Bull Environ Contam Toxicol (2012) 89:455–460
DOI 10.1007/s00128-012-0744-2

Determination of Metal (Cu, Zn, Se, Cr and Cd) Levels in Tissues of the Cyprinid Fish, *Capoeta trutta* (Heckel, 1843) from Different Regions of Keban Dam Lake (Euphrates-Turkey)

Durali Danabas · Mesut Ural

Received: 3 November 2011 / Accepted: 10 July 2012 / Published online: 19 July 2012

Abstract The aim of this study was to evaluate Copper (Cu), Zinc (Zn), Selenium (Se), Chromium (Cr) and Cadmium (Cd) concentrations in liver, muscle, gills and kidney tissues of *Capoeta trutta* collected from four sites of Keban Dam Lake, Turkey. The highest heavy metal level in all tissues was for Zn, while Cd was the lowest. The lowest heavy metal levels were generally found at Station 4 (Agin) for all tissues ($p < 0.05$). There were statistically significant differences among stations for Cu, Zn, Cr and Se in gills; for Cu, Zn, Se and Cr in liver and kidney; and Cu, Zn and Cr in muscle ($p < 0.05$). Cadmium concentrations did not differ between sites for any of the tissues. Turkish Food Codex sets the maximum limits of Zn, Cu and Cd as, 50, 20 and 0.05 mg kg^{-1} dry weight, respectively, in the muscle of fish used for human consumption. In our study, the level of Zn was higher than Turkish permissible limits only at Station 3 (Guluskur). Cadmium levels were much higher than permissible limits at three stations [S1 (Pertek), S2 (Kockale) and S3], whereas Cu levels were within permissible limits in all stations.

Keywords Heavy metal · *Capoeta trutta* · Accumulation · Muscle · Keban Dam Lake

Contamination of waters with heavy metals is a recognized environmental problem (Staniskiene et al. 2006). There are numerous sources of metal contamination/pollution, including mining, agricultural and forestry activities, waste disposal, industrial discharges, and fuel combustion (Kennicutt et al. 1992; Olsson 1998).

Some metals are known to be toxic, even at low concentrations, including arsenic (As), cadmium (Cd), mercury (Hg), lead (Pb), etc., (Masters 1997; Le et al. 2009). Others, such as copper (Cu) and cobalt (Co), are known to be essential elements and play important roles in biological metabolism at very low concentrations (Le et al. 2009), and either an excess or deficit can disturb biochemical functions in both humans and animals (Danabas et al. 2011; Gulec et al. 2011).

Metals differ from other toxic substances in that they are totally non-degradable, which means they are virtually indestructible in the environment (Masters 1997). Thus, their content has steadily increased in soils and subsequently accumulated in plants, animals, and even in humans (Che et al. 2006).

Pollutants enter fish through five main routes: via food or non-food particles, gills, oral consumption of water and the skin. Upon absorption, the pollutant is carried in the blood stream to either a storage point or to the liver for transformation and/or storage. Pollutants transformed in the liver, may be stored there, excreted in the bile, transported to other excretory organs such as gills or kidneys for elimination, transported to and stored in fat tissue (Heath 1991; Nussev et al. 2000; Al-Kahtani 2009; Danabas et al. 2011).

Copper and zinc (Zn) are needed in trace amounts for carrying out vital functions and for growth in animals (Cousins 1985). Also, Cu is used in producing alloys, as a chemical catalyst, and as a raw material in dyes and algaecides (Torres et al. 1987). Discharge of Cu from these sources without any treatment increases its concentration in aquatic environments, increasing the potential for toxic action in aquatic organisms (Stagg and Shuttleworth 1982; Lauran and McDonald 1985; Atabeyoglu and Atamanalp

D. Danabas (✉) · M. Ural
Fisheries Faculty, Tunceli University, 62000 Tunceli, Turkey
e-mail: dalid07@gmail.com

2010). Selenium (Se) is an essential trace element that exists in a variety of inorganic and organic forms in nature. The predominant dietary forms are selenocysteine and selenomethionine. Among its biologic functions, Se is a component of glutathione peroxidase, which is part of the antioxidant defense against free radicals. Selenium deficiency results in a decline in tissue Se-dependent glutathione peroxidase activity (Yoshizawa et al. 2003). Levels of Se were analyzed because Se offers some protection against mercury (Hg) exposure (Lemire et al. 2010; Burger and Gochfeld 2011). Many heavy metals are highly toxic. For example, along with Hg and Pb, Cd is one of the "big three" heavy metal poisons. Cadmium occurs as a constituent of lead and zinc ores, from which it can be extracted as a byproduct. Cadmium is used to electroplate metals to prevent corrosion, as a pigment, as a constituent of alkali storage batteries, and in the manufacture of some plastics (Manahan 2003).

