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RESEARCH ARTICLE

Investigation of As, Cu, Fe, Ni and Zn Concentrations of Some Potentially Toxic Elements in Water, Sediment and Gill Tissues of Different Trout Species (Salmo Trutta and Oncorhynchus Mykiss) and Shabut (Tor Grypus) Fish in Atatürk Dam Lake

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ABSTRACT

In this study, the accumulation concentration of copper (Cu), iron (Fe), nickel (Ni), zinc (Zn), and arsenic (As) in water, sediment, and gill tissues of brown trout (Salmo trutta), rainbow trout (Oncorhynchus mykiss), and shabut (Tor grypus) fish in Atatürk Dam Lake were evaluated by ICP-MS. Regarding Fe and Ni accumulation, the difference between rainbow trout and other species was found to be statistically significant ($p<0.05$). In terms of Cu and Zn accumulation, it was determined that the difference between Brown trout and other species was statistically significant, and the concentration of As accumulation was less and statistically significant ($p<0.05$). In shabut fish, it was determined that Fe accumulation in terms of weight was statistically significant ($p<0.05$) and As and Cu accumulated more than other fish gills ($p<0.05$). In water samples, it was determined that the concentration of Cu and Fe (1. and 3. regions) were above the reference values according to the reference values of the surface water quality regulation of the Republic of Turkey, and the concentration of Fe was above the reference limits set by the World Health Organization (2022). In sediment samples, Cu and Fe concentration were found to be above the serious and toxic effect reference values. As a result, it was observed that metals accumulated in gill samples of different fish species living in Atatürk Dam at different rates depending on the species, and the concentration of Fe and Cu were high in sediment and Fe in water samples.

Keywords: Fish, ICP-MS, PTEs (Potentially Toxic Elements), sediment, water

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Atatürk Baraj Gölü'nde Su, Sediment ve Farklı Alabalık Türleri (Salmo Trutta ve Oncorhynchus Mykiss) ve Şabut (Tor Grypus) Balıklarının Solungaç Dokularındaki Bazı Potansiyel Toksik Elementlerin As, Cu, Fe, Ni ve Zn Konsantrasyonlarının Araştırılması

ÖZ

Bu çalışmada, Atatürk Baraj Gölü'nde su, sediment ve kahverengi alabalık (Salmo trutta), gökkuşağı alabalık (Oncorhynchus mykiss) ve şabut (Tor grypus) balıklarının solungaç dokularındaki bazı metallerin; bakır (Cu), demir (Fe), nikel (Ni), çinko (Zn) ve arsenik (As) birikim konsantrasyonları ICP-MS cihazıyla değerlendirilmiştir. Gökkuşağı alabalıklarında uzunluk bakımından sadece Cu birikiminin istatistiki açıdan önemli olduğu görülmüştür ($p<0,05$). Birecik bölgesinden toplanan gökkuşağı alabalık solungaçlarında Fe miktarının diğer bölgelere göre daha yüksek olduğu belirlenmiştir ($p<0,05$). Fe ve Ni birikimi bakımından Gökkuşağı balıklarında diğer türler ile arasındaki farkın istatistiki olarak önemli olduğu tespit edilmiştir ($p<0,05$). Cu ve Zn birikimi bakımından Kahverengi alabalıklarında diğer türler ile arasındaki farkın istatistiki olarak önemli olduğu ve As birikim miktarının ise daha az olduğu ve istatistiki olarak önemli olduğu tespit edilmiştir ($p<0,05$). Şabut balıkları solungaçlarında ağırlık bakımından Fe birikiminin istatistiki açıdan önemli olduğu ($p<0,05$) ve As ve Cu'ın diğer balık solungaçlarından daha fazla biriktiği belirlenmiştir ($p<0,05$). Su örneklerinde; Türkiye Cumhuriyeti yer üstü su kalitesi yönetmeliğinin referans değerlerine göre Cu ve Fe miktarlarının referans değerlerinin üzerinde olduğu, Fe miktarının ise Dünya Sağlık Örgütü (2022) ve Avrupa Birliği Komisyonu (2008) 'nun belirlediği referans limitlerinin üzerinde olduğu belirlenmiştir. Sediment örneklerinde; Cu ve Fe miktarlarının ciddi ve toksik etki referans değerlerinin üzerinde olduğu belirlenmiştir. Sonuç olarak; Atatürk barajında yaşayan farklı alabalık türlerine ait solungaç örneklerinde metallerin türe göre farklı oranlarda biriktiği, su ve sediment örneklerinde de Fe ve Cu miktarlarının genel olarak yüksek çıktığı görülmüştür.

