Journal of Applied Biological Sciences 2 (3): 99-104, 2008
ISSN: 1307-1130, www.nobel.gen.tr

Determination of Heavy Metals in of Fishes, Water and Sediment from the Demirköprü Dam Lake (Turkey)

Meral ÖZTÜRK[1] Gökçe ÖZÖZEN[2] Orkide MİNARECİ[2*] Ersin MİNARECİ[2]

[1] Science Education Department, Faculty of Education, Celal Bayar University, Campus of Muradiye, Manisa, Turkey

[2] Biology Department, Faculty of Sciences and Arts, Celal Bayar University, Campus of Muradiye, 45140, Manisa, Turkey

[*]Corresponding Author
e-mail: orkide.minareci@bayar.edu.tr

Received: March 24, 2008
Accepted: May 15, 2008

Abstract

In this study, concentrations of heavy metals were measured in the surface water, sediment and fish (*Cyprinus carpio*) from the Demirköprü Dam Lake (Manisa, Turkey). The obtained results showed that, in general, the heavy metal (Cd, Cr, Cu, Fe, Ni, Pb) concentrations in water did not exceed WHO (World Health Organization, 1999), EC (Europe Community, 1998), EPA (Environment Protection Agency, 2002) and TSE-266 (Turkish Standard, 1997), WPCL (Water Pollution Control Legistation, 2004), CIW (Criterions of the Irrigation Water, 1997) guidelines. Heavy metal concentrations were found decrease in sequence of the surface water Fe > Pb > Cu > Ni > Cr > Cd, the *Cyprinus carpio* samples, in the muscle Fe > Cu > Ni > Cr > Pb > Cd, in the gill Fe > Ni > Cu > Pb > Cr > Cd, in the stomach-intestine Fe > Cu > Pb > Ni > Cr > Cd, in the air sac Fe > Pb > Cu > Ni > Cr > Cd, in the heart Fe > Ni > Pb > Cu > Cr > Cd, in the liver Fe > Cu > Ni > Pb > Cr > Cd. These obtained results show that, the heavy metal concentrations exceded the tolerable values provided by the international institutions. Generally, heavy metal concentration of the sediments were found decrease in sequence of Fe > Ni > Cu > Cr > Pb > Cd.

Key words: Heavy metal, *Cyprinus carpio*, dam lake, sediment, pollution.

INTRODUCTION

Heavy metal from man-made pollution sources are continually released into aquatic ecosystems [1]. Metals enter the aquatic environment by atmospheric deposition, by erosion of the geological matrix, or from anthropogenic sources, such as industrial efluents, and mining wastes. Bioaccumulation of trace metals by fish, together with the underlying mechanisms, has been extensively studied in field and laboratory studies [2].

Industrial wastes, geochemical structure and mining of metals create a potential source of heavy metal pollution in the aquatic environment [3]. Under certain environmental conditions, heavy metals may accumulate to a toxic concentration and cause ecological damage [4, 5].

Sediments are the sink of metals in freshwater and marine environments [6, 7]. Total concentrations of most metals in sediments are several orders of magnitude higher than aqueous concentrations [8]. However, total metals concentrations in sediments are not necessarily related to the biologically available metal concentrations. Many chemical extraction procedures have been proposed to estimate the concentration of metals in soils or sediments, which may be directly or indirectly available to organisms. Other studies report a good correlation between extractable metal concentrations and metal content in some biota. [9].

The contamination of heavy metals is a serious threat because of their toxicity,long persistence, bioaccumulation and biomagnification in the food chain [1]. Fish samples can be considered as one of the most signi.cant indicators in freshwater systems for the estimation of metal pollution level [10]. In recent years, much attention has been directed to the concentrations of some inorganic elements in freshwater fish and other aquatic organisms [11]. The commercial and edible species have been widely investigated in order to check for those hazardous to human health [12].

The common carp, *Cyprinus carpio* L., is one of the most extensively cultivated fish species in the world. Cultured carp consume arti.cial diets, generally commercial pellets containing 32% protein and 3.5% lipids. In natural lake environments, on the other hand, the major food items of wild carp are found in the sediment. Omnivorous, sediment-dwelling, fish species such as carp may therefore accumulate heavy metals more readily than pelagic species as a result of exposure to the generally higher metal content of sediment compared with the water column [13].

