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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

Bioaccumulation of heavy metals in the water, sediment and the tissues of *Carassius gibelio* (Bloch, 1782) from Eber Lake

Eber Gölü'nde (Türkiye) su, sediment ve *Carassius gibelio* (Bloch, 1782) dokularında ağır metal birikimi

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Abstract: In this research, in order to observe the seasonal change between April 2014 and February 2015, heavy metal contents in the water, sediment and the *Carassius gibelio* (Bloch, 1782) tissues (muscle, gill and liver) growing in Eber Lake were determined. The obtained results showed that trace elements were founded in water, sediment and fish tissues. Among the average annual concentrations of water samples, the highest concentration was found for Mn (0.1584 mg/L) element and the lowest concentration was found for Pb element in the spring season. the maximum Average annual concentration was calculated for Mn (0.1584 mg/L, Spring) and the minimum was determined for Pb in water. In the sediment, Fe (16245.84 mg/kg, Spring) was found to be maximum and Co was the minimum. In fish, the highest concentrations were found in liver (Mo, Ni, Pb, Co, Cu, Fe), while the lowest concentrations were found in gill (Mn, Zn) and muscle (Cd, Cr, Se) tissues While the highest heavy metal concentrations were observed in the sediment, the minimum was found in the fish tissues (the ranking was the following; liver, gill and muscle). It was concluded that the heavy metal levels measured in the Lake Eber have no risk to the environment and to the public health.

Keywords: Eber Lake, heavy metal, water, sediment, fish tissues

Öz: Bu çalışmada Nisan 2014 ile Şubat 2015 arasında Eber Gölü'nden alınan su, sediment ve *Carassius gibelio* (Bloch, 1782) dokularındaki (kas, solungaç ve karaciğer) ağır metal içeriklerinin mevsimsel değişimlerini belirlemek amaçlanmıştır. Su, sediment ve balık dokularında iz elementler tespit edilmiştir. Su örneklerinde ortalama yıllık konsantrasyonlar içerisinde en yüksek Mn (0,1584 mg/L) İlkbahar mevsimde en düşük konsantrasyon ise Pb elementinde bulunmuştur. Sediment örneklerinde ortalama yıllık konsantrasyonlar içerisinde en yüksek Fe (16245,84 mg/kg) İlkbahar mevsimde en düşük konsantrasyon ise Co elementinde bulunmuştur. Balıklarda, en yüksek konsantrasyonlar karaciğer dokusunda (Mo, Ni, Pb, Co, Cu, Fe) bulunurken, en düşük konsantrasyonlar solungaç (Mn, Zn) ve kas dokularında (Cd, Cr, Se) tespit edilmiştir. En yüksek ağır metal konsantrasyonları sedimentte gözlenirken, en düşük ağır metal konsantrasyonları balık dokularında sırasıyla karaciğer, solungaç ve kasda bulunmuştur. Eber Gölü'nde ölçülen ağır metal seviyelerinin çevre ve halk sağlığı açısından herhangi bir risk taşımadığı tespit edilmiştir.

Anahtar kelimeler: Eber Gölü, ağır metal, su, sediment, balık dokusu

INTRODUCTION

The different types of water pollutions observed in many countries will lead to life-threat problems all around the world. Heavy metal pollution is considered to be one of the most significant environmental hazards. Streams form the wetland areas which are considered as receivers by collecting the pollutants within the soil including the heavy metals as well (Brzozowska *et al*., 2011). Heavy metals are shown among those pollutants which have the abilities to cause problems. Heavy metals are important because they accumulate in biotic and abiotic elements, can stay in the environment for a long time, show toxic effects on aquatic organisms and pass on to other living things through the food chain (Shrivastava et al., 2003; Withanachchi *et al*., 2008). Therefore many studies were carried out recently both in Turkey and also worldwide related to the accumulation of the heavy metals (Icaga, 2007; Emiroğlu and Arslan, 2015; Fidan *et. al*., 2008; Zhu *et al.*, 2015; Rajeshkumar *et al.*, 2018; Tokatlı, 2019; Varol & Sunbul 2019).

The heavy metals accumulated within the sediment of the aquatic environments damage particularly the benthic organisms and also the other living organisms through the food chain (Mohiuddin *et al.*, 2011; Arslan *et al.*, 2009). In recent years, researches on trace element accumulation in lentic ecosystems have accelerated (Siddiqui *et al.* 2019; Milačič *et al*., 2019; Özparlak *et al*., 2016).

Lake Eber is one of the most important wetland areas concerning this issue. The lake is an important biodiversity area which has the characteristics of a wetland area however if the necessary measures are not taken in a very short time it will lose this characteristic (Gümüş and Akköz, 2020). Due to this critical situation Lake Eber was chosen as the research area. The most important surface water which feeds the Eber Lake is Akarçay. Akarçay carries the waste of sewage system, the sugar, beer and milk factories of Afyonkarahisar, a meat and fish combine, alkaloids and enamel factories located in Bolvadin and the waste of many small industrial places around Afyonkarahisar and Bolvadin (Kıvrak *et al*. 2012; Gümüş, 2021). This has led to intense eutrophication especially in Lake Eber (Fidan *et al.* 2008). Therefore, it was aimed to determine the heavy metal values seasonally in the lake's water, sediment and in the muscle, gill and liver tissues of the fishes.

