Concentrations of metals in water, sediment and tissues of *Cyprinus carpio* L., 1758 from Mogan Lake (Turkey)

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Abstract

In this study, some metals (aluminium, chromium, copper, iron, manganese, lead, zinc and vanadium) and metalloid (silicon) were determined in water, sediment and some tissues of fish *Cyprinus carpio* from Mogan Lake. Fish samples were caught in March 2007. As a result of the examination of metals in the water aluminium has the lowest and silicon has the highest concentration. In sediment samples taken from Mogan Lake it was determined that silicon had the highest and lead had the lowest concentrations. Respectively accumulation of metals in gills, muscles and livers was observed to follow the order of Zn > Fe > Si > Al > Mn > Pb > Cr > V, Si > Fe > Zn > Al > Pb > V > Cr > Mn and Fe > Zn > Al > Si > Pb > Mn > V > Cr > Cu.

Keywords: Metal, *Cyprinus carpio*, Concentrations, Tissue, Sediment, Mogan Lake

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Introduction

Most of pollutants are discharged into the environment every day. Of these, heavy metals are regarded as one of the most serious pollutants of the aquatic environment because of their environmental persistence and tendency to accumulate in aquatic organisms (Schüürmann and Markert, 1998). Biomonitoring of trace elements is essential to assess ecosystem health (Mico et al., 2006). Heavy metal can be categorized as: potentially toxic (aluminum, arsenic, cadmium, antimony lead and mercury) semi-essential like nickel, vanadium, cobalt and essential like copper, zinc, selenium etc. (Szentmihalyi and Then, 2007). For the normal metabolism of the fish, the essential metals are taken up from water, food or sediment (Canlı and Atli, 2003). These essential metals can also cause toxic effect when taken in excessive amounts (Tüzen, 2003).

The distribution of metals in sediments adjacent to settlement areas can provide researchers with evidence of the anthropogenic impact on ecosystems and therefore, aid in assessing the risks associated with discharged human waste. The build-up of metals in sediments has significant environmental implications for local communities, as well as for river water quality. For example, many freshwater invertebrates process sediment as a food source and can be susceptible to bioaccumulation of toxic metals. This bioaccumulation can potentially threaten the health of many species at the top of the food chain, especially birds, fish and humans (Wright and Mason, 1999). Additionally, the reclamation of metal-contaminated river and stream sediments pose a significant risk to local consumers through the remobilization of metals from agricultural lands into crops (Ross and Kaye, 1994).

Fish samples are considered to be one of the most indicative factors, in freshwater systems, for the estimation of trace metals pollution potential (Papagiannis et al., 2004). Therefore there have been many studies published on heavy metal accumulation in fish (Fernandes et al., 2008, Praveena et al., 2008, Öksüz et al., 2009, Yıldırım et al., 2009).

The municipal and industrial wastes along with agricultural drainage are rapidly polluting the lake. The lake has been facing a common problem of overgrowth of macrophytes for the last few decades. Consequently, there is a drastic reduction in fish populations (Anonymous, 1994).

The aim of the present study was to determine the metals concentrations (Mn, Pb, Zn, V, Al, Cr, Cu and Fe) and metalloid (Si) in water, sediments and in muscle, liver and gill tissues of *Cyprinus carpio* in Mogan Lake. The results obtained from this study would provide information for background levels of metals in water, sediment and fish species of the lake and enable the effective monitoring of both environmental quality and the health of the organisms inhabiting the lake ecosystem.

Material and methods

Mogan Lake is located about 20 km south of Ankara, capital of Turkey, and lies within the coordinates of 39º44'40'' N and 39º47'45'' N latitudes and 32º46'30'' E and 32º49'30'' E longitudes (Figure 1). It is near the Gölbaşı town which has undergone considerable development by the increased population and settlement in recent years. A large number of commercial establishments such as restaurants, social clubs, tea gardens as well as summer resorts have been built around the lake which became a popular site for sports, fishing, sailing, and rowing (Anonymous,1989).