Capoeta trutta is an economically important fish species as a component of a significant commercial fishery in Keban Dam Lake. There is no published information available on heavy metal levels in fish from this lake. This research was organized to especially compare the information of multiply research stations and to monitoring the pollutant levels in this dam lake. The aim of this work was to evaluate Cu, Zn, Se, Chromium (Cr), and Cd concentrations in liver, muscle, gills and kidney tissues of *C. trutta* collected from four sites of Keban Dam Lake, Turkey.

Materials and Methods

Fish, *Capoeta trutta* (Heckel, 1843) were collected by gill nets with various mesh sizes at four sampling stations in Keban Dam Lake, Turkey (Fig. 1). Fifteen fish were collected at each station. The fish were immediately anaesthetized with 0.7 g l^{-1} benzocaine in ethyl alcohol (Sardella et al. 2004). The anesthetic resulted in deep sedation with loss of swimming action and partial loss of equilibrium as previously observed (Altun and Danabas 2006). They were then transferred to the laboratory under cold conditions, measured for length and weight, and dissected. Live weight (W) and total length (TL) averages of fish caught from stations were respectively, in S1, 376.20 ± 28.39 g and 33.18 ± 1.36 cm; in S2, 230.44 ± 10.72 g and 28.27 ± 0.41 cm; in S3, 273.23 ± 18.97 g and 30.32 ± 0.78 cm, and in S4, 400.24 ± 35.72 g and 32.91 ± 0.89 cm.

These sampling stations [Pertek (S1), Kockale (S2), Guluskur (S3) and Agin (S4)] were chosen according to some properties. For example; S1 and S2 have domestic and agricultural waste discharges from two different cities (Elazig and Tunceli) and S3 has a discharge from a chrome factory without purification. Station 4 was chosen as a station with no known close discharges of importance.

Samples of gill, liver, kidney and muscle tissue were removed with stainless-steel utensils, followed by drying for 24 h at 105°C. Dried tissue subsamples (0.3 g) were placed into Pyrex vessels in a microwave digestion unit