Anahtar kelimeler: ICP-MS, balık, su, sediment, PTEs (Potansiyel Toksik Elementler)

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INTRODUCTION

Water pollution is becoming an important problem today due to the increase in population rate and the development of technology and industry. Metals transported into water by anthropogenic activities, natural events and dead organisms settle over time and accumulate in sediment and pass back into the water environment (Ercişli, 2016). Aquatic organisms such as sediment, water and fish are used in the determination of metal pollution in aquatic ecosystems and it has been reported that metal accumulation and effects are not the same in every fish and vary according to the type of metal, the concentration of accumulation, the duration of the effect, the age, reproduction period, nutrition and habitat of the organisms (Çetin et al. 2016). Fish take metals mainly through the gills. Fish gills are important tissues in metal accumulation due to their high storage properties (Rajar et al., 2024). Iron (Fe), nickel (Ni), zinc (Zn) and copper (Cu) are essential metals (Yunusa et al., 2023; Singh and Sharma, 2024). Essential metals are necessary for growth and development in living organisms. Deficiency or excess of essential metals may cause undesirable effects in living organisms (Singh and Sharma, 2024). Arsenic (As) is a highly toxic heavy metal that has no essential biological role in living organisms (Hughes et al., 2011) and exists in normal water. Nickel (Ni), one of the essential metals, swells the gill lamellae, leading to increased oxygen consumption, respiratory stroke volume and respiratory frequency (Pane et al. 2003). It has been determined that Ni has both a vital role in iron (Fe) metabolism and a role in the absorption of iron from the intestines (Latund-Dada et al. 2006). Fe is an important trace element in zinc (Zn) hemostasis (Shim and Harris 2003). Zn, which tends to accumulate in the gills, initially increases mucus secretion in the gills and then decreases mucus, leading to increased susceptibility to microbial infections (Schelkle et al. 2009). Exposure to high concentration of Fe has also been reported to reduce the concentration of copper (Cu) transporters and eventually lead to a reduction in Cu absorption (Chandrapalan and Kwong, 2020). The presence of metals in sediment poses a threat to aquatic organisms through accumulation and biomagnification (Misra et al., 2024).

In this study, the accumulation concentration of As, Cu, Fe, Ni and Zn in gill tissue, water and sediment samples of brown trout, rainbow trout and shabut collected from Atatürk Dam Lake, one of the important water resources of the Southeastern Anatolia Region, were investigated by inductively coupled plasma mass spectrometry (ICP-MS).

MATERIALS and METHODS

Working Area

Atatürk Dam is located between Adıyaman and Şanlıurfa provinces and is used for energy and irrigation purposes and is also very important for the fishery sector (Duman and Çelik 2001).

Fish Sampling

The study was conducted in June and July without sex determination, taking into account the reproductive period of the fish. The approximate locations where the fish samples were collected are shown on the map (Figure 1). The fish samples used in the study were selected to be at least 500 to 1500 grams (g) (60 in total). The lifeless fish samples were placed in polypropylene containers and brought to the laboratory. The standard, fork and total lengths of the collected fish samples were measured on a measuring board with an error of ±1 mm and their weights were measured on a Weightlab brand precision balance and gill tissue samples were taken from the fish. Four water samples (10 ml) and four sediment samples (10 g) were also collected from the places where the fish samples were collected.

Figure 1: Areas where fish samples were collected.

Inductively Coupled Plasma Mass Spectrometry Analysis

The tissue samples were treated with 8 ml of 65% nitric acid followed by 3 ml of 30% hydrogen peroxide and placed in a Teflon reactor. Thermal incineration in the microwave was performed gradually at 130 ºC for 10 minutes, 150 ºC for 10 minutes and 180 ºC for 10 minutes. After incineration, distilled water was added to the ash and filtered through filter paper. Heavy metal analyses in the filtrate were measured by inductively coupled plasma mass spectrometry (ICP-MS, Perkin Elmer, Inc., Waltham, MA, USA) (Ütme and Temamoğulları 2021). The same procedure was applied to water and sediment samples. In the study, limit of detection (LOD) and limit of quantification (LOQ) values were determined as 0.05614 ppb and

