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Determination of Some Metal Levels in Muscle Tissue of Nine Fish Species from Beyşehir Lake, Turkey

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Abstract

Concentrations of some metals were determined in muscle tissues of nine fish species from Beyşehir Lake, Turkey by using atomic absorption spectrophotometer. Most of metal levels in *Alburnus akili* were higher than those of other fish species as followings: Pb 5.25 mg kg^{-1}, Cd 4.00 mg kg^{-1}, Zn 23.75 mg kg^{-1}, Ni 4.01 mg kg^{-1}, Cr 24.45 mg kg^{-1}, Mn 17.53 mg kg^{-1}, Co 5.90 mg kg^{-1}, Mg 283.06 mg kg^{-1}, Sr 27.40 mg kg^{-1}, K 514.09 mg kg^{-1} and Li 49.38 mg kg^{-1}. The highest concentrations of Cu and Ca were determined in *Scardinius erythrophthalmus* as 2.68 mg kg^{-1} and 538.83 mg kg^{-1} respectively. The highest concentrations of Bi and Na were measured in *Gobio gobio microlepidotus* as 6.05 mg kg^{-1} and 423.56 mg kg^{-1} respectively. Maximum Fe (13.98 mg kg^{-1}) content was determined in *Tinca tinca* compared to other species. Concentrations of Pb and Cd in the muscle tissue of all the fish species exceeded the tolerance levels of national and international guidelines but were below Provisional Tolerable Weekly Intake (PTWI) limits set by FAO/WHO. The contents of Ni, Cr and Mn in specimens were also higher than the tolerance levels of some guidelines. On the contrary, levels of Zn, Cu and Fe were below the limits of guidelines and PTWI.

Keywords: Fish, metal concentration, Beyşehir Lake, Turkey.

Beyşehir Gölü'ndeki Dokuz Balık Türünün Kas Dokularındaki Bazı Metal Seviyelerinin Belirlenmesi

Özet

Bu çalışmada Beyşehir Gölü'ndeki dokuz balık türünün kas dokularındaki bazı metallerin konsantrasyonları atomik absorbsiyon spektrofotometre yöntemiyle tespit edilmiştir. *Alburnus akili*'deki çoğu metal seviyesi diğer balık türlerindekilerden yüksek bulunmuştur (Pb 5,25 mg kg^{-1}, Cd 4,00 mg kg^{-1}, Zn 23,75 mg kg^{-1}, Ni 4,01 mg kg^{-1}, Cr 24,45 mg kg^{-1}, Mn 17,53 mg kg^{-1}, Co 5,90 mg kg^{-1}, Mg 283,06 mg kg^{-1}, Sr 27,40 mg kg^{-1}, K 514,09 mg kg^{-1} ve Li 49,38 mg kg^{-1}). En yüksek Ca (2,68 mg kg^{-1}) ve Cu (538,83 mg kg^{-1}) konsantrasyonu *Scardinius erythrophthalmus*'da belirlenmiştir. En yüksek Bi (6,05 mg kg^{-1}) ve Na (423,56 mg kg^{-1}) konsantrasyonu *Gobio gobio microlepidotus*'da ölçülmüştür. Maksimum Fe (13,98 mg kg^{-1}) içeriği ise diğer türlerle karşılaştırıldığında *Tinca tinca*'da tespit edilmiştir. İncelenen tüm balık türlerinin kas dokularındaki Pb ve Cd konsantrasyonları ulusal ve uluslararası referansların tolerans seviyelerini aşmış, bununla birlikte FAO/WHO'nun tespit ettiği PTWI (Provisional Tolerable Weekly Intake) limitlerinin altında kalmıştır. Örneklerin Ni, Cr ve Mn düzeyleri de bazı uluslararası referansların tolerans seviyelerini aşmıştır. Zn, Cu ve Fe seviyeleri ise uluslararası referansların ve PTWI limitlerinin altındadır.

Anahtar Kelimeler: Balık, metal konsantrasyonu, Beyşehir Gölü, Türkiye.

Introduction

Heavy metals from anthropogenic pollution sources are continually released into aquatic ecosystems as lakes, and heavy metals are serious threat because of their toxicity, long persistence, bioaccumulation and biomagnification in the food chain (Eisler, 1988). Heavy metals are environmentally ubiquitous, readily dissolved and transported by water and readily taken up by aquatic organisms (Alam *et al*., 2002). Pollution of the aquatic environment with heavy metals has become a serious health concern during recent years. Fishes are often at the top of aquatic food chain in water ecosystems and fish living in the polluted waters may accumulate toxic trace metals (Mansour and Sidky, 2002). It is well known that fish, as a regular constituent of the human diet, can represent a dangerous source of certain heavy metals.

Several studies about metal pollution of Beyşehir Lake have been reported by researchers recently. The accumulation of some heavy metals (Cd, Pb, Hg and Cr) was measured in water, sediment, plankton and fish samples by Altındağ and Yiğit (2005). Heavy metal content of *Cyprinus carpio*, *Leuciscus cephalus* and *Stizostedion lucioperca* were studied by Tekin-Özan and Kir (2006 and 2008). Tekin-Özan (2008) and Aktumsek and Gezgin (2011) reported heavy metal content in water, sediment and tissues of *Tinca tinca*.

In this study, concentrations of sixteen metals (Pb, Cd, Zn, Cu, Ni, Cr, Mn, Fe, Co, Mg, Sr, Bi, Na, K, Li and Ca) in the nine fish species from Beyşehir Lake (*Phoxinellus anatolicus* Hanko, 1924, *Alburnus akili* Battalgil, 1942, *Gobio gobio microlepidotus* Battalgil, 1942, *Leuciscus lepidus* Heckel, 1843, *Carassius gibelio* (Bloch, 1782), *Cyprinus carpio* L., 1758, *Scardinius erythrophthalmus* L., 1758, *Tinca tinca* (L., 1758) and *Sander lucioperca* (L., 1758)) were determined, because these fish species have been consumed as food by local people. *P. anatolicus*, *A. akili* and *G. gobio microlepidotus*, *C. gibelio* and *S. erythrophthalmus* in Beyşehir Lake have been evaluated in regard to metal content for the first time. Among them, *P. anatolicus*, *A. akili* and *G. gobio microlepidotus* are also endangered and endemic species from Turkey. The liver is the main site of accumulation, biotransformation and excretion of pollutants in fish (Shinn, 2009). However, the muscle is the section of fish that is consumed by human. It is required to verify whether contaminants like heavy metals are within the recommended limits for human consumption (Shinn, 2009). Therefore the metal content in the muscle was analysed in the present study. Especially, the mean concentrations of Pb, Cd, Zn, Cu, Ni, Cr, Mn and Fe were evaluated in terms of national and international guidelines and other studies.