Chemical, toxicological and ecological approaches have been studied extensively in assessing impacts of heavy metal pollution in aquatic environments. Each of these approaches has its inherent limitations. Aquatic organisms have been used in comparative monitoring of pollution e.ects in different systems and to locate the sources of toxicants [14, 15]. In sense of lives health and environmental pollution, determination of the heavy metal concentration in drinking water is as useful as determination of the same quantity in usage water. Demirköprü Lake's water is important for farmers who using the Lake's water for the agricultural irrigation in its surroundings.

Although, trace elements in various wastes contaminate into lakes by different ways play important roles in physiological activities of organisms at low concentrations, but when it goes beyond their natural concentration levels, it may become

hazardous to ecosystem. The present study was carried out to determine the levels of some heavy metals (Cd, Cr, Cu, Fe, Ni, Pb) in muscle, liver, gill, stomach-intestine, air sac and heart of fish species (*Cyprinus carpio*) from the Demirköprü Dam Lake. It should be noted that this fish species are considered to be an essential part of the diet in the region. Heavy metal levels in water and sediment samples from the area were also determined in the representative sites of the dam lake.

MATERIALS AND METHODS

Demirköprü Dam Lake is on the Gediz River in west Anatolia, Turkey (38^0 37' N, 28^0 19 'E - 38^0 44' N, 28^0 27 'E). Maximum lake capasity is 1.320.000.000 m^3. Lake area is 47.66 km^2 and stuffing capacity is 4.300.000 m^3 [16]. In this study, surface water and sediment samples were taken from two different sampling sites at Demirköprü Dam Lake in 2005 (Figure 1). The fish (*Cyprinus carpio*) samples were also caught from the same localities. The two determined stations have been determined considering the geographical structure of the dam, environmental conditions and sediment structure.

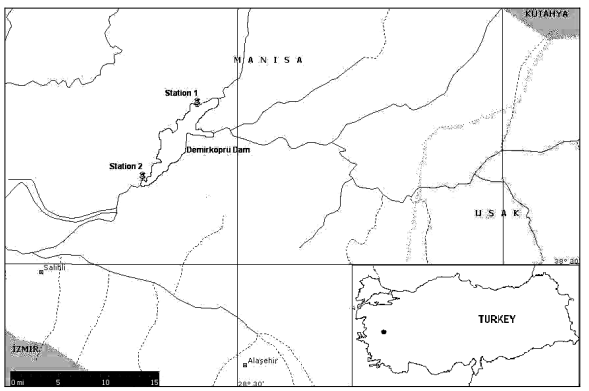

Figure 1. Demirköprü Dam Lake and Research Stations.

The samples were brought to the laboratory on the same day. Water samples have been put into 100 cc polyethylene bottles which are used for metal analyses of water. As soon as water samples are taken for analyses, bottle content has been acidified by adding 1cc HCl (37%). By doing that biological activities of present microorganisms and bacteria were immobilized and metal conversion was prevented [17].

The sediments were dried at 105°C for 24 h. The dried sediments were passed through a 160 µm mesh stainless screen to remove larger particles. Fish samples were kept at 30°C until analysis. Before analysis, muscle, liver, gill, stomach-intestine, air sac and heart from fish (*Cyprinus carpio*) were removed. Samples of tissues from fish were weighed and dried. Sediment and fish samples have been digested in the microwave digestion devices. A microwave digestion system (CEM Mars 5 ESP 1500 PLUS) was used to prepare the samples for analysis. Sediment and organic digesting works have been performed in accordance with the EPA 3051 (1986) methods [18]. The advantage of microwave digestion against the classical method are the shorter time, less consumption of acid and keeping volatile compounds in the solution [19, 20, 21]. After digestion, the residues diluted to 25 ml with 05% of HNO_3. Instrument calibrated standard solutions were prepared from commercial materials. The water used was deionized and distilled. The metal analysis of samples (Cd, Cr, Cu, Fe, Ni, Pb) were carried out by using Varian- Terra Model Liberty II ICP (Inductively Coupled Plasma) – AES (Atomic Emission absorption spectrophotometer). Heavy metal concentrations of samples have been given as ppm. All calculation was carried out on a Microsoft EXCEL program for winXP.

RESULTS AND DISCUSSION

Concentrations of heavy metal concentrations in water and sediment are shown in Tables 1 and 2, respectively.