0.1853 ppb for As; 0.04119 ppb and 0.136 ppb for Cu; 1.41 ppb and 4.653 ppb for Fe; 0.0188 ppb and 0.062304 ppb for Ni; 1.042 ppb and 3.4386 ppb for Zn, respectively. Correlation coefficient (R^2) values in the calibration equation were found as 0.9998 for Fe; 0.9999 for Ni; 0.9998 for Zn; 0.9999 for Cu; 0.9974 for As, respectively. Relative standard deviation (RSD) value in the calibration equation was as 3.7 for Fe; 9.8 for Ni; 4.1 for Zn; 4.7 for Cu; 8.7 for As, respectively. Recovery study was found as 99.87 for Fe; 102.64 for Ni; 99.35 for Zn; 100.82 for Cu; 100.06 for As, respectively.

Statistical Analysis

Differences between normally distributed groups were analyzed by one-way analysis of variance (ANOVA) and the significance of the differences was checked by post hoc Duncan test. This two test were performed to determine the relationship between the weight and length of the fish and the accumulated heavy metals in the gills. SPSS version 23 for Windows (IBM Corp., Armonk, NY, USA) was used for statistical analysis. $p<0.05$ was considered statistically significant. Results are presented as mean ± standard error of the mean (S.E.M.).

RESULTS

As a result of the study, it was observed that different concentration of heavy metal accumulation were found in the gill tissues of rainbow trout, brown trout and shabut fish (Table 1). It was determined that the difference in Fe and Ni in the gills between brown trout and shabut fish species was statistically insignificant ($p>0.05$), while the difference between rainbow fish and these species was statistically significant ($p<0.05$). Ni was found to accumulate less in rainbow trout than in other fish species. It was determined that Fe, Ni, Zn and Cu, except As, accumulated less in the gill samples of rainbow trout. It was determined that the concentration of As was similar between Rainbow trout and Shabut fish species; and the concentration of As accumulation in Brown trout was less and statistically significant ($p<0.05$). The difference in Cu and Zn accumulation in brown trout compared to other fish gills was statistically significant ($p<0.05$). In terms of the concentration of Cu accumulation in the gills, it was determined that Shabut > Brown trout > Rainbow trout, respectively, and the difference between all species was statistically significant ($p<0.05$). In terms of the concentration of Zn accumulation in the gills, it was determined that Brown trout > Shabut > Rainbow trout, respectively, and the difference was statistically significant. It was determined that As and Cu accumulated more in the gills of shabut than in the gills of other fish ($p<0.05$). In addition it was observed that as the concentration of Cu, Fe, Ni, Zn and As in the water and sediment environment increased, the amount of accumulation in the gill tissues of fish increased.

Table 1. Potentially toxic elements, ppb, mean ± SEM.

Groups	Rainbow Trout	Brown Trout	Shabut	P<0.05
Fe±SEM	3387.26^{a}±275.04	73046.18^{b}±14832.11	51711.22^{b}±3381.78	0.000
Ni±SEM	5.422^{a}±0.48	99.105^{b}±16.23	76.97^{b}±10.21	0.000
Zn±SEM	4036.33^{a}±172.18	112768.71^{c}±8601.24	23561.50^{b}±1117.33	0.000
As±SEM	172.51^{b}±17.57	72.61^{a}±5.32	232.66^{b}±51.63	0.003
Cu±SEM	296.57^{a}±15.91	502.76^{b}±25.76	706.72^{c}±36.71	0.000

The difference between the averages Decribed with different letters in the same row is significant ($p<0.05$).

In Table 2, it was observed that there was no statistically significant difference ($p>0.05$) in the concentration of As, Cu, Fe, Ni and Zn in the gill tissue samples of rainbow trout examined based on weight, while only Cu accumulation was statistically significant in terms of length ($p<0.05$). In addition, it was determined that the concentration of Fe in rainbow trout gills collected from Birecik region was higher than the other regions, and this difference was statistically significant ($p<0.05$). In Table 2, it is seen that there is no statistically significant difference ($p>0.05$) in the concentration of As, Cu, Fe, Ni and Zn in the gill tissue samples of brown trout analyzed according to weight, length and regions where the samples were collected.