Materials and Methods

The Study Area and Fish Samples

Beyşehir Lake located in the southwest Anatolia, is the largest freshwater lake in Turkey (Figure 1). The lake is far away from Konya approximately 75 km. The lake is nearly 50 km long and 15-20 km wide, and the depth is approximately 10 m. It is an important irrigation and drinking water source, and

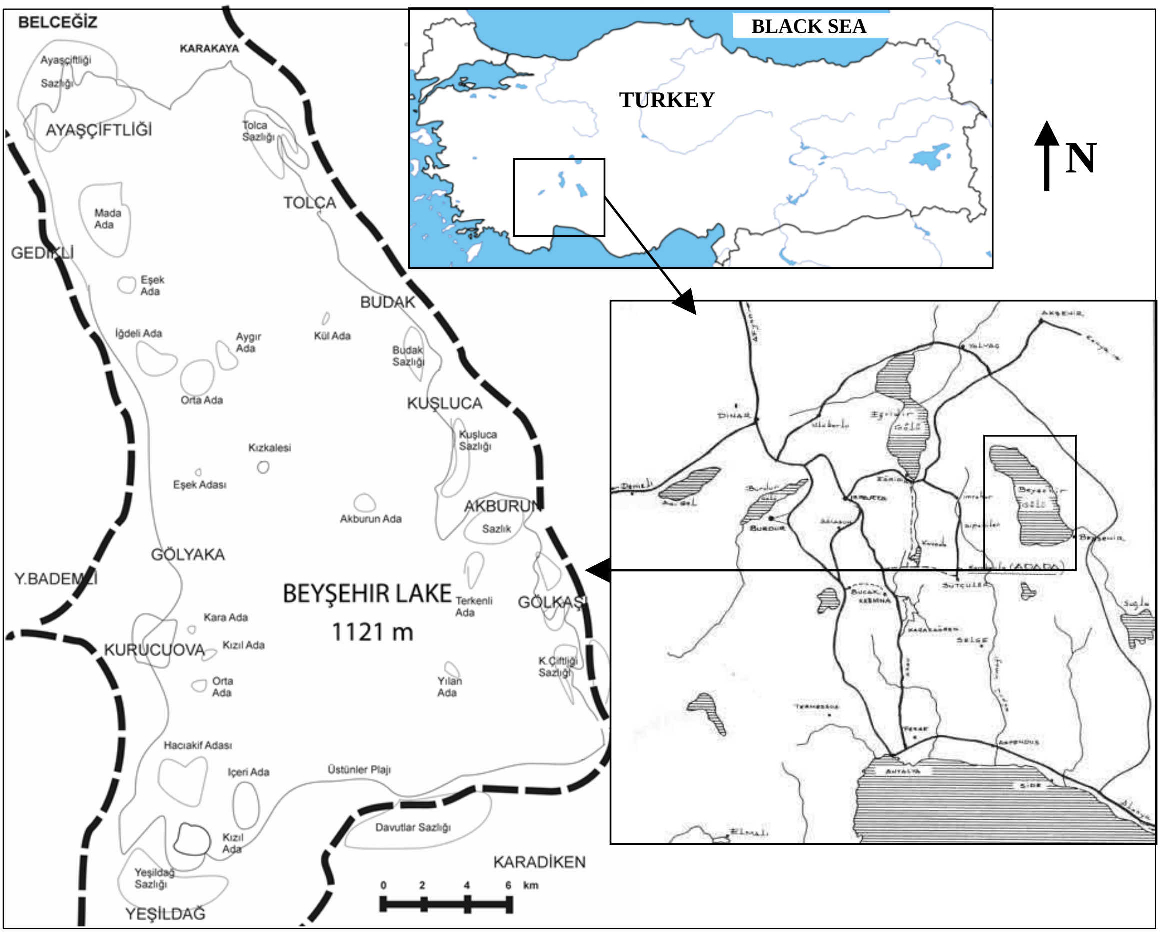

Figure 1. Map of Beyşehir Lake in Turkey.

bird nesting and visiting area (Yarar and Magnin, 1997).

Fish used in the experiment were Cyprinid species (*P. anatolicus*, *Alburnus akili*, *G. gobio microlepidotus*, *S. erythrophthalmus*, *T. tinca*, *C. carpio*, *C. gibelio* and *L. lepidus*) and Percid species (*S. lucioperca*). The fish (total 37 samples) were purchased after landing from local fisherman in March and April 2010 and were kept at -20°C until analysis. The fish samples taken were mostly consumed sizes, the same ages and sizes because these may be important factors for metal accumulation in fish.

Chemical Analysis

An Analytic Jena model contrAA 300 atomic absorption spectrometer (Germany) and CEM-MDS 2000 closed vessel microwave system were used in this study. A stock standard solution of metals at a concentration of 1000 mg L^{-1} was purchased from Merck (Frankfurter Str. 250, 64293 Darmstadt, Germany). Deionised water (Millipore Milli-Q Plus water purification system 18.2 MX cm^{-1}, resistivity, France) was used for all dilutions. The working solutions with a concentration of metals were prepared by appropriate dilutions of the stock solution immediately prior to their use. Laboratory glassware was kept overnight in a 10% v/v HNO_3 solution and then rinsed with deionised double distilled water.