MATERIAL AND METHODS

Study area

Ecologically it is one of Turkey's most shallow and eutrophic lakes. Almost the lake's entire surface is covered with reeds and canes, there are some open water surfaces (lake mirrors) which do not exceed 5-10 hectares. The average depth of the lake does not exceed 3-4 meters. Lake Eber is a tectonic lake situated in the Lake District in the north of the Sultan Mountains and the south of the Emir Mountain between the geographic coordinates of 38° 40'N and 31° 12' S. It is 65 km far from the city of Afyonkarahisar and the altitude of the water surface is 966 m. The water, sediment and fish tissues (muscle, gill, liver) were gather seasonally among April 2014 and March 2015. When determining the stations during the field studies five points were selected which reflected the structure of the lake homogenously including the inflow of Akarçay which is the most important river feeding the lake with high pollution load. The station 1. is in the shallowest part of the lake. Station 2 was located on the where the eber village settlement is dominated. Station 3 and station 4 was located on the where it could reflect all domestic, agricultural, industrial discharges and natural–geologic effects. Station 5. is located in the area at the entrance of Akarçay Stream and exposed to agricultural and domestic discharges. Water and sediment samples taken from the stations were collected using appropriate containers. The fish (*Carassius gibelio*) samples were also caught from the same localities. In each sampling season, 40 fish (160 fish in total) were caught by making a net with the help of professional fishermen from the same field. In the heavy metal analysis all samples were brought with cold chains from the land to the laboratory. The geographical locations of the stations and the locations on Lake Eber were given in Figure 1.

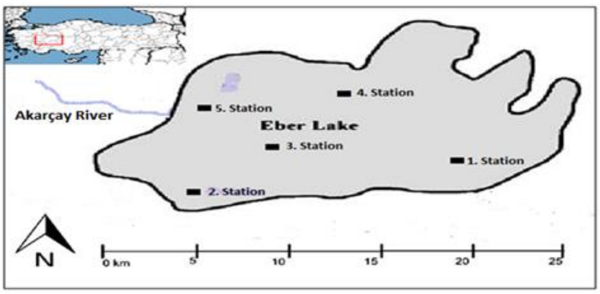

Figure 1. Eber Lake sampling stations

Element analysis

The water samples brought to the laboratory were passed over a 45 µm membrane filter (Whatman) (GF/C) and were put into 500 mL coloured flasks, 5mL of nitric acid was added and the flask were stored in the refrigerator at 4 ºC until the analysis was made (Skujins, 1998). The sediment samples were taken from the same areas as the water samples. An Ekman Grab was used to collect the sediment samples. Some of the sediment samples (1 kg) were put into glass petri plates after they had been sifted, and they were dried by being kept in the drying oven at 105ºC for 24 hours. The solubilisation process was performed in the microwave oven (CEM Mars Xpress 5) after 0.2 g. samples adding 5 mL of HCl, 3 mL of HNO_3 and 2 mL of pure water. After the tubes taken out of the oven were kept at room temperature, the solution was transferred to the falcon tubes with a 45 µm membrane filter and completed with 25 mL of distilled water (Mohiuddin *et al*., 2011). The samples taken from the tissues were awaited for 24 hours at 105 ºC. The sample tissues (each of them weighting 0.2 g) taken from the fish tissues were taken to separate polypropylene containers. The solubilisation process of the taken tissues were carried out in a microwave oven (CEM Mars Xpress 5) after adding 6 mL of HNO_3 (% 65) and 4 mL distilled water. The tubes which were removed from the oven later were cooled down to room temperature and the solution in the tubes was transferred to falcon tubes through 45 µm membrane filter. The amount of the solution within the tubes was completed to 25 mL with pure water. The prepared samples were stored at +4°C before analysis (UNEP, 1984). Samples ready for analysis were analyzed by ICP-OES (Varian Vista). The wavelengths of the elements measured in the device were respectively Co 238.892 nm, Mo 202.032 nm, Cd 214.439 nm, Cr 267.716 nm, Cu 327.395 nm, Fe 238.204 nm, Mn 257.610 nm, Ni 231.604 nm, Pb 220.353 nm, Se 203.985 nm and Zn 213.857 nm.

The averages were taken after reading the samples 3 times. In addition the accuracy of the results was tested with the prepared fish reference materials. The measuring device was tested by fish reference material TORT-2 (Lobster hepatopancreas) in order to verify the validity of its analytical method. According to these results the accuracy of the recorded values was between 87% and 95% according to the reference value (Table 1).