The data in Table 1 and Table 2 also show that the concentrations of Cr, Cu, Fe, Ni and Pb in water and sediments from Station 1 were higher than those obtained from Station 2. The Cd, Cr, Cu, Fe, Ni, Pb concentrations in lake water in the two sampling sites are within the TSE-266, WPCL, CIW, WHO, EPA and EC standards. The average concentration of

Table 1. The concentration of heavy metals in water from the Demirköprü Dam Lake and standards (TSE-266, WPCL, CIW, WHO, EPA, EC) (Mean±S.D, all values in ppm)

Locality	Cd	Cr	Cu	Fe	Ni	Pb
TSE-266	0.01	0.05	3	0.2	-	0.05
WPCL	0.003	0.02	0.02	0.3	0.02	0.01
CIW	0.01	0.1	0.2	5	0.2	5
WHO	0.01	0.05	-	-	0.02	0.05
EPA	0.01	0.05	1.3	0.3	-	0.05
EC	5	50	2	0.2	20	10
Station 1	ND*	0.006±0.003	0.02±0.005	0.6±0.3	0.016±0.01	0.02±0.012
Station 2	0.001±0.005	0.005±0.001	0.01±0.005	0.26±0.28	0.007±0.005	0.009±0.006
C1	0.001	0.006	0.01	0.97	0.006	0.005
C2	0.0036	0.099	0.034	0.121	0.062	0.218
C3			0.22	0.062	0.015	
C4			0.002	0.43	0.012	

*Not determined.

TSE, Institution of Turkish Standards [22], WPCL, Water Pollution Control Legistation [23]
CIW, Criterions of the irrigation water [16], WHO, World Health Organization [24]
EPA, Environment Protection Agency [25], EC, European Communities [26]
C1 Avşar Dam Lake [27], C2 Gediz River [28], C3 Atatürk Dam Lake [29], C4 Hazar Lake [30].

Fe in the lake water is higher than the TSE-266, WPCL, EPA and EC standards. But the average concentration of Fe is very similar to standard values. Other heavy metal concentrations are lower than the TSE-266, WPCL, CIW, WHO, EPA and EC standards.

The results obtained from the water samples have been compared with "Environment Law-Water Pollution Control Legistation, Land-Based Water Quality Classification" [23] and it has been found that the Demirköprü Dam Lake was of the first quality water class (Table 1). It is clear that so far the Demirköprü Dam Lake does not have a pollution source in terms of heavy metals. In the criterions of the irrigation water report (CIW) given as a result "Gediz River Basin Study", maximum heavy metal concentrations allowed in irrigation waters have been stated [16]. These values and our study results have been compared and found low heavy metal concentrations. In this case, the water taken from Demirköprü Dam Lake is proper for irrigation.

The heavy metals levels of water in Demirköprü Dam Lake are compared to the metal levels of water in Gediz River and Atatürk Dam Lake with the exception of Fe, which was lower. Although the concentrations of Ni and Pb in the lake water were higher than the Hazar Lake, the concentration of Cu was higher than the Avşar Dam Lake.

Heavy metal concentrations in the lake water were decreased in sequence of Fe > Pb > Cu > Ni > Cr > Cd. Özözen investigated heavy metals concentrations in water of Avşar Dam Lake and reported the sequence to be in Fe > Cu > Cr > Cd > Pb > Ni.

The average concentrations of Cd and Fe in sediments obtained in this study are higher than those reported in Gediz River. The concentration is Pb was higher than the Avşar Dam Lake and the concentration is Cu was higher than the the Hazar Lake. The average concentration of Cu, Fe, Ni in the lake sediment are lower than the Atatürk Dam Lake.

Heavy metal concentrations in the lake sediments were decreased in sequence of Fe > Ni > Cu > Cr > Pb > Cd. Özözen investigated heavy metals concentrations in sediments of Avşar Dam Lake and reported the sequence to be in Fe > Ni > Cu > Cr > Pb > Cd.

The heavy metals levels of sediment in Demirköprü Dam Lake are compared to the metal levels of sediment in some lakes in world (Table 3). Generally the average Cd and Pb concentrations determined in Demirköprü Dam Lake was found to be lower than the other studies, Fe was higher. Differences between our data and those of partly originates probably from differences in geological mining history of localities and urban and domestic activities.