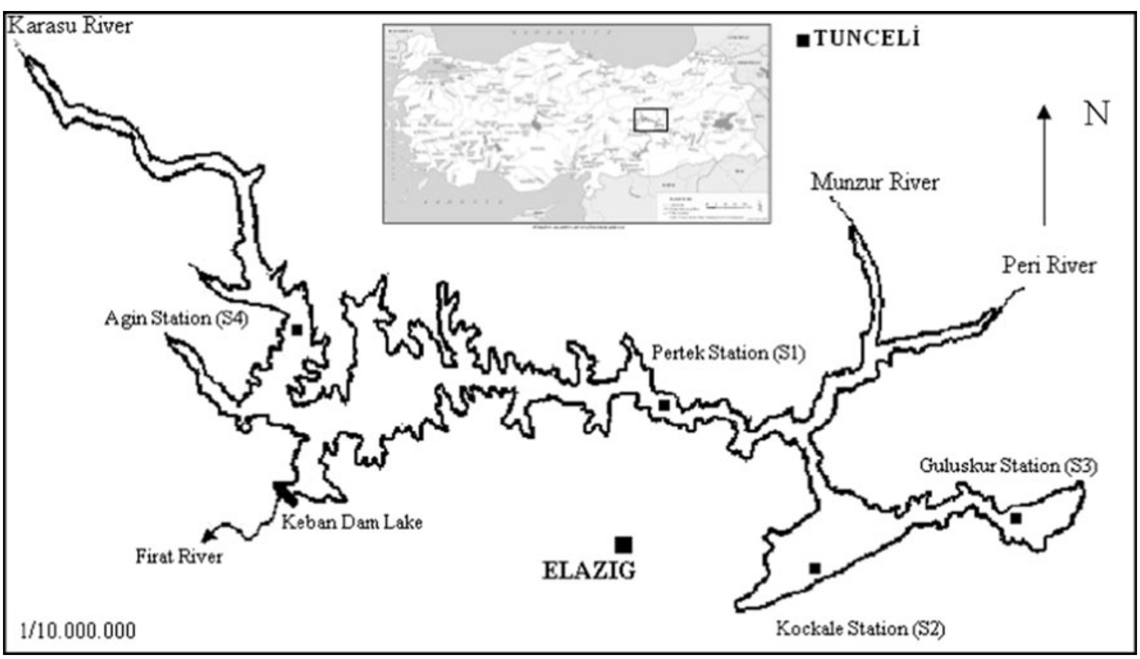

Fig. 1 The map of sampling stations on Keban Dam Lake, Turkey

Table 1 Mean (± SEM) water quality parameters at the four sampling stations (n = 3)

Water quality parameters	Stations			
	Pertek (S1)	Kockale (S2)	Guluskur (S3)	Agin (S4)
Temperature (°C)	15.2 ± 0.1[a]	15.5 ± 0.1	15.3 ± 0.2	15.1 ± 0.2
pH	8.0 ± 0.1	8.3 ± 0.1	8.2 ± 0.2	8.1 ± 0.3
Dissolved O_2 (mg l^{-1})	8.7 ± 0.2	7.7 ± 0.9	8.4 ± 0.3	9.2 ± 0.1
Free CO_2 (mg l^{-1})	6.2 ± 0.2	6.8 ± 0.4	7.1 ± 0.1	5.6 ± 0.4
Nitrite (mg l^{-1})	0.052 ± 0.001	0.049 ± 0.002	0.045 ± 0.004	0.013 ± 0.005
Nitrate (mg l^{-1})	17.9 ± 0.2	18.4 ± 0.1	18.1 ± 0.2	6.8 ± 0.3
Ammonia (mg l^{-1})	1.30 ± 0.2	2.0 ± 0.1	0.60 ± 0.3	0.01 ± 0.01
Phosphate (mg l^{-1})	3.48 ± 0.02	4.12 ± 0.01	2.76 ± 0.05	0.02 ± 0.001
Total hardness (mg l^{-1})	70.9 ± 0.1	74.5 ± 0.2	67.7 ± 0.1	42.9 ± 0.2

[a] Means (± Standard error of means)

(CEM Star 5, Terra Analysis and Measurement Equipment Trade Co., Ankara, Turkey). $HClO_4$: HNO_3 acids of 1:3 proportions for fish were inserted in the reactors, respectively. Samples were mineralized at 200°C for 30 min. Afterwards the samples were filtered in such a way as to make their volumes equal to 100 ml with ultra-pure distilled water. The levels of Cu, Zn, Se, Cr and Cd in samples were determined by ICP-OES (Varian 720 ES, Germany). Metal concentrations were reported as means of triplicate analyses (Astm 1985; Apha 1992; Epa 2001).

Temperature, dissolved oxygen and pH were measured by YSI professional multiparameter and the other parameters were measured by titrimetric methods (Table 1) (Apha 1992).

SPSS v15.0 statistical software was used for statistical analysis (SPSS Inc., Chicago, IL, USA). Mean metal concentrations from the stations were analyzed for differences at the $p < 0.05$ level by ANOVA followed by Duncan's multiple range test.

Results

Higher concentrations of free CO2, nitrite, nitrate, ammonia, phosphate and total hardness were observed at sites S1, S2 and S3, as compared to S4. However, the highest dissolved oxygen level was measured at S4.