Table 1. Values of metals found in certified and observed reference material TORT-2

Elemental value (mg/kg)	Certified value	Observed value	Recovery (%)	RSD (%)
Cd	26.7±0.6	22.6319	87	12.2
Cr	0.77±0.15	0.7376	95	3.6
Co	0.51±0.09	0.4727	92	5.2
Cu	106±10	94.6928	88	11.2
Fe	105±13	99.7398	94	7.4
Pb	0.35±0.13	31.6438	90	6.7
Ni	2.50±0.19	2.2319	89	4.1
Se	5.63±0.67	5.1448	91	2.7

Statistical analysis

The statistical differences of heavy metal accumulations between the fish tissues and stations were determined by a Duncan Multiple Comparison Test (p<0.05) one-way anova analysis of variance using the SPSS 21packet program. The results of heavy metals are given as mean values (Steel *et al*. 1996; Barlas, 2005).

RESULTS

The seasonal heavy metal values of Lake Eber's water and sediments were determined and the annual average heavy metal levels are given in Table 2 and Table 3.

The minimum Cd level in water samples was detected at the first station (0.0003 mg/L) in autumn. The maximum Cd level was detected at the fifth station (0.0008 mg/L) in winter. The maximum Co level in the water was observed at the fifth station in summer while the minimum level was recorded at the second station in winter. The Co concentration was measured to be higher in summer than in the other seasons. The Co level at the fifth station was significantly higher statistically compared to the other stations (p<0.05). The maximum Cr value was detected in the first station (0.0017 mg/L) at the first station. In spring, the highest Cr concentration was found at the first station (0.0017 mg/L). Cr could not be detected at the second station in autumn and at the first and third station in the winter. The highest Fe concentration in the water was detected at the first station (0.1259 mg/L). The annual average Mn level in the water varied between 0.0181and 0.0488 mg/L. The minimum level in was detected at the fifth station (0.0003 mg/L) in winter. The maximum level was detected at the fifth station (0.0008 mg/L) in spring. The Mo concentration in the water was higher in the winter months than in the other months. The maximum Mo concentration was observed at the third station in winter (0.0049 mg/L) while the lowest Mo concentration was observed at the first station (0.0013 mg/L) in the summer. The fifth station (0.0049 mg/L) had the highest Ni concentration found in summer. Significant difference was determined among the stations in relation to the Ni values of the water. The Ni concentration was statistically higher at the fifth station. The fifth station (0.0008 mg/L) had the highest Pb concentration in spring. Pb was not detected in water at any station in the summer. Statistically significant difference was determined in the Pb values among the station (p<0.05). The Se was not observed in the water during all seasons except 3 stations. The fifth station (0.0507 mg/L) had the highest Zn concentration found in spring. It was not detected except the fourth station during the winter. Significant differences were not determined in the Cr, Se, Zn, Mo, Fe, Mn and Cd values among the different stations (p>0.05).

In the sediment of Lake Eber, the highest Cd level was found at the fifth station in the autumn (5.6435 mg/kg). This value was above the toxic effects threshold (TET) value (4.98 mg/kg) determined by MacDonald *et al* (2000). The values observed at all the other stations during all seasons were lower than the threshold effect level (TEL) (0.596 mg/kg), lowest effect level (LEL) (0.6 mg/kg) and minimal effect threshold (MET) (0.9 mg/kg) values (MacDonald et al., 2000). The Cd level was significantly higher statistically at the fifth station than at the other stations (p<0.05) (Table 3). The highest Co concentration was founded at the first station (1.796 mg/kg) in the summer while the lowest was seen at the second station (0.2767 mg/kg) in the spring. The highest Cr concentration in the sediment was observed generally in the summer season except the fourth and fifth stations. The highest Cr level of sediment samples was observed at the first station (41.1762 mg/kg) in the summer. The Cr concentration values obtained from the sediment were below the MET (55 mg/kg) and TET (111 mg/kg) values and above the TEL (3.3 mg/kg) and LEL (26 mg/kg) values at some of the stations. The highest Cu level in the sediment was observed at the fifth station (32.1933 mg/kg) during the autumn while the lowest level was seen at the third station (5.5892 mg/kg) during the spring. The Cu values obtained from the sediment were all below the TET value (149 mg/kg). The Cu and Cr concentration was statistically significantly higher at the first and fifth stations compared to the other stations (p<0.05).

The Fe level was significantly higher statistically at the first and fifth stations compared to the others (p>0.05). The Fe levels of Lake Eber's sediment were observed between 3285.455 and 12424.48 mg/kg during the spring, between 2633.244 and 14524.79 mg/kg during the summer and 3551.377 and 16245.84 mg/kg during the autumn and between 3971.337 and 16199.74 mg/kg during the winter. The maxium Mn level of the sediment was found at the third station (775.2915 mg/kg) in the spring while the minimum concentration was observed at the first station (180.9605 mg/kg) during the summer. The Mn concentration was statistically significantly higher at the third and fourth stations compared to the other stations (p<0.05) (Table 3). The Mn concentrations of the sediment taken from Lake Eber was recorded between 192.0395 and 533.6344 mg/kg during the spring, between 180.9605 and 417.6687 mg/kg during the summer, between 267.4343 and 775.2915 mg/kg during the autumn, between 613.7977 and 16199.74 mg/kg during the winter. The highest Mo concentration in the sediment was observed at the first station (775.2915 mg/kg) in the winter, while the lowest concentration was found at the fifth station (180.9605 mg/kg) during the winter. The Mo levels in the sediment was recorded between 1.3607 and 2.0979 mg/kg in the spring, between 0.907 and 2.27 mg/kg during the summer, between 1.3804 and 3.2159 mg/kg during the autumn and between 1.2465 and 3.2773 mg/kg during the winter.