The concentrations of heavy metals in the muscle, liver, heart, stomach-intestine, air sac and gills of *Cyprinus carpio* samples are given in Table 4. -Heavy metal concentrations in the fish samples were decreased in sequence of the muscle Fe > Cu > Ni > Cr > Pb > Cd, the gill Fe > Ni > Cu > Pb > Cr >

Table 2. Mean concentrations of elements in sediments compared with data from the literature (in Turkey) (Mean±S.D, all values in ppm)

Locality	Cd	Cr	Cu	Fe	Ni	**Pb**
Station 1	0.7±0.3	6.75±2.54	15.1±4.6	15681±7043	14.3±8.1	6.5±4.4
Station 2	0.82±0.07	3.58±3.03	9.3±4.88	12631±5484	7.41±12.5	2.66±2.58
C1	0.76	14.48	29.98	25268	29.99	4.04
C2	0.64	140	257	5066	60.5	18.9
C3	-	-	22.70	19265	139.69	-
C4	-	-	6.4	30000	130	-

C1 Avşar Dam Lake [27], C2 Gediz River [28], C3 Atatürk Dam Lake [29], C4 Hazar Lake [30].

Table 3. Mean concentrations of elements in the lake sediments compared with data from the literature (in world) (Mean±S. D, all values in ppm)

Locality	**Cd**	**Cr**	**Cu**	**Fe**	**Ni**	**Pb**
Station 1	0.7±0.3	6.75±2.54	15.1±4.6	15681±7043	14.3±8.1	6.5±4.4
Station 2	0.82±0.07	3.58±3.03	9.3±4.88	12631±5484	7.41±12.5	2.66±2.58
D1	0.2	-	37.40	53.20	-	14.60
D2	7.0	12.9	26.1	-	-	54.6
D3	2	30	38	19393	17	10
D4	18.4	337	727	40.6	87	620
D5	1.9	-	25	-	-	360
D6	1.20	1.15	2.05	30.2	1.60	9.7
D7	1.80	1.85	2.95	98.9	2.95	13.4
D8	1.25	1.30	2.65	44.1	2.05	12.9

D1 Tanganyika Lake [31], D2 Lake Victoria [32], D3 Lake Texoma [33], D4 Lake Geneva [34], D5 Lochnagar Lake [35], D6 Wielkie Lake [36], D7 Boszkowo Lake [36], D8 Dominickie Lake [36].

Table 4. The heavy metal concentrations of *Cyprinus carpio* samples from the Demirköprü Dam Lake (Mean±S.D, all values in ppm(wet weight)).

Heavy metals	Muscle	Gill	Stomach-intestine	Air sac	Heart	Liver
Cd	0.44±0.28	0.57±0.37	0.43±0.25	0.71±0.41	0.74±0.5	0.4±0.4
Cr	2.84±1.4	1.25±0.58	0.62±0.36	0.94±0.55	1.07±0.65	1.26±0.24
Cu	3.55±1.53	3.83±0.18	3.03±0.61	3.49±1.09	2.52±0.73	4.02±0.98
Fe	34.96±14.57	54.77±18.83	64.06±21.52	30.82±10.6	85.63±20.52	27.48±6.10
Ni	3.16±0.57	3.91±1.51	0.69±0.18	1.42±1.17	2.96±2.99	4.02±1.39
Pb	1.58±0.96	1.67±1.23	2.49±2.35	5.81±2.85	2.53±2.34	3.29±1.83

Table 5. The tolerable values of some heavy metals in the fishes.

	Cd	Cr	Cu	Fe	Ni	Pb
UNEP,1985 mg/kg	0.3	-	-	-	-	3
IAEA/ AL/ 144; IAEA MEL/ 72 mg/kg 200	0.189	0.73	3.28	1.46	0.60	0.12
Resmi Gazete 1991 (in Turkish) mg/kg	0.1	-	20	-	-	1
Directive 2001/ 22/EC mg/ kg *	0.1	-	-	-	-	0.4

* Official journal food safety [37]

Cd, the stomach-intestine Fe > Cu > Pb > Ni > Cr >Cd, the air sac Fe > Pb > Cu > Ni > Cr >Cd, the heart Fe > Ni > Pb > Cu > Cr >Cd, the liver Fe > Cu > Ni > Pb > Cr > Cd.

When the values obtained in the *Cyprinus carpio* samples are compared with the tolerable values, it has been determined that the pollution has reached levels hazardous for the health of human (Table 5). Cd, Cr, Ni and Pb average values were higher than tolerable values.

