

Assessment of heavy metal concentrations in the food web of lake Beyşehir, Turkey

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Abstract

The accumulation of heavy metals (Cd, Pb, Hg and Cr) was measured by atomic absorption spectrophotometry in water, sediment, plankton and fish samples collected from Lake Beyşehir, which is important bird nesting and visiting areas, and irrigation and drinking water sources. In Lake Beyşehir, the accumulation orders of heavy metals were $Cd > Pb > Cr > Hg$ in water, $Pb > Cd > Cr > Hg$ in sediment, $Pb > Cd > Cr > Hg$ in plankton, and $Cd > Pb > Cr > Hg$ in the muscles and gills of chub, carp, tench, except for the muscle of pikeperch, in which it was $Pb > Cd > Cr > Hg$ ($P < 0.05$). In addition to this, accumulation orders of heavy metals in the food web was also found to be water > plankton > sediment > fish tissues, except for Cr. According to international criterias and Turkish regulations, heavy metal concentrations especially Cd and Pb in Lake Beyşehir were markedly above the permissible levels for drinking water. © 2005 Published by Elsevier Ltd.

Keywords: Cadmium; Mercury; Lead; Chromium; Food web; Lake

1. Introduction

Hundreds of pollutants are discharged into the environment every day. Of these, heavy metals are regarded as serious pollutants of the aquatic environment because of their environmental persistence and tendency to be concentrated in aquatic organisms (Harte et al., 1991; Schüürmann and Markert, 1998). Most heavy metals released into the environment find their way into the aquatic phase as a result of direct input, atmospheric deposition and erosion due to rain (Veena et al., 1997). Therefore, aquatic animals may be exposed to elevated levels of heavy metals (Kalay and Canlı, 2000). Heavy

metals may affect organisms directly by accumulating in the body or indirectly by transferring to the next trophic level of the food chain. Contamination of aquatic ecosystems by heavy metals can be confirmed in water, sediment and organisms (Förstner and Wittmann, 1983). The high accumulation of heavy metals in these components can result in serious ecological changes. One of the most serious results of their persistence is the biological amplification of metal in the food chain (Ünlü and Gümgüm, 1993). Metals transferred through aquatic food webs to fish, humans and other piscivorous animals are of environmental and human health concern (Chen et al., 2000). Cadmium (Cd), mercury (Hg) and lead (Pb) are non-essential heavy metals; their role in cells is not known. The lake Beyşehir which is located in south-western Turkey is the conservation area, and has importance of irrigation and drinking purposes. Most of surface water in western Turkey is getting dirty

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due to industrialization and urbanization. In the present study, it was aimed to evaluate the pollution level of this aquatic ecosystem via determining the accumulation of Pb, Cd, Cr and Hg in the water, sediment, plankton and fish samples of lake Beyşehir.

2. Materials and methods

2.1. Study area

Beyşehir lake is located 75 km from the city of Konya (37° 45' North–31° 30' East). The lake is approximately 45 km long, 24 km wide and 10 m deep, covering an area of 1125 m². It is tectonic/karstic in origin and is one of the largest freshwater lake in Turkey (Fig. 1). The water of the lake is used for irrigation and drinking purposes. In addition to these, four fish species (*Leuciscus cephalus*, *Cyprinus carpio*, *Tinca tinca*, *Lucioperca lucioperca*) present in this lake. Of them, *L. lucioperca* has commercial importance. It falls in class “A” and is an important visiting site for several bird species (Yarar and Magnin, 1997).

Water, sediment, plankton and fish samples were collected from three different stations of Beyşehir lake (Fig. 1) during the spring of 2001. Water samples were obtained by means of a Nansen Sampler 0.5 m below the water surface in one-litre bottles precleaned with polyethylene and acidified by adding 0.5% concentrated nitric acid. Plankton samples were collected with the aid of a Hydrobios–Kiel plankton net (25 cm diameter and 55 µm mesh size) by horizontal and vertical hauls at each station. The upper 10 cm of sediments were collected with an Ekman sampler. The each fish species

($n = 16$) was collected using a standard skimmer at selected stations and placed in plastic bags and brought to the laboratory. All samples were frozen at -18°C (Bernhard, 1976) and analysed by a Hitachi Z 8200 polarized Zeeman atomic absorption spectrophotometer at the Ankara University Research Centre (Eaton et al., 1995). In addition, some physico-chemical parameters of the lake were determined during the sampling period. Among these, dissolved oxygen and temperature were measured by a YSI 51 B type oxygen-meter, pH by a WTW 340-A/SET-1 model pH-meter, electrical conductivity by a WTW LF 92 type conductometer and light permeability by a secchi disk 20 cm in diameter. Biometric evaluations were performed by using Chi square and ANOVA tests (Microsoft Excel).