The highest Ni concentration in the sediment was recorded at the first station (46.30458 mg/kg) in spring. The Ni values obtained from the sediment were below the TET value (48.6 mg/kg). The maximum Pb concentration in the sediment was founded at the fifth station in winter (17.194 mg/kg) while the minimum concentration was measured at the fourth station (3.4189 mg/kg) in summer. The Pb concentration was significantly higher statistically at the first and fifth stations compared to the other stations ($p<0.05$). The Pb values obtained from the sediments were below the values of MacDonald *et al* (2000) quality criteria. The highest Se level in the sediment was observed at the first station (3.0274 mg/kg) in the spring. It was not detected at the fourth and fifth stations during the summer, at the fourth station during the autumn and at the third station during the winter. The highest Zn level was measured at the fifth station (91.1524 mg/kg) in spring, while the lowest level was observed at the fourth station (15.6252 mg/kg) in summer. The Zn concentration was considerably higher at the fourth station compared to the other stations ($p<0.05$). Significant differences were not determined in the Co, Mo, and Ni values among the different stations ($p>0.05$).

The heavy metal levels in the tissues (muscles, gill and liver) of *Carassius gibelo* (Bloch, 1782) taken from Lake Eber seasonally are shown in Table 4. The heavy metal concentrations within the muscle tissue of the fish were compared to the quality criteria of the Turkish Food Codex (2011). The highest Cd concentration in the fish tissue was found in autumn in the muscle tissue (0.0598 mg/kg) (Table 4). Significant difference was not determined in the Cd values within the fish tissues ($p>0.05$). The Co concentration in the fish tissues was the highest in the liver (0.2206 mg/kg) and the lowest in the gill (0.0987 mg/kg) in spring. In the summer the lowest Co concentration was observed in the gill (0.0112 mg/kg) and the highest in the liver 0.1214 mg/kg, in autumn the highest Co concentration was observed in the muscle 0.1415 mg/kg while the lowest was in the liver 0.0716 mg/kg, in winter the highest Co concentration was found in the muscle 0.1685 mg/kg while the lowest was found in the gill (0.0766 mg/kg). Statistically significant difference was not determined in the Co values of the fish tissues among the stations. In spring the Co concentration in the liver was considerably higher statistically compared to the other seasons and tissues ($p<0.05$). The Cr concentration in the fish tissues was the highest in the muscle 0.7989 mg/kg and the lowest in the liver 0.4803 mg/kg in spring, during the summer the lowest Cr concentration was observed in the liver 0.0111 mg/kg and the highest in the muscle 0.782 mg/kg, in autumn the highest Cr concentration was observed in the gill (0.3645 mg/kg) while the lowest was in the liver 0.1156 mg/kg, in the winter the highest Cr concentration was found in the gill 0.2112 mg/kg while the lowest was found in the liver 0.0877 mg/kg. The Cr concentration of some freshwater fish was reported as 1.32-4.20 mg/kg by Alaş *et al*., (2014). The Cr level in the fish tissue was significantly higher in the muscles during the spring compared to the other seasons and tissues. The Cu concentration in the fish tissue was found to be the highest in the liver in all seasons except summer. The values obtained from the muscle tissue in all seasons were lower than the acceptable limit values given by the Turkish Food Codex (20 mg/kg). Statistically significant difference was determined in the Cu values of the fish tissues between the stations ($p<0.05$). The highest Cu concentration was found in the liver tissue during winter (2.1995 mg/kg) (Table 4). The Fe accumulation in the fish tissue of Lake Eber were the following in all seasons liver>gill>muscle. In this study the amount of Fe was determined between 11.3897 and 208.0796 mg/kg. The Fe level in the fish tissue was statistically significantly higher in the liver (208.0796 mg/kg) (Table 4) during autumn compared to the other tissues and seasons ($p<0.05$). In this study, the amount of Mn was determined between 0.0379 and 14.7615 mg/kg. The Mo concentration in the fish tissues was the highest in the liver 0.1511 mg/kg and the lowest 0.0832 mg/kg ins spring, during the summer highest Mo concentration was observed in the muscle 0.1044 mg/kg and the lowest in the gill 0.1214 mg/kg, in autumn the highest Mo concentration was observed in the gill 0.0997 mg /kg while the minimum was in the muscle 0.0633 mg/kg, in the winter the highest Mo concentration was found in the gill 0.0943 mg/kg while the lowest was found in the gill 0.0742 mg/kg. The Mo level was significantly higher statistically in the liver in summer compared to the other seasons and tissues ($p<0.05$). In our study the highest Ni value was observed in the liver (0.7328 mg/kg) in spring (Table 4). The values measured in the gill and liver during the winter were below the measurable limit values. The Ni level in the liver in spring was statistically significantly higher than in other tissues in other seasons ($p<0.05$). Lead was detected below the measurable limit values in the gills and liver during the summer and winter season and in the muscle during the autumn. The highest Pb values was measured during the spring in the liver (0.0876 mg/kg). Significant difference was determined in the Pb values within the fish tissue ($p<0.05$). Selenium was found below the limit value in the muscle during spring, in the gill during the summer, and in the liver during the autumn and winter. In this research, the highest Se level was measured in the muscle tissue in winter (0.336008 mg/kg) (Table 4). Significant difference was determined in the Se values within the fish tissue ($p<0.05$).