The results confirm the differences of accumulation of heavy metals in the different tissues. The highest concentrations of Cd, Fe, and Ni were found in the heart. Although, the highest level of Cu in the liver was found. Moreover, Cu accumulation in *Cyprinus carpio* was found to be the highest level in liver [38]. Studies carried out with various fish species have shown that heavy metals accumulate mainly in metabolic organs such as liver that stores metals to detoxificate by producing metallothioneins [39, 40, 41]. The ability of toad, *Bufo marinus* to tolerate high levels of hepatic metals is attributed to the localization of the metal in liver lysosomes where it is made innocuous [42].

Papagiannis et al., have determined the level of Cu in various tissues of the *Cyprinus carpio* species in Pomvatis Lake (Greece) [43]. In this research, it has been found that the highest level of Cu in the liver and the lowest level of Cu in the muscle. In our examples, it has been found that the level of Cu in the liver higher than the muscle.

The Fe, Cu, Cr and Ni accumulation in the muscle of *Cyprinus carpio* samples of Demirköprü Dam Lake is higher than those in Atatürk Dam Lake [29], Gölcük Lake [44] and Tokat's Lakes [45]. Analysis of the heavy metal levels in muscles of fish samples showed that an average Fe is the highest and Cd is the lowest (Table 4). Similar results were reported from a number of fish species which shows that muscle is not an active tissue in accumulating heavy metals [29, 39, 41, 46].

Öztürk et al. have found that the highest level of Fe and the lowest level of Cd in the muscle, gill, air sac, stomach-intestine and liver of *Cyprinus carpio* species in Altınkaya Dam [47]. In our previous study, we determined that there were same results in metal concentrations of organs and tissues of the *Cyprinus carpio* samples.

Alam et al., the concentrations of elements were determined in the muscle, liver, intestine, kidney, and gonads of cultured and wild carp caught in Lake Kasumigaura, Japan. Despite having a reputation for being heavily polluted, the carp were not heavily burdened with metals. Metal concentrations were lowest in muscle, and did not exceed established quality standards for fish. The metal concentrations should pose no health problems for consumers of fish [48]. In our study, there are no high levels of heavy metals in fish.

CONCLUSIONS

Consequently, it can be concluded that the concentrations of heavy metals in water from Demirköprü Dam Lake are lower than the TSE-266, WPCL, CIW, WHO, EPA and EC standards, with the exception of Fe. But the average concentration of Fe is very similar to standard values. The concentrations of Cr, Cu, Ni and Pb in sediments from Demirköprü Dam Lake are lower than the sediment samples obtained from Gediz River, which is known as a polluted site. There are high levels of heavy metals in fish, it has been determined that the pollution has reached levele hazardous for the health of human. Potential dangerous may occur in the future depending on the agricultural development in this region. As the Demirköprü Dam is also used for agricultural irrigation purposes, performance of pollution researches at certain periods is of significance for both environment and public health.

REFERENCES

[1] Eisler R. 1988. Zink hazards to fish, wildlife and invertebrates: a synoptic review. US Fish Wildlife. Service Biology of Reproduction, 85.

[2] Boudou A, Ribeeyre F. 1989. Fish as ''biological model'' for experimental studies in ecotoxicology. In: Boudou, A., Ribeeyre, F. (Eds.); Aquatic Ecotoxicology: Fundamental

Concepts and Methodologies, vol. 2, pp 127–162. CRC Press, Boca Raton, FL, USA.

[3] Lee YH, Stuebing RB. 1990. Heavy metal contamination in the River Toad, Bufo juxtasper (Inger), near a copper mine in East Malaysia. Bulletin of Environmental Contamination Toxicology. 45: 272–279.

[4] Jefferies DJ, Freestone PJ. 1984. Chemical analysis of some coarse fish from a Suffolk River carried out part of the preparation for the first release of captive-bred otters. Journal of the Otter Trust. 1: 17–22.

[5] Freedman B. 1989. The impacts of pollution and other stresses on ecosystem structure and function. In: Environmental Ecology. Academic Press, London.

[6] Arjonilla M, Forja JM, Gomez-Parra A. 1994. Sediment analysis does not provide a good measure of heavy metal bioavailability to Cerastoderma glaucum (Mollusca: Bivalvia) in con.ned coastal ecosystems. Bulletin of Environmental Contamination Toxicology. 52: 810–817.

[7] Weimin Y, Batley GE, Ahsanullah M. 1994. Metal bioavailability to the soldier crab *Mictyris longicarpus*. The Science of the Total Environment. 141: 27–44.

