, liver accumulated the highest concentration of Cd while muscles accumulated the lowest concentration. Hg showed high concentration in kidney and lowest concentration in gills. The average concentrations were 6.2, 0.72, 3.1 and 12.3 ppb, in liver, gills, muscles and

Figure 2. Concentrations of Pb in tissues (ppb) of *T. nilotica.*

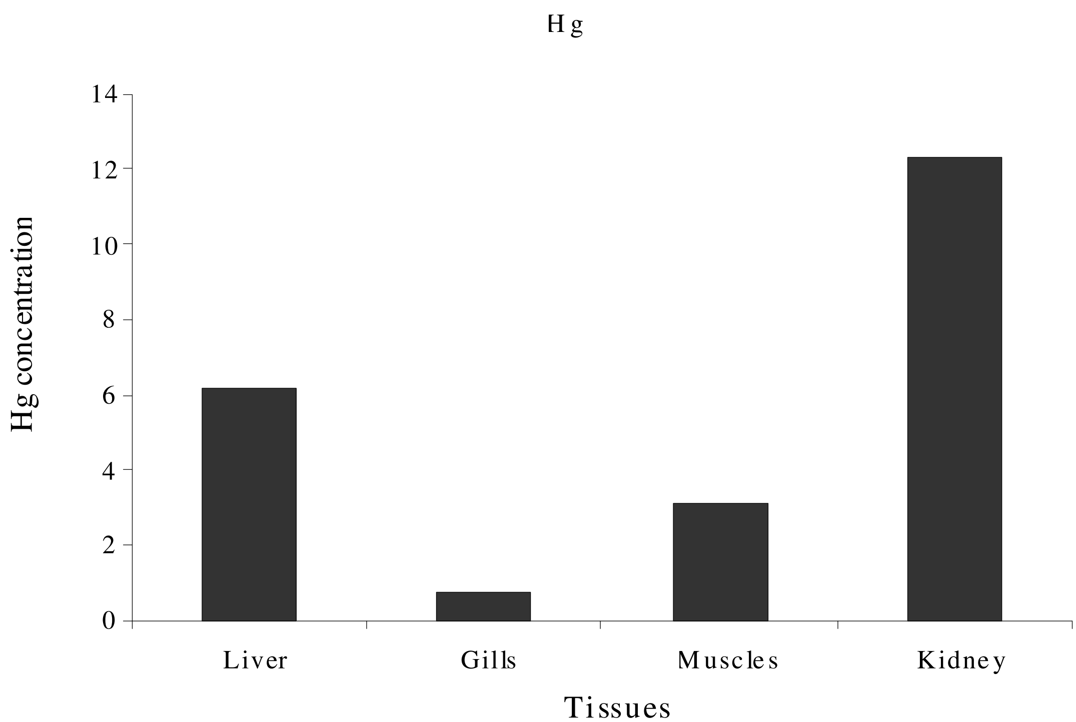

Figure 3. Concentrations of Hg in tissues (ppb) of *T. nilotica.*

kidney, respectively. Cu attained the highest concentrations among the studied heavy metals in all fish tissues. The average concentrations were 11533, 2060, 1080 and 7990 ppb in liver, gills, muscles and kidney, respectively. The data showed that, liver accumulated the highest concentration while muscles accumulated the lowest concentration. The average concentration of Cr in different fish organs, liver, gills, muscles and kidney; was