Before analysis, a bit of dorsal muscle from each fish was removed. Tissues were washed with double-distilled water and were dried in filter paper at 60°C for 24 h. Dried fish samples were homogenized in a blender and one gram of homogenate was digested by microwave digestion system. In recent years, microwave digestion processes have been used in numerous studies. The advantage of microwave digestion against the classical method are the shorter time, less consumption of acid and keeping volatile compounds in the solution. CEM-MDS 2000 closed vessel microwave system (maximum pressure 800 psi, maximum temperature 220°C) was used. Digestion conditions for microwave system for the samples were applied as 2 min for 250 W, 2 min for 0 W, 6 min for 250 W, 5 min for 400 W, 8 min for 550 W, ventilation: 8 min (Tuzen *et al*., 2009). After digestion, the residues diluted to 50 mL with deionised water. Instrument calibrated standard solutions were prepared from commercial materials. The metal analyses of samples (Pb, Cd, Zn, Cu, Ni, Cr, Mn, Fe, Co, Mg, Sr, Bi, Na, K, Li and Ca) were carried out by using Contr AA 300 Atomic Absorption Spectrophotometer. The operating parameters for working elements were set as recommended by the manufacturer. The absorption wavelength and detection limits were presented in Table 1. Metal contents were expressed as mg kg^{-1} dry weight (dw).

Results

The mean and minimum-maximum concentrations of Pb, Cd, Zn, Cu, Ni, Cr, Mn, Fe, Co, Mg, Sr, Bi, Na, K, Li and Ca (mg kg^{-1} dw) in muscle of fish species in Beyşehir Lake were summarized in Table 2. Most of metal levels in *A. akili* were higher than those of other fish species as follows: Pb 5.25 mg kg^{-1}, Cd 4.00 mg kg^{-1}, Zn 23.75 mg kg^{-1}, Ni 4.01 mg kg^{-1}, Cr 24.45 mg kg^{-1}, Mn 17.53 mg kg^{-1}, Co 5.90 mg kg^{-1}, Mg 283.06 mg kg^{-1}, Sr 27.40 mg kg^{-1}, K 514.09 mg kg^{-1} and Li 49.38 mg kg^{-1}. The highest concentrations of Cu and Ca were determined in *S. erythrophthalmus* as 2.68 mg kg^{-1} and 538.83 mg kg^{-1} respectively. The highest concentrations of Bi and Na were measured in *G. gobio microlepidotus* as 6.05 mg kg^{-1} and 423.56 mg kg^{-1} respectively. Maximum Fe content (13.98 mg kg^{-1}) was determined in *T. tinca* compared to other species.

Discussion

Pb and Cd belong to non-essential and toxic metals group and Pb has no known function in biochemical processes. These metals have a high potential for bioconcentration in fish and are accumulated in multiple organs. Usually, Pb levels in teleost muscle tissue are considerably lower than in liver (Wagner and Boman 2003). Pb concentration in muscle of fish ranged from 1.62 to 5.25 mg kg^{-1} in this study and the lowest concentration was measured in *S. lucioperca* (Table 2). These values were higher than those reported by other studies in Beyşehir Lake (Table 3). Pb concentrations of fish species of Beyşehir Lake in previous studies were reported as 0.35, 0.42 and 0.68 mg kg^{-1} for *Tinca tinca*, *Leuciscus cephalus* and *S. lucioperca*, respectively (Altındağ and Yiğit, 2005; Aktümsek and Gezgin, 2011). However, the highest Pb level was reported as 250 mg kg^{-1} in *L. cephalus* in Kızılırmak River from Turkey by Akbulut and Akbulut (2010). Pb concentrations in all fish specimens of this study exceeded FAO/WHO (1989), IAEA-407 (Wyse *et al.*, 2003), TFC (2002), EC (2006) and Chine (Cheung *et al.*, 2008) guidelines limits except for Range of International Standards (Yamazaki *et al*., 1996) (Table 4).

The Cd values in the muscle of fish species were found in a range of 2.17-4.00 mg kg^{-1} in present study. These amounts were higher than those of other studies in Beyşehir Lake (Table 3). Cd content was reported as 0.54, 0.58, 0.60 and 0.64 mg kg^{-1} in *C. carpio*, *L. cephalus*, *T. tinca* and *S. lucioperca* respectively in Beyşehir Lake by Altındağ and Yiğit (2005). Cd concentrations in all fish specimens of this study were too higher than those reported by other studies from Turkey (Table 3) and all guidelines limits in Table 4.

Zn and Cu are the essential trace elements for both animals and humans. Zn is an essential component of a large number of enzymes

Table 1. Analytical characteristics of the contrAA 300 atomic absorption spectrophotometer for the determination of metal ions

Analytical parameters	Pb	Cd	Zn	Cu	Ni	Cr	Mn	Fe	Co	Mg	Sr	Bi	Na	K	Li	Ca
Linear range ($\mu g\ L^{-1}$)	10-5000	10-5000	10-5000	10-5000	10-5000	10-5000	10-5000	10-5000	10-5000	10-5000	10-5000	10-5000	10-5000	10-5000	10-5000	10-5000
Slope (Abs / $\mu g\ L^{-1}$)	0.043	0.217	0.321	0.160	0.070	0.035	0.113	0.051	0.083	0.420	0.002	0.022	0.487	0.326	0.196	0.001
Correlation coefficient (R^2)	0.996	0.973	0.955	0.998	0.999	0.998	0.984	0.990	0.999	0.936	0.988	0.999	0.954	0.995	0.988	0.995
Detection limit ($\mu g\ L^{-1}$)	0.285	0.385	0.501	0.227	0.150	0.787	0.584	0.454	0.166	0.596	0.494	0.170	0.994	0.340	1.765	1.141
Relative standart deviation (R.S.D %) (n = 3)	0.10	0.02	0.01	0.03	0.06	0.13	0.04	0.09	0.05	0.01	1.90	0.20	0.01	0.01	0.02	1.03
Wave lenght (nm)	217.000	228.802	213.857	324.754	232.003	357.869	279.482	248.327	240.725	285.213	460.733	223.061	588.995	766.491	670.785	422.673

Table 2. Metal concentrations in muscle of fish species in Beyşehir Lake [a]