In Table 2, it was determined that there was no statistically significant difference ($p>0.05$) in the concentration of Fe and Ni in the gill tissue samples of shabut fish according to weight and length, the difference in the concentration of Fe was not statistically significant in terms of length, the difference was statistically significant ($p<0.05$) in terms of weight (600-1110g); the difference in terms of metal accumulation between the regions where the samples were collected was not statistically significant ($p>0.05$).

Table 2. The concentration of potentially toxic elements in the gill tissues of fish caught from Atatürk Dam Lake. ppb. average ± SEM.

Species	Parameters		N	Fe	Ni	Zn	As	Cu	p<0.05
Rainbow trout (Oncorhynchus Mykiss)	Weight(g)	500-699	5	3977.38±785.52	5.92±1.31	4365.16±448.58	158.24±58.46	297.88±21.21	Fe:0.091
		700-799	5	4152.9±490.61	5.49±0.42	4054.44±381.57	192.70±22.92	338.60±37.24	Ni:0.937
		800-1100	5	2620.2±230.82	5.23±0.77	3888.3±271.38	184.38±8.58	283.96±33.15	Zn:0.731
		1101-1400	5	2798.56±242.79	5.03±1.33	3837.42±316.76	154.74±39.80	265.84±34.04	As:0.857
		Total	20	3387.26±275.04	5.42±0.48	4036.33±172.18	172.51±17.57	296.57±15.91	Cu:0.447
	Length(cm)	32-37	10	3634.1±412.02	5.59±0.68	3987.74±260.54	178.45±30.05	332.85±18.85	Fe:0.384 Ni:0.728
		38-43	10	3140.42±368.91	5.24±0.7	4084.92±238.26	166.58± 19.82	260.29±20.52	Zn:0.786
		Total	20	3387.26±275.04	5.42±0.48	4036.33±172.18	172.515±17.57	296.57±15.91	As:0.745 Cu:0.018
	Area	Birecik	10	3940.79±471.13	5.58±0.65	4242.57±278.31	191.01±24.33	309.19±26.16	Fe:0.040 Ni:0.743
		Bozova	10	2833.73±171.32	5.25±0.73	3830.09±195.61	154.02±25.22	283.95±18.69	Zn:0.241
		Total	20	3387.26±275.04	5.42±0.48	4036.33±172.18	172.51±17.57	296.57±15.91	As:0.305 Cu:0.443
Brown Trout *(Salmo Trutta)*	Weight(g)	600-799	10	52388.82±5214.93	94.03±22.56	121842.15±11699.29	73.29±5.18	473.69±28.48	Fe:0.170 Ni:0.764
		800-999	10	93703.54±28404.74	104.18±24.46	103695.28±12537.83	71.94±9.63	531.84±42.47	Zn:0.304
		Total	20	73046.18±14832.11	99.1±16.23	112768.71±8601.24	72.61±5.32	502.76±25.76	As:0.903 Cu:0.270
	Length(cm)	27-32	10	53537.38±5358.46	92.42±24.58	112480.13±10866.9	66.55±5.16	485.53±28.07	Fe:0.196 Ni:0.692
		33-38	10	92554.98±28668.07	105.79±22.32	113057.3±13937.63	78.68±9.21	520.00±44.15	Zn:0.974
		Total	20	73046.18±14832.11	99.1±16.23	112768.71±8601.24	72.61±5.32	502.76±25.76	As:0.266 Cu:0.518
	Area	Birecik	10	46982.52±5054.56	87.7±23.18	116236.54±13361.42	73.79±5.21	458.57±29.43	Fe:0.078 Ni:0.497
		Bozova	10	99109.84±27428.91	110.51±23.38	109300.89±11452.75	71.44±9.60	546.96±38.77	Zn:0.698
		Total	20	73046.18±14832.11	99.1±16.23	112768.71±8601.24	72.61±5.32	502.76±25.76	As:0.832 Cu:0.086

Table 2-Continuation. The concentration of potentially toxic elements in the gill tissues of fish caught from Atatürk Dam Lake. ppb. average ± SEM.