Table 2: Seasonal and annual average heavy metal values of water taken from Eber Lake stations (mg/L)

Season	Station	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Se	Zn
Spring	1	0.0008	0.0022	0.0017	0.0021	0.1259	0.022	0.0015	0.0021	ND	ND	0.0386
	2	0.0006	0.0029	0.0004	0.0013	ND	0.0113	0.0033	0.0023	ND	ND	0.0156
	3	0.0004	0.0018	0.0005	0.00005	ND	0.0094	0.0037	0.0019	ND	0.0004	0.0179
	4	0.0005	0.0016	0.0002	ND	ND	0.0092	0.0033	ND	ND	ND	0.0106
	5	0.0004	0.0036	0.0013	ND	0.0969	0.1584	0.003	0.0053	0.0008	ND	0.0131
Summer	1	0.0005	0.0015	0.0001	0.0016	ND	0.0106	0.0013	0.0012	ND	ND	0.0099
	2	0.0005	0.0032	0.0004	ND	0.0049	0.0618	0.0043	0.0004	ND	ND	0.0136
	3	0.0006	0.0021	0.0003	ND	ND	0.0616	0.0026	0.0012	ND	0.0063	0.0079
	4	0.0005	0.0023	0.0003	ND	ND	0.0094	0.0015	0.0016	ND	ND	0.011
	5	0.0005	0.0049	0.0009	ND	0.0117	0.0109	0.0019	0.0095	ND	ND	0.0036
Autumn	1	0.0003	0.0019	0.0003	0.0013	ND	0.031	0.0025	0.0014	ND	ND	0.0265
	2	0.0005	0.002	ND	ND	ND	0.0092	0.0038	0.0027	ND	ND	0.0191
	3	0.0008	0.0016	0.0006	ND	ND	0.0284	0.0021	0.00002	ND	ND	0.0267
	4	0.0005	0.0025	0.0001	ND	ND	0.0554	0.0016	0.0004	ND	ND	0.0194
	5	0.0006	0.0022	0.0002	ND	ND	0.0175	0.0049	ND	0.001	ND	0.0507
Winter	1	0.0005	0.0023	ND	ND	ND	0.0087	0.0036	0.0015	ND	ND	0.0074
	2	0.0004	0.0012	0.0004	ND	0.0911	0.0124	0.0042	0.0008	0.0002	ND	0.0034
	3	0.0005	0.0024	ND	ND	0.0167	0.0116	0.0049	0.0017	ND	ND	0.0009
	4	0.0005	0.002	0.00006	ND	ND	0.0101	0.0041	0.0012	ND	ND	ND
	5	0.0008	0.0025	0.0002	ND	ND	0.0085	0.0044	0.002	ND	0.0063	0.0015
Annual Mean	1	0.0005^{a*}	0.002^{b}	0.0005^{a}	0.0013^{a}	0.0314^{a}	0.0181^{a}	0.0022^{a}	0.0016^{ab}	ND	ND	0.0206^{a}
	2	0.0005^{a}	0.0023^{ab}	0.0003^{a}	0.0003^{b}	0.024^{a}	0.0237^{a}	0.0039^{a}	0.0015^{ab}	0.00005^{b}	ND	0.0129^{a}
	3	0.0006^{a}	0.002^{b}	0.0003^{a}	0.00001^{b}	0.0041^{a}	0.0278^{a}	0.0033^{a}	0.0012^{ab}	ND	0.0016^{a}	0.0133^{a}
	4	0.0005^{a}	0.0021^{b}	0.0001^{a}	ND**	ND	0.021^{a}	0.0026^{a}	0.0008^{b}	ND	ND	0.0102^{a}
	5	0.0006^{a}	0.0033^{a}	0.0006^{a}	ND	0.0271^{a}	0.0488^{a}	0.0035^{a}	0.0042^{a}	0.0004^{a}	0.0015^{a}	0.0172^{a}

*Averages indicated by different letters in the same column are statistically different ($p<0.05$) ** ND: Not Detected <0,0001 mg/kg

Table 3. Seasonal and annual average heavy metal values of sediment taken from Eber Lake stations (mg/kg)