Species	n	Pb	Cd	Zn	Cu	Ni	Cr	Mn	Fe	Co	Mg	Sr	Bi	Na	K	Li	Ca
Phoxinellus anatolicus	10	2.83 ±1.21[b] 0.79-5.39[c]	3.99 ±2.76 <BDL*-10.82	19.33 ±4.30 13.68-28.43	1.62 ±1.06 0.91-4.53	1.83 ±0.87 1.15-4.23	14.93 ±7.04 10.58-34.16	9.63 ±1.55 8.08-13.31	6.46 ±5.31 2.12-19.02	3.43 ±1.56 2.57-7.64	199.21 ±70.72 135.05-389.17	12.96 ±6.26 8.08-13.31	2.70 ±2.03 <BDL-6.85	340.37 ±161.00 297.53-680.07	318.80 ±104.22 261.66-597.15	27.36 ±12.58 20.96-61.72	379.33 ±215.97 148.00-759.56
Alburnus akili	3	5.25 ±2.32 3.86-7.93	4.00 ±1.64 2.26-5.52	23.75 ±5.23 18.43-28.89	1.10 ±0.36 0.86-1.51	4.01 ±1.02 3.02-5.05	24.45 ±4.96 19.49-29.41	17.53 ±3.27 14.26-20.80	6.00 ±1.62 <BDL-7.14	5.90 ±1.79 3.91-7.37	283.06 ±78.81 196.90-351.51	27.40 ±5.44 21.12-30.71	4.09 ±1.68 2.41-5.76	395.65 ±78.17 320.54-476.55	514.09 ±79.91 430.70-590.00	49.38 ±13.53 34.61-61.16	497.35 ±337.58 159.77-834.93
Gobio gobio microlepidotus	3	3.55 ±1.52 2.38-5.26	2.35 ±0.89 1.50-3.27	11.17 ±1.22 10.05-12.47	1.74 ±0.59 1.30-2.41	3.49 ±2.07 1.72-5.76	9.85 ±1.66 8.12-11.43	8.54 ±0.50 8.02-9.01	9.79 ±0.44 <BDL-10.10	2.76 ±0.24 2.55-3.02	213.46 ±84.51 136.45-303.86	21.77 ±10.03 12.74-32.56	6.05 ±1.46 <BDL-7.07	423.56 ±106.95 330.36-540.33	423.70 ±170.83 265.96-605.14	49.32 ±28.02 20.96-76.99	537.93 ±331.85 226.68-887.11
Leuciscus lepidus	3	2.01 ±0.57 1.91-2.63	2.17 ±0.18 2.16-2.35	10.78 ±5.02 6.20-16.14	1.93 ±.60 1.30-2.50	1.60 ±0.10 1.50-1.66	11.58 ±1.02 10.50-12.54	7.96 ±0.82 7.47-8.90	2.77 ±0.11 <BDL-3.66	2.67 ±0.15 2.50-2.77	151.43 ±8.62 143.61-160.67	13.54 ±0.80 12.77-14.36	1.66 ±1.25 0.50-2.99	251.54 ±42.83 209.24-294.88	263.14 ±12.03 250.50-274.45	21.34 ±0.81 20.50-22.11	537.93 ±378.68 179.63-934.13
Carassius gibelio	4	2.51 ±0.30 2.21-2.86	2.29 ±0.06 2.20-2.34	13.98 ±2.70 10.31-16.82	2.35 ±0.64 1.56-2.89	1.71 ±0.29 1.50-2.14	12.40 ±0.41 11.98-12.85	9.34 ±0.36 8.83-9.63	2.61 ±2.43 0.75-6.18	2.87 ±0.16 2.66-3.04	148.42 ±14.74 127.77-162.45	15.30 ±0.72 14.69-16.15	3.47 ±2.92 <BDL-6.83	221.07 ±33.32 209.42-261.30	275.59 ±10.27 260.54-283.10	22.36 ±0.86 21.19-23.07	218.58 ±87.31 169.78-349.34
Cyprinus carpio	3	2.84 ±1.17 1.68-4.02	2.17 ±0.13 2.06-2.32	12.49 ±3.31 9.32-15.92	1.62 ±0.92 1.09-2.68	1.43 ±0.85 0.50-2.17	12.11 ±1.31 10.60-13.02	9.35 ±0.53 8.76-9.76	3.03 ±0.48 <BDL-3.37	2.85 ±0.33 2.50-3.14	161.06 ±18.49 140.61-176.58	10.21 ±1.27 8.74-10.97	1.72 ±0.87 0.76-2.47	261.07 ±28.61 230.94-287.86	281.91 ±15.30 264.30-291.96	22.41 ±1.40 20.83-23.49	375.56 ±63.06 312.50-438.62
Scardinius erythrophthalmus	4	1.94 ±1.14 0.52-3.13	2.31 ±0.30 <BDL-2.60	20.17 ±2.99 17.62-24.37	2.68 ±1.87 1.21-5.40	0.91 ±0.77 0.25-2.01	11.68 ±0.92 10.68-12.76	8.51 ±0.52 8.38-9.24	7.04 ±0.42 <BDL-7.34	2.79 ±0.17 2.62-2.90	203.73 ±45.31 138.16-240.39	11.11 ±3.13 7.99-14.55	5.60 ±2.34 <BDL-7.89	370.26 ±48.19 334.39-440.93	265.48 ±14.81 248.31-282.64	21.41 ±1.13 20.38-22.94	538.83 ±206.08 264.83-726.01
Tinca tinca	4	3.34 ±1.28 2.45-5.23	2.74 ±1.37 1.45-4.60	14.05 ±6.67 6.07-20.31	1.69 ±0.74 1.10-2.73	1.99 ±0.15 1.83-2.18	13.05 ±3.06 11.05-17.61	9.89 ±2.35 8.62-13.41	13.98 ±10.09 1.13-25.77	3.00 ±0.86 2.42-4.26	161.84 ±16.89 138.71-177.58	12.50 ±3.61 10.19-17.89	4.02 ±2.70 2.03-7.95	292.80 ±93.96 184.71-372.24	270.83 ±15.06 259.48-292.67	23.62 ±5.43 20.34-31.74	323.68 ±277.69 83.36-697.27
Sander lucioperca	3	1.62 ±0.62 1.03-2.32	2.17 ±0.18 2.00-2.36	8.20 ±1.37 7.00-9.70	1.38 ±0.06 1.32-1.43	1.08 ±0.12 1.01-1.22	12.21 ±0.32 12.01-12.58	9.11 ±0.10 9.00-9.20	2.03 ±0.56 1.49-2.60	2.61 ±0.19 2.50-2.82	142.76 ±3.36 140.00-146.50	13.28 ±0.71 12.75-14.09	1.68 ±0.20 1.50-1.89	312.52 ±58.55 275.23-380.00	265.49 ±4.84 260.91-270.56	21.20 ±1.05 20.00-21.94	66.33 ±14.57 52.48-81.52

[a] Values given as mg kg^{-1} dry weight; [b] mean ± standard deviation, results are means of three replicates; [c] minimum-maximum values
* BDL, Below Detection Limit.