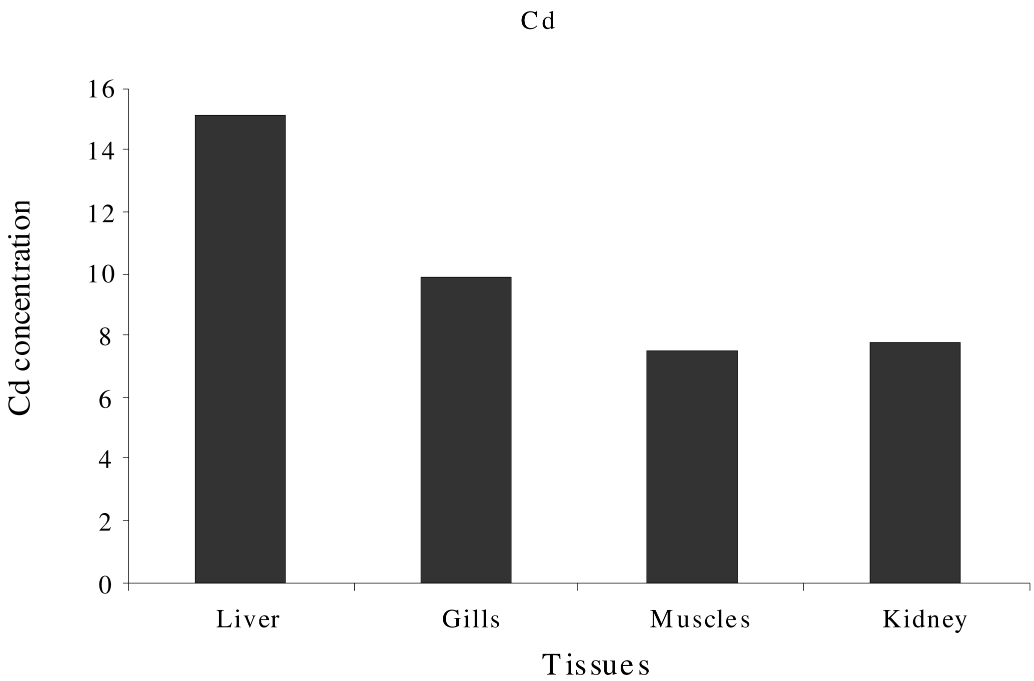

Figure 4. Concentrations of Cd in tissues (ppb) of *T. nilotica.*

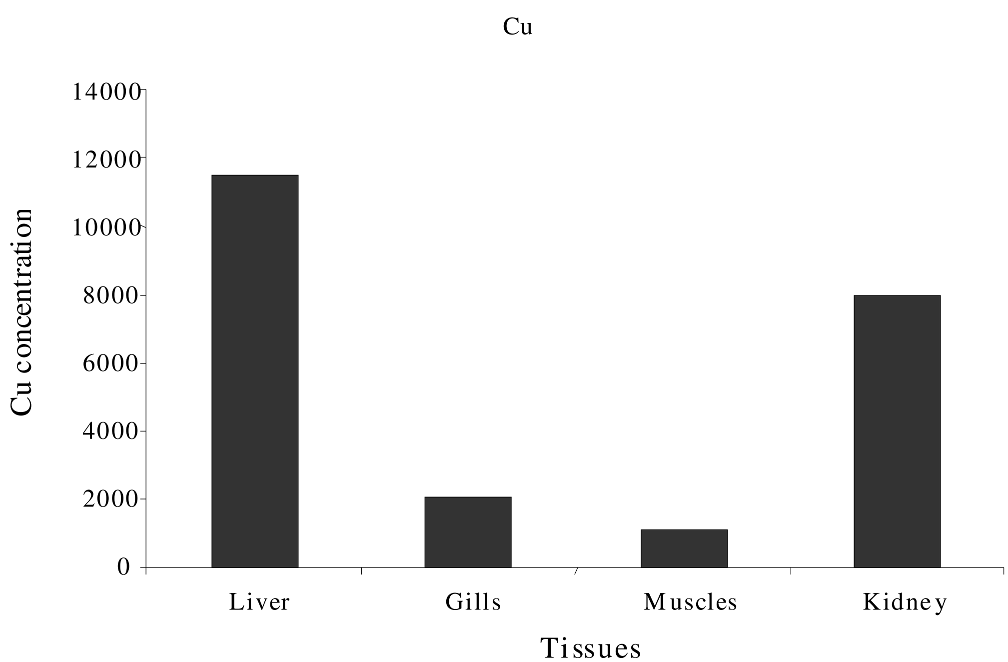

Figure 5. Concentrations of Cu in tissues (ppb) of *T. nilotica.*

328, 386 230 and 512 ppb, respectively. This means that 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.

Transfer factor (TF)

The transfer factor in different organs from water and sediments is shown in Table 4. The results showed that transfer factor of water were greater than those of sediments