									Fe:0.039
		600-1110		44862.55±4757	66.36±15.49	23556.33±1674.27	294.77±99.53	651.67±37.09	Ni:0.311
		1115-1625	10	58559.89±3903.19	87.58±13.22	23566.68±1570.98	170.55±22.21	761.78±60.35	Zn:0.996
	Weight(g)	Total	10	51711.22±3381.78	76.97±10.20	23561.50±1117.33	232.66±51.63	706.72±36.71	As:0.239
			20						Cu:0.138
									Fe:0.422
		40-52	10	48905.92±3737.61	75.95±13.99	22988.66±1212.54	289.50±93.38	661.42±35.18	Ni:0.924
	Length(cm)	53-65	10	54516.52±5706.89	77.99±15.61	24134.35±1930.80	175.82±42.66	752.03±63.23	Zn:0.621
Shabut		Total	20	51711.22±3381.78	76.97±10.20	23561.50±1117.33	232.66±51.63	706.72±36.71	As:0.283
(Tor Grypus)									Cu:0.227
									Fe:0.857
		Birecik	10	51077.48±6655.34	67.28±15.13	23601.68±2012.22	261.25±102.78	708.99±73.39	Ni:0.356
	Area	Bozova	10	52344.96±1975.94	86.66±13.78	23521.33±1105.34	204.07±22.60	704.46±17.43	Zn:0.972
		Total	20	51711.22±3381.78	76.97±10.20	23561.50±1117.33	232.66±51.63	706.72±36.71	As:0.594
									Cu:0.953

N: Number of Group Samples.

The concentration of As, Cu, Fe, Ni, Ni and Zn in water and sediment samples taken from the places where fish samples were collected during the study are given in Table 3. It was determined that the concentration of Fe and Cu were generally high in the water samples and especially Bozova Ni (1st and 2nd region) and Zn (2nd region) metals were below the detection limits. According to the reference values of the surface water quality regulation of the Republic of Turkey, it was determined that the concentration of Cu (1, 2, 3 and 4 regions) and Fe (1 and 3 regions) were above the reference values, while the concentration of As, Ni and Zn were below the reference values. In our study, it was determined that the concentration of As, Cu, Ni and Zn in the water samples were below the reference limits determined by the World Health Organization (2022) and the European Commission (1998), while the concentration of Fe in the collected water samples was above WHO reference values (Table 3).

Table 3. The Fractions of As, Cu, Fe, Ni and Zn in water samples and recommended reference values(ppb).

Area	As	Cu	Fe	Ni	Zn
1	9.9	12.6	145.7	<0.000	13.8
2	9.3	19.8	11.4	<0.000	<0.000
3	8.6	9.5	144.6	0.4	39.7
4	9.3	17.5	34.4	0.2	5.6
Maximum allowable environmental quality standard (Yer üstü su kalitesi yönetmeliği, 2016)	53	3.1	101	34	231
WHO (2022)	10	2000	10	70	-
Directive of the Council of the European Union (1998)	10	2000	10	20	-

1 and **2**. Bozova district, **3** and **4**. Birecik district.

In addition, according to the heavy metal limits determined in sediment samples according to MacDonalds (2000), it was determined that Cu, Fe, Ni and Zn analyzed in our study were above the threshold effect value, but As was below the threshold reference value in all regions; Cu, Fe, Ni (1st, 2nd, 3rd region) and Zn (1st and 2nd region) accumulation were above the possible effect reference value, Ni (4th region), Zn (3rd and 4th region) and As in all regions were below the possible effect reference value. According to the serious and toxic effect reference values, it was determined that As, Ni and Zn were below these values in all regions, while Cu and Fe were above the serious and toxic effect reference values (Table 4).

Table 4. The Fractions of As, Cu, Fe, Ni and Zn in sediment samples and the recommended reference values (ppb).

Area	As	Cu	Fe	Ni	Zn
1	4941.78	2909064.10	4511931.96	41184.14	336847.20
2	5942.07	1712703.17	9930015.32	56969.78	358343.76
3	4924.13	2161277.37	4478824.61	36510.56	286369.51
4	4923.67	2784446.15	4213026.84	33961.20	307047.65
The Threshold Effect Value (Macdonald et al., 2000)	9790	31600	35800	22700	121000
Possible Impact Value (Macdonald et al., 2000)	17000	197000	913000	36000	315000
The Serious Impact Value (Macdonald et al., 2000)	33000	110000	250000	75000	820000
Toxic Effect Value (Macdonald et al., 2000)	17000	86000	170000	61000	540000

Threshold impact value: Below this value, it rarely causes an adverse effect; Potential effect concentration: Above this value, it will cause an adverse effect; Serious impact quantity: Sediment is contaminated with heavy metals and above this value causes a serious adverse effect on organisms living in the sediment; Toxic impact quantity: When the sediment contains high concentration of heavy metals and causes toxic effects on the organisms living in this sediment (MacDonald et al., 2000).