3. Results

The physico-chemical parameters determined in Beyşehir lake are given in Table 1. According to these parameters, the temperature varied between 20 and 25.5 °C; the pH between 7.8 and 8.2; the EC between 300 and 400 µs/cm; the dissolved oxygen between 8.0 and 11.8 mg/l and secchi depth between 1.38 and 1.75 m during the study period in Lake Beyşehir.

The concentrations of heavy metals in water, sediment, plankton and fish samples collected from Lake Beyşehir are given in Tables 2 and 3. In water samples,

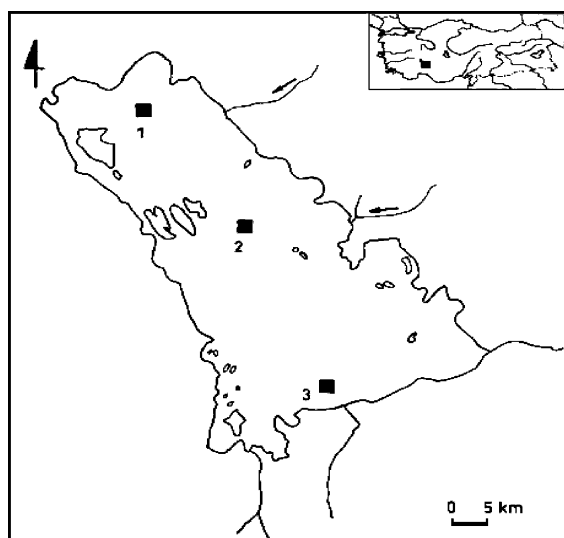


Fig. 1. Map of Lake Beyşehir and the sampling stations.

Table 1
Some physico-chemical parameters of Lake Beyşehir

Parameters	Mean (Min–Max)
Temperature (°C)	23 (20–25.5)
pH	8.0 (7.8–8.2)
EC (µs/cm)	351.6 (300–400)
DO (mg/l)	9.2 (8.0–11.8)
Secchi depth (m)	1.56 (1.38–1.75)

Table 2
Mean, minimum and maximum heavy metal concentrations in water, plankton, sediment in Lake Beyşehir

Cd mean (Min–Max)	Pb mean (Min–Max)	Hg mean (Min–Max)	Cr mean (Min–Max)
<i>Water (µg/l)</i>			
110 (101–117)	86 (65–96)	2.07 (1.95–2.19)	28 (27–28)
<i>Sediment (µg/g)</i>			
13.05 (12.10–14.25)	32.65 (31.10–33.45)	0.24 (0.22–0.25)	10.63 (9.93–11.12)
<i>Plankton (µg/l)</i>			
53.10 (48.56–56.97)	55.46 (49.81–64.54)	2.15 (1.92–2.43)	49.96 (48.01–51.42)

Table 3

Mean, minimum and maximum heavy metal concentrations ($\mu\text{g/g}$) of fish species in Lake Beyşehir

Heavy metals	Fishes		<i>L. cephalus</i>	<i>C. carpio</i>	<i>L. lucioperca</i>	<i>T. tinca</i>
Cd	Muscle	Mean	0.578	0.543	0.643	0.598
		Min–Max	0.570–0.585	0.500–0.585	0.620–0.665	0.565–0.630
	Gill	Mean	0.590	0.658	0.613	0.563
		Min–Max	0.540–0.640	0.575–0.740	0.590–0.635	0.530–0.595
Pb	Muscle	Mean	0.348	0.303	0.678	0.415
		Min–Max	0.255–0.440	0.255–0.350	0.675–0.680	0.170–0.660
	Gill	Mean	0.358	0.420	0.380	0.238
		Min–Max	0.110–0.605	0.170–0.670	0.300–0.460	0.175–0.300
Hg	Muscle	Mean	0.012	0.022	0.023	0.028
		Min–Max	0.003–0.020	0.021–0.022	0.016–0.029	0.025–0.030
	Gill	Mean	0.017	0.017	0.016	0.019
		Min–Max	0.012–0.021	0.015–0.019	0.011–0.021	0.015–0.023
Cr	Muscle	Mean	0.245	0.308	0.260	0.235
		Min–Max	0.125–0.365	0.300–0.315	0.250–0.260	0.215–0.255
	Gill	Mean	0.245	0.155	0.338	0.148
		Min–Max	0.180–0.310	0.150–0.156	0.325–0.350	0.140–0.155