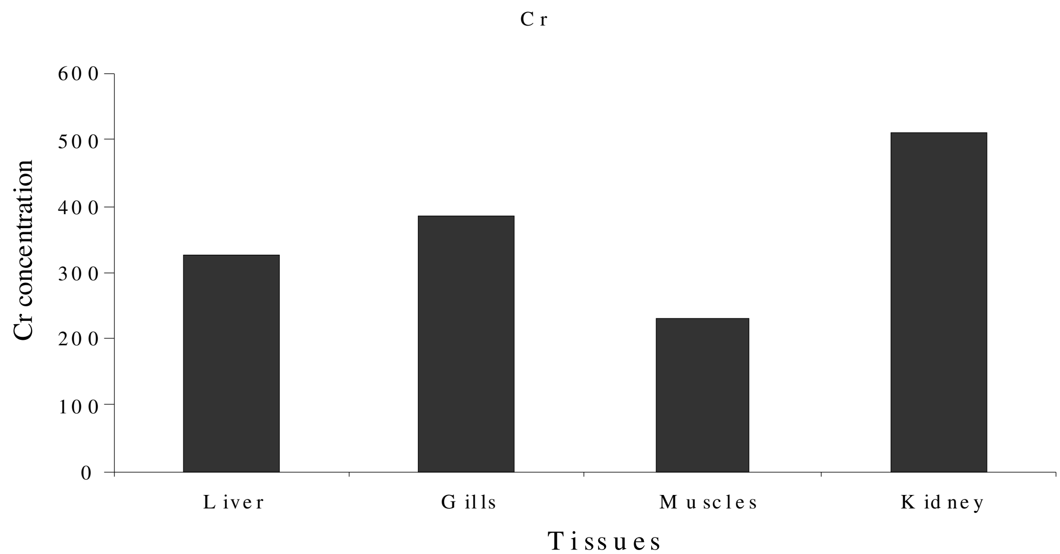

Figure 6. Concentrations of Cr in tissues (ppb) of *T. nilotica*.

Table 4. Transfer factor (TF) of heavy metals in different tissues of *Tilapia* sp. from the Wadi ecosystem (water and sediment).

Parameter	Lead	Cadmium	Mercury	Copper	Chromium
Water/ liver	63.895	17.356	23.846	263.913	51.25
Sediment/ liver	0.024	0.211	0.422	1.170	0.034
Water/Gills	149.16	11.379	2.769	47.139	60.313
Sediment/Gills	0.057	0.138	2.769	0.209	0.041
Water/ muscles	41.789	8.621	11.923	24.714	35.938
Sediment/ muscles	0.016	0.105	0.211	0.110	0.024
Water/kidney	290.53	8.966	47.308	182.838	80.000
Sediment/kidney	0.112	0.109	0.837	0.811	0.054

sediments. All the transfer factor of water was greater than 1 except Hg in gills, while all of the sediments were less than 1 except for Cu in all organs.

DISCUSSION

In natural aquatic ecosystems, metals occur in low concentrations, normally at the nanogram to microgram per liter level. In recent times however, the occurrence of metal contaminants especially the heavy metals in excess of natural loads has become a problem of increasing concern. This situation has arisen as a result of the rapid growth of population, increased urbanization and expansion of industrial activities, exploration and exploitation of natural resources, extension of irrigation and other modern agricultural practices as well as the lack of environmental regulations (FAO, 1992). The level of heavy metals recorded in water in this study were generally low when compared with the limit of chronic reference values suggested by WHO (1985) and USEPA (1986). This study revealed that the sediment from Wadi Hanifah contained very high significant amounts of heavy metals when compared with their concentration in water. Sediments act as the most important reservoir or sink of metals and other pollutants in the aquatic environment (Gupta et al., 2009). Heavy metal contamination in sediment can affect the water quality and bioaccumulation of metals in aquatic organisms, resulting in potential long-term implication on human health and ecosystem (Fernandes et al., 2007). The results of the present study showed that, liver accumulate and concentrate highest concentrations of Cu and Cd. Jent et al. (1998) found that, Cd and Cu concentration increased in fish liver collected from water near the agricultural areas. Rashed (2001) found the same results in tilapia fish collected from Nasser Lake. The high accumulation in the Kidney of Pb and Cr corroborated the results obtained by Phillips and Russo (1978). Also, Malik et al. (2010) reported that the kidney was the major site for Cr accumulation.

Although, fish is the main source of Hg in human diet (Malik et al., 2010), Hg was found to be the least accumulating metal during this study. The present results agree with those obtained by Malik et al. (2010). Muscles are the main edible part of fish and can directly influence human health. Therefore, most governorates have established toxicological limits for heavy metals in seafood (Agah et al., 2009). According to WHO (2005), the allowable concentration for Pb, Cd, Cu were 200, 50 and 10000 ppb, respectively. However, such food limits are not defined to all the elements (Agah et al., 2009). The element levels of fish muscles in this study were below the allowable concentration suggested by WHO (2005) and have no threat to public health. The results showed that the transfer factors of all elements in fish from water were greater than 1 except for Hg in gills and this mean that the fish undergo bioaccumulation of these elements from Wadi Hanifah water (Kalfakakour and Akrida-Demertzi, 2000; Rashed, 2001). The transfer factor of water is greater than those of sediments and all transfer factor from sediment was less than 1 except for Cu in all organs and this showed that fish bioaccumulate these elements from water (Rashed, 2001). This result might be due to the feeding behavior of fish which is filter feeder and the result was concordant with the findings of Ali and Fishar (2005). This study indicates that, water of Wadi Hanifah is by far suitable for fishing activity and consumption of this species is safe. However, it is quite evident that there was bioaccumulation of heavy metals in fish tissues and condition may get worse. Therefore, a regular monitoring of heavy metal levels in fishes is necessary.

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