Table 3. Metal concentrations in the muscle of fish species belong to the same genus in Beyşehir Lake and other near study areas from Turkey

Metals	Fish species	Locality	Mean or minimum-maximum levels of metal concentrations (mg kg^{-1})	References
Pb	*Phoxinellus anatolicus*	Suğla Lake	BDL[a]	Çağlar (2010)
	Alburnus alburnus	Enne Dame Lake	BDL	Uysal *et al.* (2009)
	Leuciscus cephalus	Beyşehir Lake	0.35 (dw[b])	Altındağ and Yiğit (2005)
	Leuciscus cephalus	Beyşehir Lake	BDL	Tekin-Özan and Kir (2006)
	Leuciscus cephalus	Dipsiz Stream	0.23 (ww[c])	Demirak *et al.* (2006)
	Leuciscus cephalus	Kızılırmak River	250	Akbulut and Akbulut (2010)
	Leuciscus cephalus	Sarıçay (1) and Sarıçay(2)	0.07 and 0.30 (ww)	Yılmaz *et al.* (2007)
	Leuciscus cephalus	Enne Dame Lake	BDL	Uysal *et al.* (2009)
	Carassius carassius	Yarseli Dam Lake	1.50 (ww)	Aygun *et al.* (2004)
	Carassius carassius	Enne Dame Lake	BDL	Uysal *et al.* (2009)
	Cyprinus carpio	Beyşehir Lake	0.30	Altındağ and Yiğit (2005)
	Cyprinus carpio	Sır Dam Lake	0.13 (ww)	Erdoğrul and Erbilir (2007)
	Cyprinus carpio	Suğla Lake	BDL	Çağlar (2010)
	Tinca tinca	Beyşehir Lake	0.09 (ww)	Aktumsek and Gezgin (2011)
	Tinca tinca	Beyşehir Lake	0.42	Altındağ and Yiğit (2005)
	Sander lucioperca	Beyşehir Lake	0.68 (dw)	Altındağ and Yiğit (2005)
	Sander lucioperca	Beyşehir Lake	BDL	Tekin-Özan and Kir (2006)
Cd	*Alburnus alburnus*	Enne Dame Lake	0.05 (ww)	Uysal *et al.* (2009)
	Leuciscus cephalus	Beyşehir Lake	0.58 (dw)	Altındağ and Yiğit (2005)
	Leuciscus cephalus	Dipsiz Stream	0.01 (ww)	Demirak *et al.* (2006)
	Leuciscus cephalus	Menzelet Dam Lake	0.32 (ww)	Erdoğrul and Ateş (2006)
	Leuciscus cephalus	Sarıçay (1) and Sarıçay(2)	0.02 and 0.01 (ww)	Yılmaz *et al.* (2007)
	Leuciscus cephalus	Enne Dame Lake	0.07 (ww)	Uysal *et al.* (2009)
	Carassius carassius	Enne Dame Lake	0.16 (ww)	Uysal *et al.* (2009)
	Cyprinus carpio	Menzelet and Sır Dam Lake	0.27 and 2.87 (ww)	Erdoğrul and Ateş (2006)
	Cyprinus carpio	Beyşehir Lake	0.54 (dw)	Altındağ and Yiğit (2005)
	Tinca tinca	Beyşehir Lake	0.01 (ww)	Aktumsek and Gezgin (2011)
	Tinca tinca	Beyşehir Lake	0.60 (dw)	Altındağ and Yiğit (2005)
	Sander lucioperca	Beyşehir Lake	0.64 (dw)	Altındağ and Yiğit (2005)
Zn	*Phoxinellus anatolicus*	Suğla Lake	7.77 and 6.93 (sum[d] and win[e], ww)	Çağlar (2010)
	Alburnus alburnus	Enne Dame Lake	21.10 (ww)	Uysal *et al.* (2009)
	Leuciscus cephalus	Beyşehir Lake	8.49 (ww)	Tekin-Özan and Kir (2006)
	Leuciscus cephalus	Dipsiz Stream	11.06 (ww)	Demirak *et al.* (2006)
	Leuciscus cephalus	Kızılırmak River	42.72 (dw)	Akbulut and Akbulut (2010)
	Leuciscus cephalus	Sarıçay (1) and Sarıçay (2)	6.35 and 9.66 (ww)	Yılmaz *et al.* (2007)
	Leuciscus cephalus	Enne Dame Lake	16.31 (ww)	Uysal *et al.* (2009)
	Carassius carassius	Kovada Lake	13.82 (ww)	Tekin-Özan and Kir (2007)
	Carassius carassius	Enne Dame Lake	30.06 (ww)	Uysal *et al.* (2009)
	Cyprinus carpio	Beyşehir Lake	7.49 and 11.32 (2003 and 2004, dw)	Tekin-Özan and Kir (2008)
	Cyprinus carpio	Suğla Lake	11.58 and 10.87 (sum and win, ww)	Çağlar (2010)
	Tinca tinca	Beyşehir Lake	0.65 (ww)	Aktumsek and Gezgin (2011)
	Tinca tinca	Beyşehir Lake	2.97 and 6.93 (spr[f] 2003 and 2004, dw)	Tekin-Özan (2008)
	Sander lucioperca	Beyşehir Lake	6.85 (ww)	Tekin-Özan and Kir (2006)
	Sander lucioperca	Kovada Lake	8.14 (ww)	Tekin-Özan and Kir (2007)
Cu	*Phoxinellus anatolicus*	Suğla Lake	0.51 and 0.83 (sum and win, ww)	Çağlar (2010)
	Alburnus alburnus	Enne Dame Lake	BDL	Uysal *et al.* (2009)
	Leuciscus cephalus	Beyşehir Lake	BDL	Tekin-Özan and Kir (2006)
	Leuciscus cephalus	Dipsiz Stream	0.79 (ww)	Demirak *et al.* (2006)
	Leuciscus cephalus	Menzelet Dam Lake	3.17 (ww)	Erdoğrul and Ateş (2006)
	Leuciscus cephalus	Sarıçay (1) and Sarıçay (2)	0.19 and 0.57 (ww)	Yılmaz *et al.* (2007)
	Leuciscus cephalus	Enne Dame Lake	0.87 (ww)	Uysal *et al.* (2009)
	Carassius carassius	Kovada Lake	BDL	Tekin-Özan and Kir (2007)
	Carassius carassius	Enne Dame Lake	1.51 (ww)	Uysal *et al.* (2009)
	Carassius carassius	Yarseli Dam Lake	0.90-7.80 (ww)	Aygun *et al.* (2004)
	Cyprinus carpio	Beyşehir Lake	BDL	Tekin-Özan and Kir (2008)
	Cyprinus carpio	Menzelet and Sır Dam Lake	0.94 and 0.02 (ww)	Erdoğrul and Ateş (2006)
	Cyprinus carpio	Suğla Lake	0.31 and 0.36 (sum and win, ww)	Çağlar (2010)
	Tinca tinca	Beyşehir Lake	0.21 (ww)	Aktumsek and Gezgin (2011)
	Tinca tinca	Beyşehir Lake	BDL	Tekin-Özan (2008)
	Sander lucioperca	Beyşehir Lake	BDL	Tekin-Özan and Kir (2006)
	Sander lucioperca	Kovada Lake	BDL	Tekin-Özan and Kir (2007)
Ni	*Phoxinellus anatolicus*	Suğla Lake	BDL	Çağlar (2010)
	Alburnus alburnus	Enne Dame Lake	BDL	Uysal *et al.* (2009)
	Leuciscus cephalus	Enne Dame Lake	1.11 (ww)	Uysal *et al.* (2009)