The highest heavy metal level in all tissues was Zn, while Cd was the lowest (Table 2). The lowest heavy metal levels were generally measured at S4 (Agin) for all tissues ($p < 0.05$). There were statistically significant differences among stations for Cu, Zn, Cr and Se in gills; for Cu, Zn, Se and Cr in liver and kidney; and for Cu, Zn and Cr in muscle ($p < 0.05$). Cadmium concentrations did not differ between sites for any of the tissues. The highest levels of Cu (16.82 ± 3.27 mg kg^{-1}), Zn (81.52 ± 20.02 mg kg^{-1}), Se (8.65 ± 0.15 mg kg^{-1}), Cr (9.53 ± 2.67 mg kg^{-1}) and Cd (2.94 ± 0.36 mg kg^{-1}) were obtained in liver, liver, kidney, gills and kidney tissues of fish caught from S1, S3, S3, S2 and S1, respectively.

Determination of the concentrations of metals in fish is an important subject with respect to both nature management and human consumption of fish (Amundsen et al. 1997). Turkish Food Codex (2002) sets the maximum limits of Zn, Cu and Cd as respectively, 50, 20 and 0.05 mg kg^{-1} dry weight in the muscle of fish. The level of Zn is higher in S3 than the maximum limits. Cadmium levels were higher in three stations (S1, S2 and S3) than the limits, whereas Cu levels were within limits at all stations. Mean concentrations of Cd in muscle tissue were more than 20-fold higher than the permissible limits established in the Turkish Food Codex. The permissible Cr levels for fish muscle are 1.0 mg kg^{-1} reported by FAO (Kandemir et al. 2010). The levels of Cr are under the permissible limits in all of the stations except for S1.

Al-Kahtani (2009) studied the accumulation of metals in tilapia fish (*Oreochromis niloticus*) from Al-Khadoud Spring, Al-Hassa, Saudi Arabia. He stated that levels of metals were higher in liver than muscle and the levels in liver and muscle tissues were ranked Zn > Cu > Cd. The metal levels of our study are lower than his results. Karadede and Unlu (2000) studied the concentrations of some trace metals in muscle of various species from Ataturk Dam Lake (Euphrates, Turkey). They reported that levels of Cu and Zn in *A. marmid*, *C. trutta* and *C. mossulensis* were 0.81 and 8.71 mg kg^{-1}; 1.68 and 5.32 mg kg^{-1} and 2.41 and 17.96 mg kg^{-1}, respectively. They expressed that levels of Zn and Cu were lower than the limits like those in our study.

Papagiannis et al. (2004) studied the Cu and Zn levels in freshwater fish from Pamvotis Lake (Greece). They reported that levels of Cu and Zn in *C. carpio* were 3.08 and 52.81 mg kg^{-1}, respectively. They mentioned that there are no guidelines on acceptable levels of Cu and Zn

Table 2 Mean (± SEM) Cu, Zn, Se, Cr and Cd contents in fish samples (mg kg^{-1}- dry weight) of Pertek (S1), Kockale (S2), Guluskur (S3) and Agin (S4) Stations on Keban Dam Lake (Elazig, Turkey)

Fish tissues	Metals	Stations			
		Pertek (S1)	Kockale (S2)	Guluskur (S3)	Agin (S4)
Gills	Cu	4.88 ± 0.68[b]*	6.82 ± 0.47[c]	4.55 ± 0.56[b]	0.06 ± 0.02[a]
	Zn	54.0 ± 3.74[b]	59.8 ± 4.68[b]	60.7 ± 5.58[b]	0.16 ± 0.01[a]
	Se	7.85 ± 2.25[c]	5.52 ± 0.49[b]	6.25 ± 0.84[bc]	0.03 ± 0.002[a]
	Cr	8.06 ± 0.14[b]	9.53 ± 2.67[b]	1.88 ± 0.78[a]	0.04 ± 0.003[a]
	Cd	1.38 ± 0.12	1.68 ± 0.08	1.25 ± 0.07	ND
Liver	Cu	16.82 ± 3.27[c]	7.90 ± 0.95[b]	15.32 ± 4.03[c]	0.15 ± 0.02[a]
	Zn	42.0 ± 7.35[b]	28.2 ± 3.58[ab]	81.5 ± 20.02[c]	0.2 ± 0.02[a]
	Se	6.15 ± 0.95[b]	4.40 ± 0.80[b]	4.47 ± 0.81[b]	0.03 ± 0.003[a]
	Cr	7.98 ± 0.21[b]	3.25 ± 1.72[a]	4.17 ± 3.12[ab]	0.04 ± 0.007[a]
	Cd	1.22 ± 0.07	1.11 ± 0.03	1.42 ± 0.10	ND
Kidney	Cu	3.64 ± 1.02[b]	3.05 ± 0.26[b]	3.52 ± 0.66[b]	0.13 ± 0.04[a]
	Zn	25.7 ± 3.97[b]	24.4 ± 2.07[b]	47.3 ± 18.8[b]	0.16 ± 0.02[a]
	Se	4.60 ± 0.70[b]	5.39 ± 0.58[b]	8.65 ± 0.15[c]	0.03 ± 0.006[a]
	Cr	8.06 ± 0.10[c]	2.57 ± 0.65[b]	0.45 ± 0.15[a]	0.04 ± 0.004[a]
	Cd	2.94 ± 0.36	2.01 ± 0.09	1.86 ± 0.27	ND
Muscle	Cu	5.68 ± 1.32[c]	2.50 ± 0.48[b]	6.12 ± 0.80[c]	0.12 ± 0.06[a]
	Zn	18.6 ± 0.84[ab]	27.9 ± 1.85[b]	56.2 ± 16.15[c]	0.53 ± 0.42[a]
	Se	5.60 ± 0.50	6.11 ± 0.70	ND	0.46 ± 0.44
	Cr	7.66 ± 0.13[c]	0.43 ± 0.09[b]	0.40 ± 0.10[b]	0.04 ± 0.005[a]
	Cd	1.14 ± 0.04	1.16 ± 0.03	1.10 ± 0.09	ND