[8] Louma SN. 1989. Can we determine the biological availability of sediment-bound trace elements? Hydrobiologia. 176/177: 379–396.

[9] Conder JM, Lanno RP, Basta NT. 2001. Assessment of metal availability in smelter soil using earthworms and chemical extractions. Journal of Environmental Quality. 30: 1231–1237,

[10] Rashed MN. 2001. Monitoring of environmental heavy metals in fish from Nasser lake. Environment International. 27: 27–33.

[11] Farkas A, Salanki J, Specziar A. 2003. Age and size-specific patterns of heavy metals in the organs of freshwater fish Abramis brama L. populating a low-contaminated site. Water Research. 37: 959–964.

[12] Begüm A, Amin MdN, Kaneco S, Ohta K. 2005. Selected elemental composition of the muscle tissue of three species of fish, *Tilapia nilotica*, *Cirrhina mrigala* and *Clarius batrachus*, from the fresh water Dhanmondi Lake in Bangladesh. Food Chemistry. 93: 439–443.

[13] Phillips DJH. 1980. Quantitative aquatic biological indicators: Their use to monitor trace metal and organochlorine pollution. Applied Science Publishers Ltd., London, UK, 488.

[14] Phillip RC, 1989. Water quality, sediments and the macroinvertebrate community of residential canal estates in southeast Queensland, Australia: a multivariate analysis. Water Research. 23: 1087.

[15] Mengchang HE, Wang Z, Tang H. 1998. The chemical, toxicological and ecological studies in assessing the heavy metal pollution in Le An River, China. Water Research. 32: 510–518.

[16] Anonim. 1997. Gediz Havzası Çalışmaları. T.C. İzmir Çevre İl Müdürlüğü, Türkiye.

[17] Uysal H, Tunçer S. 1983. İzmir Körfezi pollusyonlu zeminde yaşayan *Arca amygdalum* Philliipi 1984 ve *Corbula gibba* Olivi'deki ağır metal konsantrasyonlarının dağılımı. Ege University Faculty of Science Journal, Series B (Supplementary). 542- 548.

[18] EPA (Environmental protection Agency). 1986. Test Methods For Evalvation Solid Waste, Physical/Chemical Methods, 3. ed; V.S. Environmental protection Agency, Office Of Solid Waste and Emergency Response. V.S. Goverment Printing Office: Washington, DC, 1-14.

[19] Krushevska A, Barnes MR, Amarasiriwaradena C. 1993. Decomposition of biological samples for inductively coupled plasma atomic emission spectrometry using an open focused microwave digestion system. The Analyst. 118: 1175-1181.

[20] Gulmini M, Ostacoli G, Zelano V. 1994. Comparison between microwave and conventional heating procedures in Tessier's extractions of calcium, copper, iron and manganese in a lagoon sediment. The Analyst. 119: 2075-2080.

[21] Sures B, Taraschewski H, Haug C. 1995. Determination of trace metals (Cd, Pb) in fish by electrothermal atomic absorption spectrometry after microwave digestion. Analytica Chimica Acta. 311: 135-139.

[22] TSE. 1997. Institution of Turkish Standards, Annual Progress Report.

[23] Environment Law-Water Pollution Control Legistation, Land-Based Water Quality Classification, Turkey. 2004.

[24] WHO. 1993. Guidelines for drinking water quality. Recommendations, vol. 1, 2nd ed. World Health Organization, Geneva.

[25] EPA (Environmental protection Agency). 2002. http://www.epa.gov (last updated

04.04.2008)

[26] EC (European Communities). 1998. Official journal of the European Communities (OJ L 330).

[27] Özözen G. 2005. Demirköprü ve Avşar barajlarından alınan balık, su ve sediment örneklerinde bazı ağır metal konsantrasyonlarının belirlenmesi. Yüksek lisans tezi. Celal Bayar Üniversitesi Fen Bilimleri Enstitüsü, Manisa, Türkiye.

[28] Uzunoğlu, O. 1999. Gediz nehrinden alınan su ve sediment örneklerinde bazı ağır metal konsantrasyonlarının belirlenmesi. Yüksek lisans tezi. Celal Bayar Üniversitesi Fen Bilimleri Enstitüsü, Manisa, Türkiye.

[29] Karadede H, Ünlü E. 2000. Concentrations of some heavy metals in water, sediment and fish species from the Atatürk dam lake (Euphrates), Turkey. Chemosphere. 41(9): 1371-1376.