Table 3. (continued)

Metals	Fish species	Locality	Mean or minimum-maximum levels of metal concentrations (mg kg^{-1})	References
Ni	*Carassius carassius*	Enne Dame Lake	BDL	Uysal *et al.* (2009)
	Cyprinus carpio	Sır Dam Lake	0.47 (ww)	Erdoğrul and Erbilir (2007)
	Cyprinus carpio	Suğla Lake	BDL	Çağlar (2010)
	Tinca tinca	Beyşehir Lake	0.09 (ww)	Aktumsek and Gezgin (2011)
Cr	*Phoxinellus anatolicus*	Suğla Lake	BDL	Çağlar (2010)
	Alburnus alburnus	Enne Dame Lake	BDL	Uysal *et al.* (2009)
	Leuciscus cephalus	Beyşehir Lake	0.25 (dw)	Altındağ and Yiğit (2005)
	Leuciscus cephalus	Beyşehir Lake	BDL	Tekin-Özan and Kir (2006)
	Leuciscus cephalus	Dipsiz Stream	2.54 (ww)	Demirak *et al.* (2006)
	Leuciscus cephalus	Kızılırmak River	38.11	Akbulut and Akbulut (2010)
	Leuciscus cephalus	Enne Dame Lake	BDL	Uysal *et al.* (2009)
	Carassius carassius	Enne Dame Lake	0.39 (ww)	Uysal *et al.* (2009)
	Cyprinus carpio	Beyşehir Lake	0.31	Altındağ and Yiğit (2005)
	Cyprinus carpio	Suğla Lake	0.03 and 0.04 (sum and win, ww)	Çağlar (2010)
	Tinca tinca	Beyşehir Lake	0.02 (ww)	Aktumsek and Gezgin (2011)
	Tinca tinca	Beyşehir Lake	2.35	Altındağ and Yiğit (2005)
	Sander lucioperca	Beyşehir Lake	0.26	Altındağ and Yiğit (2005)
	Sander lucioperca	Beyşehir Lake	BDL	Tekin-Özan and Kir (2006)
Mn	*Phoxinellus anatolicus*	Suğla Lake	0.18 and 0.14 (sum and win, ww)	Çağlar (2010)
	Alburnus alburnus	Enne Dame Lake	BDL	Uysal *et al.* (2009)
	Leuciscus cephalus	Beyşehir Lake	BDL	Tekin-Özan and Kir (2006)
	Leuciscus cephalus	Enne Dame Lake	0.38 (ww)	Uysal *et al.* (2009)
	Leuciscus cephalus	Sarıçay (1) and Sarıçay(2)	0.11 and 1.20 (ww)	Yılmaz *et al.* (2007)
	Carassius carassius	Kovada Lake	BDL	Tekin-Özan and Kir (2007)
	Carassius carassius	Enne Dame Lake	0.48 (ww)	Uysal *et al.* (2009)
	Cyprinus carpio	Beyşehir Lake	BDL	Tekin-Özan and Kir (2008)
	Cyprinus carpio	Sır Dam Lake	0.30 (ww)	Erdoğrul and Erbilir (2007)
	Cyprinus carpio	Suğla Lake	0.22 and 0.17 (sum and win, ww)	Çağlar (2010)
	Tinca tinca	Beyşehir Lake	0.02 (ww)	Aktumsek and Gezgin (2011)
	Tinca tinca	Beyşehir Lake	BDL	Tekin-Özan (2008)
	Sander lucioperca	Beyşehir Lake	BDL	Tekin-Özan and Kir (2006)
	Sander lucioperca	Kovada Lake	BDL	Tekin-Özan and Kir (2007)
Fe	*Phoxinellus anatolicus*	Suğla Lake	4.04 and 3.28 (sum and win, ww)	Çağlar (2010)
	Alburnus alburnus	Enne Dame Lake	24.88 (ww)	Uysal *et al.* (2009)
	Leuciscus cephalus	Beyşehir Lake	4.71 (ww)	Tekin-Özan and Kir (2006)
	Leuciscus cephalus	Sarıçay (1) and Sarıçay(2)	4.47 and 4.24 (ww)	Yılmaz *et al.* (2007)
	Leuciscus cephalus	Enne Dame Lake	11.32 (ww)	Uysal *et al.* (2009)
	Carassius carassius	Kovada Lake	11.58 (ww)	Tekin-Özan and Kir (2007)
	Carassius carassius	Enne Dame Lake	18.44 (ww)	Uysal *et al.* (2009)
	Cyprinus carpio	Beyşehir Lake	1.46 and 2.97 (2003 and 2004, dw)	Tekin-Özan and Kir (2008)
	Cyprinus carpio	Sır Dam Lake	0.85 (ww)	Erdoğrul and Erbilir (2007)
	Cyprinus carpio	Suğla Lake	9.43 and 6.74 (sum and win, ww)	Çağlar (2010)
	Tinca tinca	Beyşehir Lake	0.04 (ww)	Aktumsek and Gezgin (2011)
	Tinca tinca	Beyşehir Lake	7.35 and 8.51 (spr 2003 and 2004, dw)	Tekin-Özan (2008)
	Sander lucioperca	Beyşehir Lake	6.12 (ww)	Tekin-Özan and Kir (2006)
	Sander lucioperca	Kovada Lake	21.14 (ww)	Tekin-Özan and Kir (2007)
Co	*Alburnus alburnus*	Enne Dame Lake	BDL	Uysal *et al.* (2009)
	Leuciscus cephalus	Enne Dame Lake	BDL	Uysal *et al.* (2009)
	Leuciscus cephalus	Kızılırmak River	0.62 (dw)	Akbulut and Akbulut (2010)
	Leuciscus cephalus	Sarıçay (1) and Sarıçay(2)	BDL and 0.03 (ww)	Yılmaz *et al.* (2007)
	Cyprinus carpio	Sır Dam Lake	0.01 (ww)	Erdoğrul and Erbilir (2007)
	Carassius carassius	Enne Dame Lake	BDL	Uysal *et al.* (2009)
Mg	*Alburnus alburnus*	Enne Dame Lake	243.93 (ww)	Uysal *et al.* (2009)
	Leuciscus cephalus	Enne Dame Lake	292.75 (ww)	Uysal *et al.* (2009)
	Carassius carassius	Enne Dame Lake	324.10 (ww)	Uysal *et al.* (2009)