Season	Station	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Se	Zn
Spring	1	0.3624	1.5429	29.012	25.6042	12424.48	192.0395	1.9669	46.3045	12.7267	3.0274	66.4788
	2	0.1667	0.2767	11.862	10.169	5368.347	353.9277	1.3607	19.6738	5.0009	2.374	31.3378
	3	0.133	0.3842	5.0594	5.5892	3285.455	533.6344	1.5259	15.8469	3.6497	0.2635	25.0848
	4	0.1665	0.5154	10.0565	11.0674	4382.358	355.7712	2.0979	19.8341	5.3219	1.5143	32.2830
	5	3.1074	0.6269	27.3750	29.9756	9778.956	200.8294	2.0909	25.9991	10.2345	2.5967	91.1524
Summer	1	0.275	1.796	41.1762	25.5576	13331.67	180.9605	1.4054	22.3749	12.272	2.5117	51.4702
	2	0.1666	0.3846	14.4272	12.6427	6621.718	224.6447	2.27	23.625	5.8811	0.5383	27.5589
	3	0.115	0.3537	12.0906	10.6679	5034.166	319.7483	1.4291	14.5262	5.7035	1.9036	22.1982
	4	0.1006	0.3186	5.5649	6.8079	2633.244	417.6687	1.2943	13.9233	3.4189	ND	15.6252
	5	3.8949	0.6504	30.7425	24.7902	14524.79	246.2176	0.907	31.1456	14.63	ND	64.3621
Autumn	1	0.2843	0.3909	25.7425	26.7874	15864.94	303.2335	1.3804	25.9143	12.2412	2.0762	51.2592
	2	0.1966	0.5485	13.7591	17.1517	8835.225	416.925	3.2159	21.7762	8.0622	0.9626	31.8664
	3	0.1257	0.7858	6.0432	9.159	4620.155	775.2915	2.5177	13.29	5.3555	2.3851	20.6419
	4	0.1129	0.9328	4.6858	7.1566	3551.377	710.626	2.4275	10.7329	4.69	ND	18.5806
	5	5.6435	0.8497	34.7876	32.1933	16245.84	267.4343	1.3892	36.064	17.1591	2.2285	78.9697
Winter	1	0.3072	0.671	14.8066	18.9685	13707.47	457.6013	3.3277	18.2166	11.7165	2.1832	45.3732
	2	0.198	0.8413	14.5196	15.0903	7548.085	429.8555	2.0681	17.6466	10.1386	2.1119	33.243
	3	0.1238	0.619	5.3709	8.0475	3971.337	613.7977	2.2252	10.525	5.7073	ND	20.3113
	4	0.1585	0.557	10.2756	16.6193	5474.896	600.4953	2.1735	19.0524	7.5022	0.6107	24.5946
	5	0.9725	0.6896	33.485	26.4259	16199.74	371.3087	1.2465	30.1273	17.194	1.6401	65.0904
Annual Mean	1	0.3072^{b*}	1.1002^{a}	27.6844^{a}	24.2294^{a}	13832.14^{a}	283.4587^{b}	2.0201^{a}	28.2026^{a}	12.2393^{a}	2.4496^{a}	53.6453^{b}
	2	0.182^{b}	0.5128^{a}	13.642^{b}	13.7634^{b}	7093.34^{c}	356.3382^{ab}	2.2287^{a}	20.6804^{a}	7.2707^{b}	1.4967^{ab}	31.0015^{c}
	3	0.1244^{b}	0.5357^{a}	7.1410^{b}	8.3659^{b}	4227.77^{b}	560.618^{a}	1.9245^{a}	13.547^{a}	5.104^{b}	1.138^{ab}	22.0591^{c}
	4	0.1347^{b}	0.581^{a}	7.6457^{b}	10.4128^{b}	4010.46^{b}	521.1403^{a}	1.9983^{a}	15.8857^{a}	5.2332	0.5312^{ab}	22.7709^{c}
	5	3.404^{a}	0.7041^{a}	31.5976^{a}	28.3462^{a}	14187.33^{a}	271.4475^{b}	1.4084^{a}	30.834^{a}	14.8044^{a}	1.6163^{b}	74.8936^{a}

*Averages indicated by different letters in the same column are statistically different ($p<0.05$) ** ND: : Not Detected <0,0001 mg/kg

Table 4. Heavy metals concentrations in different tissues of *Carassius gibelio* (Bloch, 1782) from Eber Lake (mg/kg, dry weight)