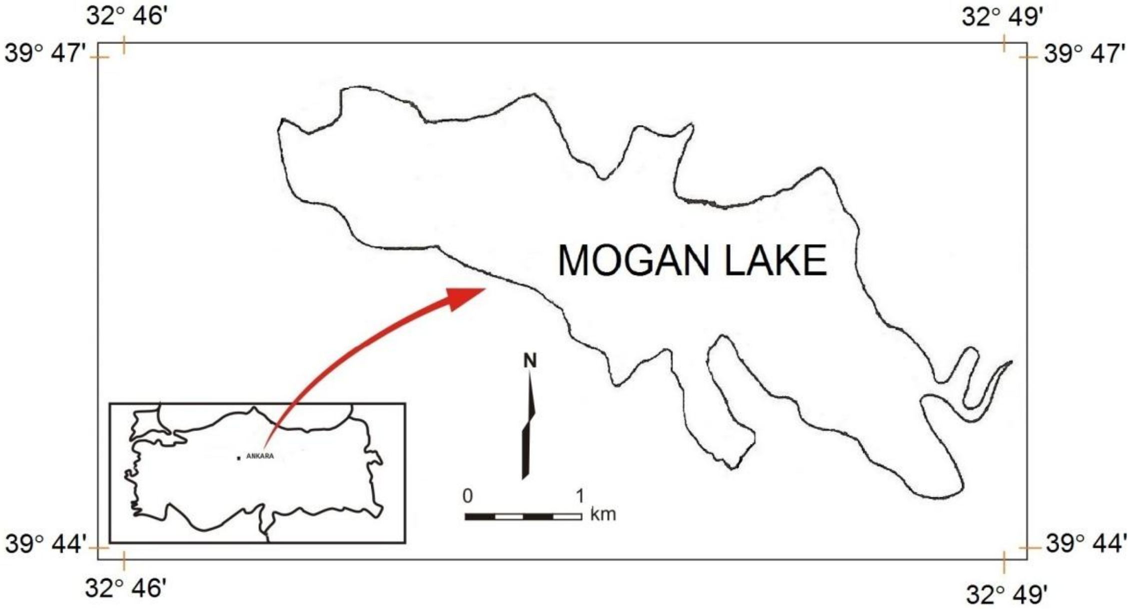

Figure 1: Map of Mogan Lake

Fish samples (*C. carpio*) were collected from Mogan Lake. During the study, 22 fish specimens were caught in March 2007. The fish obtained from the dam lake were immediately transported to the laboratory. The length and weight (min-max) of the fish were 19.6 – 22.8 mm and 122 –327g. All fish samples were kept at -20 ^{0}C until analysis. Water samples were analyzed directly. The tissue samples were weighed (1 g) before, 5 ml HNO_3 (65%) and 1 ml H_2O_2 (%33) were placed into the digestion bombs. Samples were digested in a microwave digestion system (Berghof / Microwave Digestion System MWS–3) by heating at 100 ^{0}C (Alam et al., 2002).

Determination of the elements in all samples was carried out by ICP-OES. Operational parameters used for the determination of elements by ICP-OES and studied wave length are given in Table 1.

Table 1: Operational parameters used for the determination of elements by ICP-OES

Apparatus	**Perkin Elmer Optima 5300 DV**		
RF generator	40MHz		
RF forward power	1300W		
Plasma gas (Ar) flow	15 L/min		
Aux. gas (Ar) flow	0.2 L/min		
Nebulizer gas (N2) flow	0.80 L/min		
Replicates	3		
Pump rate	2.0 mL/min (peristatic pump)		
Viewing configuration	Axial		
Studied wavelength (nm)	**Al**:396.153;	**Cr**:267.716;	**Cu**:327.393
	Fe:238.204;	**Mn**:257.610;	**Pb**:220.353
	Si:251.611;	**Zn**:206.200;	**V**:290.880

High-purity analytical reagent-grade standard solutions containing (1 g L^{-1}) of analytes and HNO_3 were purchased from Merck. Stock standard solutions were used to prepare the diluted standard solutions and model solutions, daily. Ultra pure water obtained at Innovation Pure Water System (18.3 MΩ/cm.) was used for the preparation of all standard and sample solutions. ICP-OES experiment was carried out at the same conditions of the standard solutions. Table 2 shows the accuracy of the determination method is satisfactory when it is easily seen from the relative error. Two different synthetic standard solutions were containing 100 µg/L and 200 µg/L of the trace elements were prepared.