DISCUSSION

Water, sediment, and fish are mainly used in the risk assessment of water pollution (Esmaeilzadeh et al., 2023; Singh et al., 2024). In our country and the world, many studies have been carried out using water, sediment, and fish gills to evaluate the accumulation of metals that have an important role in water pollution (Oymak et al., 2009; Tashi et al., 2022).

In our research, it was determined that Cu accumulation was higher in rainbow trout gills (32-37 cm) and Fe accumulation was statistically significant ($p<0.05$) in the gills of 600 - 1110 gram shabut in terms of weight. It was determined that Ni in rainbow trout gills and As in brown trout gills accumulated less than the other two fish species ($p<0.05$). It was determined that As and Cu accumulation in shabut fish was higher than in other fish species ($p<0.05$). In general, it was determined that rainbow trout showed less accumulation of metals except As in the gills of Shabbut and brown trout.

Oymak et al. (2009) determined Cu 1230±350 ppb, Fe 88850±29610 ppb, Ni 350±140 ppb, and Zn 13350±5120 ppb in 12 gill samples of shabut collected from Atatürk Dam by ICP-OES (inductively coupled plasma-optical emission spectrometry). In this study, which we conducted with ICP-MS device in Atatürk Dam in 2023, it was determined that the concentration of Cu, Fe, and Ni were less in different gill samples of shabut fish, while the concentration of Zn increased. This difference in the concentration of Cu, Fe, Ni and Zn in the studies conducted in the same fish species can be explained by the difference in time and analyzers. Tashi et al. (2022) reported that Fe, Ni, and Zn contents (ppb) were 177100±36170, 59±14 and 11720±4700, respectively, and there was a positive correlation between length and Fe accumulation in 9 trout gills in Punatsang Chhu river in Bhutan using ICP-OES device. In our study, there was no correlation between Fe accumulation and length in rainbow trout gills. In addition, Fe and Zn were determined less in our study results than Tashi et al. (2022). In our study, metal accumulations in gill samples were found to be Zn > Fe > Cu > As > Ni in rainbow trout, Zn > Fe > Cu > Ni > As in brown trout and Fe > Zn > Cu > As > Ni in Shabut fish, respectively. It is thought that this may be due to the concentration and duration of metal exposure of the samples used in the analysis, as well as the difference and sensitivity of the devices used.

Many researchers have stated that there are significant differences in heavy metal accumulation concentration between different species (Akgün 2007; Özvar 2020). They stated that the difference in metal accumulation in the gills may be due to the complexation of metals with mucus, which cannot be removed between the coverslips during the preparation of gill tissues for analysis, and the difference in the methods used (Yılmaz 2009). It has been reported that the reason for the difference in metal accumulations in fish may be due to differences in species, swimming behaviors, habitats, metabolic activity, feeding habits, age and size, and the methods and devices used in the analysis (Özvar 2020). Similarly, it is thought that the reason for the different the concentration of As, Cu, Fe, Ni and Zn in the gill tissues of different fish species may be due to the different methods and methods used in the analysis. In addition, Fe concentration in the gills of rainbow trout collected in Bilecik region were found to be high in our study. The heavy metal pollution detected in fish was thought to be due to the fact that Birecik region is more exposed to pollutants such as industrial and urban wastes.

Many studies have been conducted to determine heavy metal accumulation in Atatürk Dam water and sediment samples (Karadede and Ünlü 2000; Alhas et al., 2009; Ural et al. 2011; Uçkun et al 2017; Bayhan, 2021; Uçkun and Uçkun 2021). In our study, it was determined that Cu and Fe accumulated in sediment samples taken from the regions where fish gill samples were collected, was above the serious and toxic effect threshold values. In addition, it was determined that the concentration of Cu and Fe in the water samples taken from the regions where the sediment samples were taken, was high and Fe was above the limits set by WHO. Moreover, Cu (in all regions) and Fe (in regions 1 and 3) in the water samples were above the reference values according to TS regulation, but below the reference values of EU.