the average concentrations of Cd, Pb, Hg and Cr in Lake Beyşehir were 110, 86, 2.07, 28 $\mu\text{g/l}$, respectively (Table 2). In lake Beyşehir, Cd had the highest concentration and Hg the lowest concentration in water samples. In addition, the accumulation orders of heavy metals ($\text{Cd} > \text{Pb} > \text{Cr} > \text{Hg}$), and the concentrations in water samples were statistically significant (Chi square test, $P < 0.05$). According to the heavy metal concentrations given Table 2, the water of Lake Beyşehir was included to the third class category in respect to Cd and Pb concentrations in accordance with Turkish regulations, and the heavy metal concentrations such as Cd and Pb were found to be above for permissible level of drinking water in international criterias such as WHO, EU and EPA (USA), but Hg and Cr concentrations were almost in the permissible levels for drinking.

In sediment samples, the highest concentration was recorded for Pb and the lowest for Hg in Lake Beyşehir (Table 2). The concentrations of Cd, Pb, Hg and Cr in Lake Beyşehir were 13.05, 32.65, 0.24 and 10.63 $\mu\text{g/g}$, respectively. In plankton samples, the highest concentration (55.46 $\mu\text{g/l}$) was recorded for Pb and the lowest (2.15 $\mu\text{g/l}$) for Hg in Lake Beyşehir. Cd and Cr concentrations were 53.10 and 49.96 $\mu\text{g/l}$, respectively (Table 2), but the concentration of Hg was the highest level in plankton samples among four components of food webs. The differences in heavy metal accumulations were also statistically significant in plankton samples (Chi square test, $P < 0.05$).

The heavy metal accumulations in four fish species were determined. *L. cephalus*, *C. carpio*, *L. lucioperca* and *T. tinca*, are very common, and also have commercial importance. In Lake Beyşehir, in the chub, *L. cephalus*, Cd was found in the highest concentration (0.578 $\mu\text{g/g}$), and Hg in the lowest concentration (0.012 $\mu\text{g/g}$) in muscle tissues. The Cr and Pb concentrations were 0.245 and 0.348 $\mu\text{g/g}$, respectively. In gill tissues, the accumulation order was $\text{Cd} > \text{Pb} > \text{Cr} > \text{Hg}$ (Table 3). In the carp, *C. carpio*, Cd had the highest concentration (0.543 $\mu\text{g/g}$) and Hg the lowest concentration (0.022 $\mu\text{g/g}$) in the muscle tissue, but Pb and Cr concentrations were 0.303 and 0.308 $\mu\text{g/g}$, respectively. In gill tissues, the accumulation order was $\text{Cd} > \text{Pb} > \text{Cr} > \text{Hg}$ (Table 3). In the pikeperch, *L. lucioperca*, the accumulation orders of heavy metals in the muscle and gill tissues were $\text{Pb} > \text{Cd} > \text{Cr} > \text{Hg}$ and $\text{Cd} > \text{Pb} > \text{Cr} > \text{Hg}$, respectively (Table 3). In the tench, *T. tinca*, Cd was found in the highest concentration (0.598 $\mu\text{g/g}$) and Hg in the lowest concentration (0.028 $\mu\text{g/g}$) in the muscle tissues. Pb and Cr concentrations were 0.415 and 0.235 $\mu\text{g/g}$, respectively. In gill tissues, the accumulation order of heavy metals was $\text{Cd} > \text{Pb} > \text{Cr} > \text{Hg}$ (Table 3). According to the concentrations given in Table 3, heavy metal accumulations in the muscle and gill tissues among fishes were not found statistical importance (ANOVA, $P > 0.05$). Four fishes analysed, three (chub, carp and tench) are omnivores fishes, heavy metal concentrations were found almost equal quantities in these omnivores

fishes. Only Pb in muscle and Cr in gill of carnivorous fish "*L. lucioperca*" were seemingly higher than other fishes but there is no statistically significance (ANOVA, $P > 0.05$).