Table 2: Determination of analysis in synthetic samples

Containing 100 µg/l each elements in water

Sample	Al (µg/l)	Cr (µg/l)	Cu (µg/l)	Fe (µg/l)	Mn (µg/l)	Pb (µg/l)	Zn (µg/l)	V (µg/l)
Found	98.6 ±2.8	96.5 ±2.6	87.3 ±3.8	95,2 ±2.1	96,9 ±.1.1	111.3 ±1.2	96.0 ±1.8	96,5 ±3.8
Relative Error (%)	−1.4	−3.5	−12.7	-4.6	-3.1	11.3	-4.0	-3.5

Values are mean±standard deviation (*n* = 3)

Containing 200 µg/l each elements in water

Sample	Al (µg/l)	Cr (µg/l)	Cu (µg/l)	Fe (µg/l)	Mn (µg/l)	Pb (µg/l)	Zn (µg/l)	V (µg/l)
Found	197.7 ±1.3	193.9 ±1.7	176.9 ±1.1	187.9 ±2.5	188,8 ±1.35	223.3 ±4.0	184.6 ±2.8	193.1 ±1.9
Relative Error (%)	−1.2	−3.05	−11.5	-6.1	-5.6	11.5	-7.7	-3.4

Values are mean±standard deviation (*n* = 3)

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The correlation between elements in water, sediment, muscle and gills tissues of *C. carpio* was statistically tested with SPSS for Windows V.15 (SPSS statistical package program).

Results

Metal concentrations in water and sediment samples, and the muscle, gills and liver tissues of *C. carpio* are presented in Table 3-5, which include mean concentrations with associated standard deviations, minimum and maximum values and the results of other studies.

Table 3: Trace metal concentrations in Mogan Lake water and other study areas (concentration unit is in µg l^{-1})

	Al	Cr	Cu	Fe	Mn	Pb	Si	Zn	V
This study									
AM	0.906	-	-	1.492	-	-	203.58	-	-
± SD	2.874			0.482			5.768		
Min	0.13	-	-	0.59	-	-	101.04	-	-
Max	2.33			2.62			476.10		
Water quality criteria [a]									
CMC	750	16	-	-	-	65	-	120	-
CCC	87	11	-	1000	-	2.5	-	120	-
Tur. Env. Gui.[b]									
Class I	0.3	20	20	300	100	10	-	200	-
Class II	0.3	50	50	1000	500	20	-	500	-
Class III	1	200	200	5000	3000	50	-	2000	-
Class IV	>1	>200	>200	>5000	>3000	>50	-	>2000	-
WHO [c]	200	50	2000 (P)	300	500	10		3000	
TS 266 [d]	200	50	2000	200	50	10			
Dil Stream [e]	8.46	42	37	4.03		120		700	
Dipsiz Stream [f]		0.092	0.365			0.405		1.051	
Demirköprü Dam Lake [g]		6	20	260		20			
Habbaniya Lake [h]			20		14.4	19		40.8	
Balaton Lake [i]			0.46			0.04		0.97	

AM: arithmetic mean; SD: standard deviation; Min: minimum levels;
Max: maximum levels; P (Provisional value)
[a] (EPA, 2002)
[b] (Turkish Environmental Guidelines, 2004)
[c] (WHO, 1993)
[d] (TS-266, 2005)
[e] (Pekey et al., 2004)
[f] (Al-Saadi et al., 2002)
[g] (Nguyen et al., 2005)
[h] (NOAA, 2009)
[i] (Canlı and Kalay, 1998)

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The concentrations ranges of trace elements were found as follows: Al: 0.13 – 2.33 µg l^{-1} ; Fe: 0.59 – 2.62 µg l^{-1} ; Si: 101.04 – 466.10 µg l^{-1}. Metal concentrations in the lake water were decreased as Si > Fe > Al.

Table 4 shows the metals from Mogan Lake sediments and other globally published reference values for lake and dam lake sediments.

The metal concentrations in sediment samples were as follow: Cr: 22.19 – 41.31 µg l^{-1}; Cu: 9.91 – 30.19 µg l^{-1}; Fe: 3091.58 – 4007.95 µg $l^{-1;}$ Mn: 102.94 – 146.29 µg l^{-1}; Pb: 0.46 – 1.78 µg l^{-1}; Si: 38023.86 – 55556.53 µg l^{-1}; Zn: 11.27 -18.01 µg l^{-1}; V: 19.25 – 26.68 µg l^{-1}. Metal concentrations in the lake sediments decreased in the sequence of Si > Fe > Mn > Cr > V > Cu > Zn > Pb.