* Means (± Standard error of means) in the same row followed by different letters are significantly different according to Duncan's test ($p < 0.05$)

ND not determined

in fish suggested by EEC or FAO/WHO. Chi et al. (2007) stated that Cd and Zn levels in *C. carpio* from Taihu Lake (China) were 0.021 and 25 mg kg^{-1}, respectively. Ebrahimi and Taherianfard (2010) investigated concentrations of some heavy metals in cyprinid fish from the Kor River, Iran, and reported that the maximum concentrations of Cd, Pb, and Hg were higher than the permissible levels for human consumption, as we also did for Cd. On the other hand, Mendil and Uluozlu (2007) reported that levels of Cu, Zn and Cr in muscle tissue were respectively, 3.6, 48.6, 1.6 mg kg^{-1} in five cyprinid species in Tokat, Turkey. Papagiannis et al. (2004) obtained generally lower results than ours. Cu levels were higher in S1 and S3, Zn in S3, and Cr in S1 than results reported by Mendil and Uluozlu (2007).

Canpolat and Calta (2003) studied some metals in tissues and organs in *C. capoeta umbla* from the Keban Dam Lake (Turkey). They reported that the lowest levels of Fe, Zn, Mn and Cu were measured in muscle and skin, compared to other tissues and organs. Danabas et al. (2011) studied the levels of Cu in liver, muscle and gill tissues in *Capoeta trutta* (Heckel, 1843) from Munzur River (Turkey). They obtained relatively lower Cu levels in liver and higher Cu levels in muscle and gills than our results. Staniskiene et al. (2006) studied the distribution of metals (Pb, Cd, Cu, Zn, iron (Fe), nickel (Ni), Cr and manganese (Mn)) in tissues (muscle, bone, liver, gill and intestine) of freshwater fish in Lithuania. They obtained lower levels of Cd, Cu, Zn and Cr in muscle, liver and gills than ours. Le et al. (2009) studied metals in a tropical eel (*Anguilla marmorata*) from the central part of Vietnam. They obtained higher level of Zn and lower levels of Cu and Cd in muscle than our results, whereas the Cr level was similar. Arnwine and Graf (2010) studied mercury air deposition and Se levels in Tennessee fish. They determined lower Se levels in muscle of 9 fish species than Se levels of *C. trutta* in our study except in S1. Burger and Gochfeld (2011) researched Hg and Se levels in skinless muscle tissues of 19 species of saltwater fish from New Jersey and determined lower levels of Se in all species than for the level in *C. trutta* of this study.