[a] BDL, Below Detection Limit.
[b] dw, dry weight.
[c] ww, wet weight.
[d] sum, summer.
[e] win, winter.
[f] spr, spring.

Table 4. Tolerance levels of metal concentrations in fish according to guidelines [a]

Guidelines	Pb	Cd	Zn	Cu	Ni	Cr	Mn	Fe
FAO/WHO (1989)	0.50	0.50	40	30	-	-	-	-
Range of International Standards (Yamazaki *et al*., 1996)	0.50-10	0.0-2	40-100	10-100	-	-	-	-
TFC (2002)	0.2	0.05	50	20	-	-	-	-
IAEA-407 (Wyse *et al*., 2003)	0.12	0.19	67.10	3.28	0.60	0.73	3.52	146
EC (2006)	0.30	0.05	-	-	-	-	-	-
Chine (Cheung *et al*., 2008)	0.50	-	-	50	-	2<	-	-

[a] values given as mg kg^{-1}

participating in the synthesis and degradation of carbohydrates, lipids, proteins, and nucleic acids as well as in the metabolism of other micronutrients (FAO/WHO, 1998). Zn also showed a protective effect against the Cd and Pb toxicity (Malik *et al.*, 2010). Zn concentration ranged from 8.20 to 23.75 mg kg^{-1} in this study. These values match with results of Tekin-Özan and Kir (2006) and Tekin-Özan (2008) who have determined Zn content for *S. lucioperca*, *C. carpio* and *L. cephalus* in Beyşehir Lake. Zn concentrations in all fish specimens of this study were lower than all guidelines limits in Table 4, but were inacceptable level with regard to diet.

Cu is an essential part of several enzymes and is necessary for the synthesis of haemoglobin, but higher intakes of Cu can cause adverse health problems (Malik *et al*., 2010). Average Cu content varied from 1.10 to 2.68 mg kg^{-1} in present study. In previous studies in Beyşehir Lake, Cu was not determined in fish muscle (Table 3) except for Aktumsek and Gezgin (2011) who had determined 0.21 mg kg^{-1} Cu in *T. tinca*. However, Aygun *et al.* (2004) stated that maximum Cu concentration for *Carassius carassius* in Yarseli Dam Lake from Turkey was 7.80 mg kg^{-1}. Cu content in all samples of present study were lower than all guidelines limits in Table 4.

Ni is essential for normal growth and reproduction in animals and human beings, but shows carcinogenic effect when consumed in high amount (Malik *et al*., 2010). Ni content of only *T. tinca* from Beyşehir Lake has been reported by Aktümsek and Sezgin (2011) as 0.09 mg kg^{-1}. In this study, the lowest and highest Ni concentrations were found to be 0.91-4.01 mg kg^{-1} that exceeded findings of other studies from Lakes in Turkey (Table 3) and IAEA-407 (Wyse *et al*., 2003) guideline limit (Table 4). According to these results, Ni concentration of fish muscle in Beyşehir Lake may be hazardous for human health.

Cr is essential element and an important enzyme cofactor, which may become toxic when accumulating in liver and spleen (Wagner and Boman, 2003). Although slightly higher accumulation of Cr levels in hepatic tissue compared to muscle tissue had been reported by some researchers, Wagner and Boman (2003) reported that the mean Cr concentration in the freshwater fish liver tissue were somewhat lower than in the muscle tissue. The mean range of Cr was 9.85-24.45 mg kg^{-1} for analyzed fish samples in this study. These concentrations were higher than results of other studies from Lakes in Turkey (Table 3) and limits of IAEA-407 (Wyse *et al*., 2003) and Chine (Cheung *et al*., 2008) guidelines (Table 4). At the same time, Demirak *et al.* (2006) reported 38.11 mg kg^{-1} Cr for *L. cephalus* in Kızılırmak River from Turkey.

Studies have shown that fish are able to accumulate and retain heavy metals from their environment and it has been shown that accumulation of metals in tissues of fish is dependent upon exposure concentration and duration, as well as other factors such as salinity, temperature, hardness and metabolism of the animals (Heath, 1987). In this study, Pb, Cd, Ni and Cr values were considerably higher than those reported by former studies in Beyşehir Lake. This situation may point out a possible increase of pollution in Beyşehir Lake.