Table 4: Trace metal concentrations in sediment samples from Mogan Lake and other study areas (concentration unit is in µg g^{-1} dry weight)

	Al	Cr	Cu	Fe	Mn	Pb	Si	Zn	V
This study									
AM	-	28.554	15.13	3577	125.668	0.822	43719.01	13.786	22.686
± SD	-	0.788	0.784	1.048	0.776	1.788	1.504	1.812	0.890
Min	-	22.19	9.91	3091.58	102.94	0.46	38023.86	11.27	19.25
Max	-	41.31	30.19	4007.95	146.29	1.78	55556.53	18.01	26.68
NOAA [a]									
TEC		0.043	0.031			0.035		0.121	
LEL		0.026	0.016	2%	0.460	0.031		0.120	
PEC		111	149			128		459	
SEL		110	110	4%	1100	250		820	
Dipsiz Stream [b]		19.70	13.00			83.60		37.00	
Demirköprü Dam Lake [c]		6.75	15.10	15681		6.50			
Habbaniya Lake [d]			8.35		814.5	12.8		25.8	
Balaton Lake [e]			0.7-36		160.0-760	2.4-160		13.0-150	

SD: standard deviation; Min: minimum levels; Max: maximum levels,
TEC: Threshold Effect Concentration LEL : Lowest Effect Level
PEC: Probable Effect Concentration SEL: Severe Effect Level
[a] (NOAA, 2009)
[b] (Demirak et al., 2006)
[c] (Öztürk et al., 2008)
[d] (Al-Saadi et al., 2002)
[e] (Nguyen et al., 2005)

The mean concentrations of metals in the muscle, liver and gills tissues of common carp samples are given in Table 3. Metal concentrations in the fish samples decreased in the sequence for the gill as Zn > Fe > Si > Al > Mn > Pb > Cr > V > Cu; muscle as Si > Fe > Zn > Al > Pb > V > Cr > Cu and liver as Fe > Zn >Al > Si > Pb > Mn > V > Cr > Cu. The metals (Al, Cr, Cu, Fe, Mn, Pb, Zn, V) and metalloid (Si) concentrations in Mogan Lake water in three sampling sites were compared with US EPA, Turkish Environmental Guidelines and the results are obtained from the literature (Al-Saadi et al., 2002; Pekey et al., 2004; Nguyen et al., 2005; Demirak et al., 2006;). The values are given in Table 3. Water quality regulations in Turkey divide inland waters into four classes (Turkish Environmental Guidelines, 2004).

Table 5: Trace metal concentrations in the gills, muscle and liver of *Cyprinus carpio* and other studies (concentration unit is in μg g^{-1})

		Al	Cr	Cu	Fe	Mn	Pb	Si	Zn	V
This study										
Gill										
	AM	32.99	1.57	-	132.23	5.54	3.33	65.15	224.59	1.04
	± SD	17.16	0.23	-	38.25	0.27	0.80	18.69	37.19	0.50
	Min	15.02	1.35	-	97.89	5.25	2.37	41.71	176.35	0.59
	Max	63.09	1.90	-	193.86	5.92	4.67	95.17	284.30	0.28
Muscle										
	AM	17.18	1.19	-	57.20	1.00	4.15	60.92	33.24	2.05
	± SD	6.47	0.31	-	15.16	0.24	1.23	12.23	10.55	0.40
	Min	7.92	0.92	-	37.89	0.31	3.29	45.92	17.70	1.62
	Max	25.54	1.72	-	76.45	2.92	6.48	79.64	45.02	3.44
Liver										
	AM	57.32	3.31	2.03	316.19	5.63	9.19	46.04	154.59	4.59
	± SD	43.09	2.15	1.73	190.28	4.13	5.50	14.79	45.74	3.26
	Min	16.26	1.13	0.34	148.72	2.78	3.44	33.06	89.50	1.56
	Max	120.37	6.45	5.12	664.42	13.80	17.16	359.38	218.93	8.47
Seyhan River [a]										
	Gill		3.74	7.01			14.23			
	Muscle		0.62	5.12			7.04			
	Liver		1.03	32.19			9.45			
Porsuk Dam Lakes [b]										
	Muscle		<60				<100			
	Liver		<60				<100			
Ponds (Tamilnadu) [c]										
	Liver		0.863				2.000			
	Gill		0.79				1.4			
Northern Jordan Valley [d]										
	Muscle			2.48					30.31	
	Gill			9.92					27.85	
Balaton Lake [e]										
	Muscle		34.7	2.34		3.66	0.065		25.6	
	Liver		0.37	25.8		6.88	0.22		85.8	