In addition to these, accumulation orders of heavy metals in the food web were also found to be water > plankton > sediment > fish tissues, except for Cr. The average concentration of Cr was 49.96 µg/l in plankton samples, this was followed by water, sediment and fish tissues. The heavy metal concentrations were found the lowest levels in fish tissues, the reason of this may be related to the ages of fishes. In this study, fishes analysed were 2–3 years old according to scale method. Consequently it can be said that the water of lake is not suitable for drinking without refining, but the heavy metal concentrations in the fish tissues were below the permissible levels of human consumption.

4. Discussion

Heavy metals determined in water, sediment, plankton and fish samples showed different levels of accumulation in Lake Beyşehir. Pérez et al. (1999) found the accumulation order of heavy metals in the sediment of a Mexican reservoir to be Cr > Pb > Cd. Radwan et al. (1990) also found higher concentrations of heavy metals in bottom sediment than in water. Ayaş and Kolonkaya (1996) and Barlas (1999) reported 0.478 µg/g Pb in the sediment of the Göksu delta (Turkey) and 0.418–2.834 µg/g Pb in the sediment of the Sakarya river basin (Turkey), respectively. The Pb concentrations reported by both researchers are lower than those determined in the present study. Apart from these, Cd concentration was higher than Pb in the sediment of the lake Beyşehir.

In water samples, Cd in the highest and Hg in the lowest concentration were observed in lake Beyşehir. The accumulation order of heavy metals in the water samples was Cd > Pb > Cr > Hg. Also, in lake Beyşehir; Cd and Pb were found in higher concentrations than those recommended for drinking and irrigation purposes, other heavy metals were almost found at the concentrations to those recommended. As also indicated by Kerrison et al. (1998), the highest concentrations of Cd in the water of lake Beyşehir may be attributed to the low rate of accumulation of Cd in sediment. Ayaş and Kolonkaya (1996) and Barlas (1999) also reported Cd to be found in the highest accumulation in the water of Göksu delta and the Sakarya river basin, respectively. These findings are consistent to our results. Unlike these, Pérez et al. (1999) reported the accumulation order of heavy metals to be Hg > Cr > Pb in the water of a Mexican reservoir. Radwan et al. (1990) stated that relatively high concentrations of metals in water, especially in the bottom sediment,

may be related to very slow water exchange in the lake. Similarly, the high concentrations of heavy metals, especially in the water is supposed to be slow water exchange in Lake Beyşehir.

In plankton samples, the accumulation of heavy metal has been reported to depend upon several factors, such as the productivity of the water body, the physicochemical properties of the water, quantitative and qualitative species composition of zoo- and phytoplanktons, capability of heavy metal absorbance and season (Marshall and Mellinger, 1980; Kerrison et al., 1998). The accumulation order of heavy metals in planktons sampled from lake Beyşehir was Pb > Cd > Cr > Hg. Ayaş and Kolonkaya (1996) have reported significant accumulations of Hg in plankton samples in the Göksu delta but Cd, Pb and Cr were not determined. Hg was similarly found to be higher in plankton samples than other food web components, but other heavy metals were also determined.

In fish, the accumulation of heavy metals was determined in the muscle and gill tissues of four fish species (Table 3). Hilmy et al. (1985) and Kargin (1996) found higher accumulations of Cd in the gills than in the muscle tissue of *Mugil cephalus* and *Tilapia zilli*, respectively. Radwan et al. (1990) found higher accumulations of Pb than of Cd in the tench and higher accumulations of Cd than of Pb in the pike. According to Deb and Fūkushima (1999), metals may be in high concentrations in the gills, intestine and digestive glands. These organs have relatively high potential for metal accumulation. Unlike these reports, Cd concentrations in muscle and gill of four fishes did not show significant difference, but Pb in muscle of *L. lucioperca* was markedly higher than other fishes. Barlas (1999) reported 0.119–0.221 µg/g Cd and 0.169–0.351 µg/g Pb in *C. carpio* collected from the Sakarya river basin. In the present study, the concentrations of Cd and Pb in the muscle and gill tissues of carp collected from Lake Beyşehir were higher than those reported by Barlas (1999).

In lake Beyşehir, the concentrations of heavy metals in the water, sediment, plankton and fish were high, possibly due to direct contamination of the water by metals or the geochemical structure of the region. Such an assumption gives evidence that the heavy metal pollution in the Lake Beyşehir did not originate from anthropogenic affect. In addition to this slow water exchange in the lake causes high concentrations of heavy metals. Thus the higher concentrations of Pb, Cd, Cr and Hg recorded in lake Beyşehir may affect or alter the ecosystem structure and food webs of the lake.

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