[30] Özmen H, Külahçı F, Çukurovalı A, Doğru M. 2004. Concentrations of heavy metal and radioactivity in surface water and sediment of Hazar lake (Elazığ, Turkey). Chemosphere. 55: 401-408.

[31] Chale F. 2002. Trace metal concentrations in water, sediments and fish tissue from lake Tanganyika. The Science of the Total Environment. 299(1-3): 115-121.

[32] Kishe MA, Machiwa JF. 2003. Distribution on heavy metals in sediments of Mwenza Gulf of Lake Victoria, Tanzania. Environ. Int. 28, 619–625.

[33] An YJ, Kampbell DH. 2003. Total, dissolved, and bioavailable metals at Lake Texoma marinas. Environmental Pollution. 122: 253–259.

[34] Pote J, Haller L, Loizeau JL, Bravo AG, Sastre V, Wildi W. 2008. Effects of a sewage treatment plant outlet pipe extension on the distribution of contaminants in the sediments of the Bay of Vidy, Lake Geneva, Switzerland. Bioresource Technology (in press).

[35] Yang H, Rose NL, Battarbee RW. 2002. Distribution of some trace metals in Lochnagar, a Scottish mountain lake ecosystem and its catchment. The Science of the Total Environment. 285: 197-208.

[36] Szymanowska A, Samecka-Cymerman A, Kempers AJ. 1999. Environmental Research, Section B. Heavy Metals in Three Lakes in West Poland. Ecotoxicology and Environmental Safety. 43: 21-29.

[37] Official Journal Food Safety: http: // europa.eu.int./ scadplus / leg / en /cif / 94000 html

[38] Yaramaz Ö. 1986. Investigation of some heavy metal accumulation in C. carpio, S. glanis, A. anguilla from Gölcük and Marmara lake. VII Turkish Biology Congress, Izmir, Turkey. 2:444-453.

[39] Carpene E, Vasak M. 1989. Hepatic metallothionein from goldfish (Carassius auratus). Comparative Biochemistry Physiology. 92B: 463-468.

[40] Hogstrand C, Haux C. 1991. Binding and detoxification of heavy metals in lower vertebrates with reference to metallothionein. Comparative Biochemistry Physiology. 100C(1/2): 137-141.

[41] Kargin F, Erdem C. 1991. Accumulation of copper in liver, spleen, stomach, intestine, gill and muscle of Cyprinus carpio. Journal of Doga Turk Zoology. 15: 306-314.

[42] Goldfisher S, Schiller B, Sternlieb I. 1970. Copper in hepatocyte lysosomes of the toad, *Bufo marinus* L. Nature. 228: 172-173.

[43] Papagiannis L, Kagalou L, Leonardos J, Petridis D, Kalfakakou V. 2004. Copper and zinc in four freshwater fish species from lake Pamvotis (Greece). Environment International. 30: 357-362.

[44] Uysal H, Tunçer S, Yaramaz O. 1986. Gölcük ve Gölmarmara göllerinde yaşayan *C. carpio, S glanis*, *A. anguilla'*da bazı ağır metal düzeylerinin araştırılması. VIII. Ulusal Biyoloji Kongresi Tebliğleri, İzmir, Türkiye.

[45] Mendil D, Uluözlü OD, Hasdemir E, Tüzen M, Sarı H, Suiçmez M. 2005. Determination of trace metal levels in seven fish species in lakes in Tokat, Turkey. Food Chemistry. 90(1-2): 175-179.

[46] Khan AT, Weis JS, D'andrea L. 1989. Bioaccumulation of four heavy metals in two populations of Grass Shrimp, Palaemonotes pugio. Bulletin of Environmental Contamination Toxicology. 42: 339-343.

[47] Öztürk M, Bat L, Öztürk M. 1995. Altınkaya Barajında (Samsun) yaşayan *Cyprinus carpio* L. 1758 türünün çeşitli organ ve dokularındaki bazı ağır metallerin birikimi. II. Ulusal Ekoloji ve Çevre Kongresi, 11-13 Eylül, Ankara, Türkiye.

[48] Alam MGM, Tanaka A, Allinson G, Laurenson LJB, Stagnitti F, Snow ET. 2002. A comparison of trace element concentrations in cultured and wild carp (Cyprinus carpio) of Lake Kasumigaura, Japan. Ecotoxicology and Environmental Safety. 53: 348–354.