Season	Tissue	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Se	Zn
Spring	M-	0.0358^{*a}	0.1147^{bc}	0.7989^{a}	0.9949^{bc}	50.9^{d}	1.9283^{d}	0.085^{abc}	0.583^{ab}	0.017^{b}	ND	26.3751^{c}
	S.D.	0.0091	0.0391	0.6953	1.075	16.8372	0.4069	0.0624	0.5326	0.0188	-	6.0022
	G-	0.0479^{a}	0.0987^{bc}	0.6727^{ab}	1.2879^{bc}	121.38^{bc}	8.2728^{c}	0.0832^{abc}	0.4237^{bc}	0.0095^{b}	0.0354^{b}	127.2273^{a}
	S.D.	0.0167	0.0485	0.3507	0.6106	30.9984	3.6508	0.053	0.1373	0.0005	0.0054	46.9508
	L-	0.0443^{a}	0.2206^{a}	0.4803^{abc}	1.6975^{b}	182.0846^{a}	1.5688^{d}	0.1511^{ab}	0.7328^{a}	0.0876^{a}	0.1553^{ab}	84.3947^{ab}
	S.D.	0.0167	0.2107	0.1621	0.9208	33.7451	0.2511	0.1634	0.3429	0.0912	0.069	21.1185
Summer	M-	0.0352^{a}	0.1203^{bc}	0.775^{a}	1.1367^{bc}	21.0209^{d}	1.6744^{d}	0.0848^{abc}	0.1735^{cd}	0.0328^{b}	0.0552^{b}	15.147^{c}
	S.D.	0.0116	0.0274	0.782	0.418	13.9103	1.179	0.0179	0.0118	0.008	0.0552	1.7352
	G-	0.0542^{a}	0.1378^{abc}	0.5258^{abc}	0.4144^{c}	39.0372^{d}	6.067^{c}	0.0507^{c}	0.1819^{cd}	ND	ND	50.3372^{bc}
	S.D.	0.0008	0.0112	0.0705	0.1155	12.7286	1.3584	0.0307	0.1265	-	-	3.0521
	L-	0.0346^{a}	0.11098^{bc}	0.3534^{abc}	1.0031^{bc}	167.192^{ab}	1.6248^{d}	0.1773^{a}	0.1677^{cd}	ND	0.1221^{ab}	112.369^{a}
	S.D.	0.0031	0.0991	0.009	0.2674	10.9506	0.0309	0.0635	0.0475	-	0.0849	23.0366
Autumn	M-	0.0598^{a}	0.1415^{abc}	0.1188^{c}	0.6691^{c}	11.3897^{d}	1.1452^{d}	0.0633^{bc}	0.0039^{d}	ND	0.0981^{b}	15.0727^{c}
	S.D.	0.0725	0.0425	0.0467	0.1709	4.1343	0.1696	0.0066	0.0117	-	0.0849	2.1739
	G-	0.0448^{a}	0.1227^{bc}	0.358^{abc}	0.6605^{c}	107.194^{c}	14.7615^{a}	0.0997^{abc}	0.1224^{d}	0.0124^{b}	0.1038^{b}	52.5166^{bc}
	S.D.	0.0164	0.0384	0.0771	0.1177	54.757	4.3054	0.0546	0.1402	0.0264	0.0809	8.2681
	L-	0.0408^{a}	0.0716^{c}	0.1156^{c}	1.4625^{bc}	208.079^{a}	1.1771^{d}	0.0895^{abc}	0.0702^{d}	0.011^{b}	ND	29.6267^{c}
	S.D.	0.0153	0.0173	0.0613	0.2964	68.36	0.2337	0.0683	0.1524	0.0031	-	3.2853
Winter	M-	0.0388^{a}	0.1685^{ab}	0.1468^{c}	1.0723^{bc}	13.9041^{d}	1.0921^{d}	0.0752^{bc}	0.0552^{d}	0.05^{ab}	0.336^{a}	17.6810^{c}
	S.D.	0.005	0.0089	0.0475	0.2871	0.1977	0.0809	0.0229	0.0054	0.005	0.1939	2.8817
	G-	0.0475^{a}	0.0766^{c}	0.2112^{bc}	0.74234^{c}	60.4995^{d}	11.7071^{b}	0.0943^{abc}	ND**	ND	0.0072^{b}	57.6319^{bc}
	S.D.	0.0099	0.0173	0.0561	0.0265	3.4687	0.694	0.0042	-	-	0.0041	2.2548
	L-	0.0199^{a}	0.0894^{bc}	0.0877^{c}	2.1995^{a}	126.127^{bc}	1.1999^{d}	0.0742^{bc}	ND	ND	ND	24.9595^{c}
	S.D.	0.0017	0.0415	0.0072	0.6344	39.585	0.054	0.0448	-	-	-	4.1375

*Averages indicated by different letters in the same column are statistically different ($p<0.05$) ** ND: Not Detected <0,0001 mg/kg

DISCUSSION

At all stations and in all season the heavy metal values for all metals except Mn were first class according to the Turkish water quality control regulations (WPCR) and were found to be under the limit values according to EPA (Environmental Protection Agency) (EPA, 2018) and European Communities (EC, 2006). During the spring season Pb and Se were detected only at one station, while Cu was detected at two and Fe at three stations. Ni was not detected only at the fourth station. In the summer, Cu and Se could be detected only at one station while Fe could be detected at two stations. Pb was not detected at any of the stations (Table 2). In this research, the Mn was the most recorded metal in the water of the Lake Eber, and it was followed respectively by Fe, Zn, Mo, Co, Ni, Se, Cd, Cr, Cu and Pb. In this study, metals generally reach their highest values in warm seasons, while these values decrease in winter months. Comparing this study to the study conducted on the Lake Kovada (Kayrak and Tekin-Özan, 2018) and the Pondicherry Lake (Satheeshkumar and Senthilkumar 2011) in this study Mn and Fe were the most detected elements in the water. The high Mn accumulation is of anthropogenic origin due to the discharge of the Akarçay river.