AM: arithmetic mean; SD: standard deviation; Min: minimum level;
Max: maximum levels
[a] (Canlı and Kalay, 1998)
[b] (Çiçek and Koparal, 2001)
[c] (Vinodhini and Narayanan, 2008)
[d] (Al-Weher, 2008), [e] (Nguyen et al., 2005)

The aluminium levels of water in Mogan Lake were higher than Class I and Class II and were lower than Class III and Class IV Iron levels were observed to be lower than all class level. The mean concentrations of Al, Cr, Cu, Fe, Pb and Zn were lower than the criteria for the maximum concentrations and criterion continuous concentration values of the US EPA (EPA, 2002) water quality criteria. When other lakes, dam lakes and streams are considered, Mogan Lake's results are comparably unpolluted. Mean concentrations in Mogan Lake are lower than concentrations in other regions.

Discussion

The levels of metals in the sediment are given in Table 4. The metal concentrations obtained from the sediment samples were compared with Sediment Quality Guideline which showed that these concentrations did not exceed the probable effect concentration (PEC) levels. The mean concentration of Cr was higher than those reported for Dipsiz Stream. Also Cu concentration was higher than the Habbaniya Lake. The mean concentrations of Fe, Mn, Pb and Zn are lower than concentrations in Balaton Lake.

Table 5 shows mean metal concentrations in the tissues of fishes and their standard deviations for *C. carpio*. The table also includes the data of the other studies, related with the metal levels of organs. The present study deals with the metal accumulation in the gill, muscle and liver tissue. The variability observed in the metal levels of different species depends on feeding habits (Watanabe et al., 2003), ecological needs, metabolism (Canlı and Kalay, 1998), age, size and length of the fish (Al-Yousuf et al., 2000) and their habitats (Canlı and Atli, 2003).

The concentrations of Pb and Zn in gills were higher than Dipsiz Stream (Demirak et al., 2006). The concentrations of Mn, Pb and Zn in muscles were higher than Balaton Lake but the concentration of Cr in muscles was lower than Balaton Lake (Nguyen et al., 2005). The concentrations of Pb, Cr and Zn in livers were higher than Balaton Lake but the concentration of Mn in livers was lower than Balaton Lake (Nguyen et al., 2005). The concentrations of Al, Cr, Fe and Mn in liver were higher than gills and muscle respectively. The concentrations of Pb and V were found to be in the following order: liver > muscle > gill. The concentrations of Si in livers were higher than muscles and gills respectively. And also the concentrations of Zn in gills were higher than livers and muscles respectively.

Respectively, gill, muscle and liver accumulation of metal were Zn > Fe > Si > Al > Mn > Pb > Cr > V, Si > Fe > Zn > Al > Pb > V > Cr > Mn and Fe > Zn > Al > Si > Pb > Mn > V > Cr > Cu were found to be.

The muscles analyzed in this study were found to comply with the FAO maximum concentrations for Zn of higher than 150 ppm (FAO, 1983). Comparisons with the WHO standards (Fe:2.0 mg kg^{-1}, Zn: 30 mg kg^{-1}, Mn: 1.0 mg $kg^{-1}$for a 50 kg person), Turkish standards (Cu: 20.0 mg kg^{-1}, Zn: 50 mg kg−1), ITS standards (Cu:5.0 µg g^{-1}, Pb:0.50 µg g^{-1} , Zn: 50.0 µg g^{-1}), TFC standards (Pb:0.30 µg g^{-1}) and EC standards (Pb:0.20 µg g^{-1}) demonstrate that the metal contamination is higher than the levels indicated by these guidelines in the edible

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parts of the examined fish (WHO, 1996; ITS, 2000; EC, 2001; TFC, 2008). Concentrations of Cu were below the legal limit for human consumption.

The correlation between elements in water, sediment, muscle and gills of *C. carpio* was statistically tested with SPSS. The Pearson's correlation coefficient matrix for the elements was performed, as there was a linear relationship among the elements. Cu, Fe, Mn and Pb were found to have relatively higher positive correlation coefficients (for Cu, r = 0.30 between sediments and muscle; for Fe, r = 0.84 between sediments and muscle, r = 0.49 between sediments and gill; for Mn, r = 0.26 between sediments and liver; for Pb, r = 0.33 between sediments and gill). For both the elements (Cu and Fe), the correlation coefficient between sediment and muscle was found to be higher than the correlation coefficient between sediment and gill. The present study shows that precautions are needed to be taken in order to obviate the metal pollution in future. Otherwise, these pollutions can be hazardous for fish and human health.

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