Determination of the concentrations of metals in fish is an important subject, both with respect to nature management and human consumption of fish (Amundsen et al. 1997). The muscle of fish is used for human consumption, and Turkish Food Codex (2002) sets the maximum limits of Zn, Cu and Cd as respectively, 50, 20 and 0.05 mg kg^{-1} dry weight in muscle tissue. However, the maximum Cr level is 1.0 mg kg^{-1} (Kandemir et al. 2010). In our study, the level of Zn is higher in only S3 than maximum limits. Cadmium levels were higher in three stations (S1, S2 and S3) than the limits, whereas Cu levels were in limits in all stations. In addition to these, the levels of Cr were within limits in all of the stations, except S1. In conclusion, *C. trutta* caught from Keban Dam Lake, based on the higher levels of Zn in S3 and Cd in S1, S2 and S3 might be unsafe for human consumption. Care should be taken in consuming these fish, and close monitoring of heavy metal accumulation in fish from Keban Dam Lake in all seasons is recommended in view of possible health risks to consumers.

References

Al-Kahtani MA (2009) Accumulation of heavy metals in tilapia fish (*Oreochromis niloticus*) from Al-Khadoud Spring, Al-Hassa Saudi Arabia. Am J Appl Sci 6(12):2024–2029

Altun T, Danabas D (2006) Effects of short and long exposure to the anesthetic 2-phenoxyethanol mixed with ethyl alcohol on common carp (*Cyprinus carpio* L., 1758) fingerlings. Isr J Aquacult Bamid 58(3):1–5

Amundsen PA, Staldvik FJ, Lukin A, Kashulin N, Popova O, Reshetnikov Y (1997) Heavy metals contamination in freshwater fish from the border region between Norway and Russia. Sci Total Environ 201:211–214

APHA (1992) Standard methods for the examination of water and wastewater. In: Greenberg AE, Clesceri LS, Eato AD (eds) APHA 18th ed, Washington

Arnwine DH, Graf MH (2010) Mercury air deposition and Selenium levels in Tennessee fish and surface water. Tennessee Department of Environment and Conservation, Division of Water Pollution Control, 7th Floor L&C Annex. Nashville, TN, p 53

ASTM (1985) Preparation of biological samples for inorganic chemical analysis 1 annual book of ASTM standards 1985, D-19 pp 740–747

Atabeyoglu K, Atamanalp M (2010) Heavy metal studies in molluscs. Ataturk Univ J Vet Sci 5(1):35–42

Burger J, Gochfeld M (2011) Mercury and selenium levels in 19 species of saltwater fish from New Jersey as a function of species, size and season. Sci Total Environ 409:1418–1429

Canpolat O, Calta M (2003) Heavy metal in some tissues and organ *of Capoete capoeta umbla* (Heckel, 1843) fish species in relations to body size, age, sex and seasons. Fresenius Environ Bull 12(9):961–966

Che D, Meagher RB, Rugh CL, Kim T, Heaton ACP, Merkle SA (2006) Expression of organomercurial lyase in Eastern cottonwood enhances organomercury resistance. In Vitro Cell Dev B 42:228–234

Chi Q, Zhu G, Langdon A (2007) Bioaccumulation of heavy metals in fishes from Taihu Lake, China. J Environ Sci 19:1500–1504

Cousins RJ (1985) Absorption, transport and hepatic metabolism of copper and zinc: special reference to metallothionein and ceruloplasmin. Physiol Rev 65:238–309

Danabas D, Benzer F, Kaplan O, Yildirim NC (2011) Levels of copper in liver, muscle and gill tissues in *Capoeta trutta* (Heckel, 1843) from Munzur River Turkey. Afr J Agric Res 6(7): 1909–1912

Ebrahimi M, Taherianfard M (2010) Concentration of four heavy metals (cadmium, lead, mercury, and arsenic) in organs of two cyprinid fish (*Cyprinus carpio* and *Capoeta* sp.) from the Kor River (Iran). Environ Monit Assess 168(1–4):575–585

Gulec AK, Yildirim NC, Danabas D, Yildirim N (2011) Some hematological and biochemical parameters in common carp (*Cyprinus carpio* L., 1758) in Munzur River, Tunceli, Turkey. Asian J Chem 23(2):910–912

Heath AG (1991) Water pollution and fish physiology. Lewis Publishers, Boca Raton, p 359