Mn belongs to the essential elements has considerably higher concentrations in liver than in muscle tissue due to its function as cofactor for the activation of a number of enzymes (Wagner and Boman, 2003). Mn values were found in a range of 7.96-17.53 mg kg^{-1} in fish muscle in this study. Except in the research of Aktümsek and Gezgin (2011), Mn has not been detected in fish of Beyşehir Lake (Table 3). All of these values were very higher than those of other studies (Table 3) and IAEA-407 (Wyse *et al*., 2003) guideline limit (Table 4).

Fe has several vital functions in the body. It serves as a carrier of oxygen to the tissues from the lungs by red blood cell haemoglobin, as a transport medium for electrons within cells, and as an integrated part of important enzyme systems in various tissues (FAO/WHO, 1998). Fe values in the samples of this study ranged from 2.03 to 13.98 mg kg^{-1}. It is similar with results of other studies except Aktümsek and Gezgin (2011) (Table 3). Fe content in all samples was rather low compared to IAEA-407 (Wyse *et al*., 2003) guideline limit.

Co is classified as an essential element, which is vital to many enzymatic systems and to the formation of noble molecules, such as vitamin B_{12}. Co concentrations in fish are low, probably due to its high affinity to organic particles in solution (Andreji *et al*., 2006). Co concentration ranged from 2.61 to

5.90 mg kg^{-1} in muscle of fish in this study. The data about Co accumulation in fish samples from Beyşehir Lake have not been reported. However, 0.01 mg kg^{-1} cobalt content in muscle of *C. carpio* was determined in Sır Dam Lake from Turkey by Erdoğrul and Erbilir (2007). Uysal *et al.* (2009) did not determine Co in muscle of fish (*C. carassius*, *L. cephalus* and *A. alburnus*) from Enne Dam Lake, Turkey. Co content in *L. cephalus* was found as 0.62 mg kg^{-1} and 0.03 mg kg^{-1} in Kızılırmak River and Sarıçay-II from Turkey, respectively (Akbulut and Akbulut, 2010; Yılmaz *et al*., 2007).

Mg functions as a cofactor of many enzymes involved in energy metabolism, protein synthesis, RNA and DNA synthesis, and maintenance of the electrical potential of nervous tissues and cell membranes (FAO/WHO, 1998). Average Mg content in muscle of fish samples varied from 142.76 to 283.06 mg kg^{-1} in this study. Similar to these values, Mg content in muscle of *A. alburnus*, *L. cephalus* and *C. carassius* was determined as 243.93, 292.75 and 324.10 mg kg^{-1} in Enne Lake from Turkey by Uysal *et al.* (2009), respectively. The tolerable Co and Mg limits for fish have not been reported by national and international guidelines.

The Sr, Bi, Na, K, Li and Ca concentrations in fish muscle examined in this study are presented in Table 2. Of them, Na, K and Ca are especially important for metabolism. The data about concentration of these minerals have not been recorded in fish species of Beyşehir and other lakes except for literatures on different fish species of Atatürk Dam Lake from Turkey (Çelik *et al*., 2008; Olgunoglu *et al.*, 2011).

It should be emphasized that Pb and Cd are accumulated in human tissues and hence they are harmful to human health. The Joint FAO/WHO Expert Committee on Food Additives has set limit for heavy metal intake based on body weight (bw). For an average adult (70 kg bw), Provisional Tolerable Weekly Intake (PTWI) for Pb and Cd are 0.025 and 0.007 mg kg^{-1} bw, respectively (FAO/WHO, 2011). Metal concentrations in edible parts of the fish muscle are very important. Average weekly fish consumption of local people is 0.3 kg/person. The main constituent of fish flesh is water, which usually accounts for about 80 per cent of the weight of a fresh white fish fillet. For this reason, the dry weight of 0.3 kg fresh fish flesh is calculated as 0.06 kg. Because Pb and Cd contents of all fish flesh from Beyşehir Lake are below PTWI limits (Table 5), consumption of these species is not objectionable in terms of these metal levels.

For an average adult (70 kg bw), the Joint FAO/WHO Expert Committee on Food Additives established a Provisional Daily Dietary Requirement/Maximum Tolerable Daily Intake (PMTDI) for Zn, Cu and Fe as 0.3-1, 0.05-0.5 and 0.8 mg kg^{-1} bw, respectively (FAO/WHO, 2011). These PMTDI values were presented and evaluated as PTWI in Table 5. Because Zn, Cu and Fe contents of all fish flesh from Beyşehir Lake are far below PTWI limits (Table 5), consumption of these species is not objectionable in terms of these metal levels. Based on the results, it was concluded that weekly consumption of 300 g/person fillet of examined nine fish species from Beyşehir Lake seems to be appropriate for human health.

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Table 5. Weekly dietary intake of some metals by eating 0.3 kg/person (which was equivalent to 0.06 kg/person dw) fresh fish fillet from Beyşehir Lake

Species	Weekly intake concentrations (mg)				
	Pb	Cd	Zn	Cu	Fe
Phoxinellus anatolicus	0.17	0.24	1.15	0.10	0.39
Alburnus akili	0.32	0.24	1.43	0.07	0.36
Gobio gobio microlepidotus	0.21	0.14	0.67	0.10	0.59
Leuciscus lepidus	0.12	0.13	0.65	0.12	0.17
Carassius gibelio	0.15	0.14	0.84	0.14	0.16
Cyprinus carpio	0.17	0.13	0.75	0.10	0.18
Scardinius erythrophthalmus	0.12	0.14	0.12	0.16	0.42
Tinca tinca	0.20	0.16	0.84	0.10	0.84
Sander lucioperca	0.10	0.13	0.49	0.08	0.12
PTWI [a] (mg kg^{-1} bw/week) (FAO/WHO, 2011)	0.025	0.007	0.21-7	0.35-3.5	5.6
PTWI (mg/week) for a 70 kg adult	1.75	0.49	14.70-490	24.50-245	392
Remark	Normal for human consumption				

[a] PTWI, Provisional Tolerable Weekly Intake.

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