In this study, Fe was the mostly recorded metal in the sediment, and followed respectively by Mn, Zn, Ni, Cr, Cu, Pb, Se, Mo, Cd, Co. Comparing to the studies which were carried out on Aktan and Tekin-Özan (2012), Habbaniya (Al-Saadi *et. al.*, 2002) and Hazar Lake (Karadede-Akın, 2009) also in this research Fe then Mn were the most observed metals in the sediment. Barlas *et al.*, (2005) reported the highest mean levels metals Cu (1.19 mg/kg), Cr (4.88 mg/kg), Pb (2.39 mg/kg), Cd (0.12 mg/kg) and Ni (8.93 mg/kg) in May 2002 in sediment samples. The highest concentration of Zn (8.36 mg/kg) was recorded in September 2002. The excess amount of Fe in the sediment of the river and lake can be explained with the fact that the Fe is the most often observed metal within the Earth's crust.

In present study, the amount of metals in the sediment as a state bonding to the metal has varied but in general the highest accumulation was observed at the fifth station. This can be caused by two reasons: one of them is the fact that Akarçay, which is one of the main source feeding the lake, enters the lake by being subjected to organic and industrial waste and the other one is the collapse of the suspended solids onto the sediment which bind the metals in the water (Kıvrak.and Uygun, 2012; Gümüş, 2021)

The amounts of Zn was determined between 4.2504 and 127.2273 mg/kg. In all seasons, the amount of Zn which was obtained from the muscle tissue was below the acceptable limit values of the Turkish Food Codex 50 mg/kg and FAO 40 mg/kg (FAO, 1989; TFC 2011). Significant difference was determined in the Zn values within the fish tissue ($p<0.05$). The Zn concentration of some fish was reported as 1.25–1.32 mg/l 100 g Zn by Özyurt *et al.*, (2009). Nawaz *et al.*, (2010) determined the levels of Cd, Pb, Hg, Zn, and Cu as 0.35–0.45, 2.1–3.0, 37.85–40.74, and 1.39–2.93 mg/kg in freshwater fish species of the River Ravi in Pakistan. *Malik et al.*, (2010) stated that in Lake Bhopal (India) the majority of the metals accumulated in the liver of the *Labeo rohita* and *Ctenopharyngodon idella* species while the least of the metals accumulated in the muscles. Zn accumulated at the highest percentage among the metals while Hg was deposited at the lowest rate. Mohammadi *et al.*, (2011) determined that within the body of *Barbus grypus* which is living in River Karoon and Dez most of the metals accumulated within the liver while in *Barbus xanthopterus* the maximum concentration rate of the metals was determined in the gill. In this study the highest concentration of the heavy metals was detected in the gill and liver of the fish tissue. In the study conducted by Fidan *et al.*, (2008) on Lake Eber, some heavy metals were determined in the muscle, gills and liver tissues of the *Carassius carassius L.,* 1758 fish. The concentration of the metals in the tissue was the following muscle<gill <liver, the most accumulated metal was Fe and Zn. Altundağ *et al.,* (2019) found the following levels of Cu<Fe<Zn in muscle tissue of carp caught from the Sapanca Lake. Uysal, (2010) the Zn level in which the highest Zn accumulation in the tissues of the *C. carpio*, *Carassius carassius* and *Rutilus rutilusspecies* were found in the gill tissue. These data showed similarities with the data which was obtained in our study. According to this study in *Carassius gibelio* (Bloch, 1782) fish the highest concentration of Co, Mo, Ni, Cu, Fe, Pb, metals were determined in the liver, while the maximum concentration of Mn and Zn were detected in the gill tissue and the highest level of Cd, Cr and Se were determined within the muscle tissue. According to the findings obtained from Lake Eber the accumulation of the metals varied according to the tissue and to the type of the metal. Canpolat and Catla (2003) reached the highest values for heavy metals in the tissue of the *Capoeta capoeta umbla* fish during the spring. These results are in line with the data obtained in our study.

CONCLUSIONS

The water and sediment quality of Lake Eber and the River Akarçay which feeds the lake with agricultural pollutants are under the influence of Afyonkarahisar's industrial and municipal discharges. The water of Lake Eber was found in normal quality except the Mn element according to criteria of WPCR, EPA and EC. In the sediment all the metals except of Cd remained below the toxic effect value given by MacDonald. The highest value of all the metals except Zn in spring was found in the sediment. The water and sediment quality of Eber Lake is affected by agricultural, industrial, and domestic discharges from Afyonkarahisar. According to the heavy metal bioaccumulations detected in tissues of the *Carassius gibelio* species, Eber Lake's biotic components are also adversely affected by anthropogenic activities. The results of the heavy metals within the muscle tissue of the *Carassius gibelio* fish were compared to the quality criteria of the Turkish Food Codex and FAO and it was observed that they remained below the limit values. In the fish tissue the highest values for heavy metals were observed in the liver and gill tissue. According to these results although there was not a conclusion which could cause risk in the biotic and abiotic factors considering the fact that some of the values exceeded the limit values and the anthropogenic activities in Lake Eber increased gradually recently, reveals the need to subject the biotic and abiotic factors to continuous monitoring.

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