Kandemir S, Dogru MI, Orun I, Dogru A, Altas L, Erdogan K, Orun G, Polat N (2010) Determination of heavy metal levels, oxidative status, biochemical and hematological parameters in Cyprinus carpio L., 1758 from Bafra (Samsun) fish lakes. J Anim Vet Adv 9(3):617–622

Karadede H, Unlu E (2000) Concentrations of some heavy metals in water, sediment and fish species from the Ataturk Dam Lake (Euphrates), Turkey. Chemosphere 41:1371–1376

Kennicutt MC, Wade TL, Presley BJ (1992). Assessment of sediment contamination in Casco Bay. Casco Bay Estuary Project Texas A&M University, p 113

Lauran DJ, McDonald DG (1985) Effects of copper on branchial ion regulation in the rainbow trout, *Salmo gairdneri* Richardson. J Comp Physiol B 155:635–644

Le QD, Shirai K, Nguyen DC, Miyazaki N, Arai T (2009) Heavy metals in a tropical eel *Anguilla marmorata* from The central part of Vietnam. Water Air Soil Pollut 204:69–78

Lemire M, Fillion M, Frenette B, Mayer A, Philibert A, Passos CJS, Guimaraes JRD, Barbosa FJR, Mergler D (2010) Selenium and mercury in the Brazilian Amazon. Opposing influences on age-related cataracts. Environ Health Perspect 118:1584–1589

Manahan SE (2003) Toxicological chemistry and Biochemistry, 3rd edn. Lewis Publishers, International Standard Book Number 1-56670-618-1, CRC Press LLC, 2000 N.W. Corporate Blvd., Boca Raton, Florida 33431, p 424

Masters GB (1997) Introductions to environmental engineering and science. Prentice Hall, New Jersey, p 65

Mendil D, Uluozlu OD (2007) Determination of trace metal levels in sediment and five fish species from lakes in Tokat. Turkey Food Chem 101(2):739–745

Nussev G, Van Vuren JHJ, Du Preez HH (2000) Bioaccumulation of chromium, manganese, nickel and lead in the tissues of the moggel, *Labeo umbratus* (Cyprinidae), from Witbank Dam, Mpumalanga. Water SA, 26:269–284. http://cat.inist.fr/?aModele=afficheN&cpsidt=973444

Olsson PE (1998) Disorders associated with heavy metal pollution. In: Leatherland JF, Woo PTK (eds) Fish diseases and disorders. CABI Publishing, New York, pp 105–131

Papagiannis I, Kagaloub I, Leonardos J, Petridis D, Kalfakakou V (2004) Copper and zinc in four freshwater fish species from Lake Pamvotis (Greece). Environ Int 30:357–362

Sardella BA, Matey V, Cooper J, Gonzalez RJ, Brauner CJ (2004) Physiological, biochemical and morphological indicators of osmoregulatory stress in 'california' mozambique tilapia (*Oreochromis mossambicus* x *O. urolepis hornorum*) exposed to hypersaline water. J Exp Biol 207:1399–1413

Stagg RM, Shuttleworth TJ (1982) The accumulation of copper in *Platichthys flesusl* and its effects on plasma electrolyte concentrations. J Fish Biol 20:419–500

Staniskiene B, Matusevicius P, Budreckiene R, Skibniewska KA (2006) Distribution of heavy metals in tissues of freshwater fish in Lithuania. Pol J Environ Stud 15(4):585–591

Torres P, Tort L, Flos R (1987) Acute toxicity of copper to mediterranean dogfish. Comp Biochem Physiol C 86:169–171

Turkish Food Codex (2002) Fisheries Regulations., Official Gazette, Addition 7, Number. 24936. Ankara, Turkey

U.S. EPA (2001) EPA method 200.7. Determination of metals and trace elements in water and wastes by inductively coupled plasma-atomic emission spectrometry Revision 4.4, EMMC Version, Method for the determination of metals in environmental samples (1994) Supplement 1, EPA/600/R-94-111

Yoshizawa K, Ascherio A, Morris JS, Stampfer MJ, Giovannucci E, Baskett CK, Willett WC, Rimm EB (2003) Prospective study of selenium levels in toenails and risk of coronary heart disease in men. Am J Epidemiol 158(9):852–860