Karadede and Ünlü (2000) determined Fe > Zn > Cu > Ni concentration in Bozova sediment samples, Fe > Ni > Zn > Cu concentration in Akpınar sediment samples, Fe > Ni > Zn > Cu concentration in Bozova sediment samples, and Zn > Fe > Cu > Ni concentration in Akpınar sediment samples, respectively; Zn > Fe > Cu > Ni in Bozova water samples, Zn > Cu > Ni in Akpınar water samples, but they could not detect

Fe. They stated that Fe was the most abundant in sediment samples and Zn was more abundant in water samples. Alhas et al. (2009) stated that the concentration of Ni > Fe > Zn > Cu in Bagpinar (Adıyaman) and Akpinar (Adıyaman) sediment samples of Ataturk Dam were determined by ICP-OES device in Bagpinar (Adıyaman) and Cu > Ni > Fe > Zn in Akpinar (Adıyaman) and Cu and Ni could not be determined in water samples and Zn > Cu concentration were determined. Ural et al. (2011) reported that Fe was in higher concentrations in sediment (Fe > Ni > Zn > Cu) and water (Fe > Zn > Cu) samples collected from Atatürk Dam, but they could not detect Ni in water samples. Uçkun et al. (2017) determined the concentration of metals in sediment samples collected from Atatürk Dam by ICP-MS device as Zn > Fe > Cu > N i > As and Fe > Zn > Cu > Ni > As in water samples, respectively. In our study, Fe > Cu > Zn > Ni > As in sediment samples and Fe > Cu > Zn > As > Ni in water samples. Uçkun et al. (2017) also stated that heavy metals accumulated more in sediment samples than in water. In our study, it was observed that more metals accumulated in sediment than in water. Uçkun and Uçkun (2021) determined the concentration of Ni > Cu in sediment samples and Cu > Ni in water samples, respectively, with the ICP-MS device collected in Atatürk Dam lake. In a study conducted in Atatürk Dam waters, it was determined that the concentration of Zn and Ni was below 5 ppb and Fe was 200 ppb (Bayhan 2021). In our study, it was observed that the concentration of Zn (Region 2) and Ni in the water samples was compatible with the study of Bayhan (2021), but the concentration of Fe was higher than our study. In this study, more Fe was found in both water and sediment compared to other metals. When compared with Table 4, it was determined that the concentrations of Cu and Fe in sediment samples were above the serious and toxic effect values. It has been stated that heavy metal accumulation above the toxic effect value will have a negative effect on organisms living in the sediment (Mac Donalds. 2000).

Çağlan Kaya (2021) found the following average values for Cu and Zn in the collected water samples, respectively: 0.93 μg/L for Cu and 2.99 μg/L for Zn in Lake Beyşehir; 0.09 μg/L for Cu and 6.91 μg/L for Zn in Lake Eğirdir; 0.02 μg/L for Cu and 1.24 μg/L for Zn in Suğla Lake; 0.09 μg/L for Cu and 10.22 μg/L for Zn in Karataş Lake; 0.23 μg/L for Cu and 2.71 μg/L for Zn in Kovada Lake; 6.63 μg/L for Zn in Gölhisar Lake; 8.75 μg/L for Zn in Çivril Lake. In our study, the average values were 14.85 μg/L for Cu and 14.77 μg/L for Zn. In the same study Cu and Zn in collected sediment samples, respectively: 17.42 mg/kg for Cu and 53.62 mg/kg for Zn in Lake Beyşehir; 12.65 μg/L for Cu and 28.96 μg/L for Zn in Lake Eğirdir; 19.79 mg/kg for Cu and 50.06 mg/kg for Zn in Lake Çivril; 16. 30 mg/kg for Cu and 53.974 mg/kg for Zn; 25.86 mg/kg for Cu and 41.61 mg/kg for Zn in Karataş Lake; 50.90 mg/kg for Cu and 73.57 mg/kg for Zn in Kovada Lake; 23.42 mg/kg for Cu and 41.27 mg/kg for Zn in Gölhisar Lake. In our study, the average values were 23.91 mg/kg for Cu and 32.21 mg/kg for Zn. It is thought that the difference in the amount of accumulation detected may be due to regional differences.

Şengül (2024) found that Cu metal accumulated the most in the water of Gölova Dam Lake. In this study in Atatürk Dam Lake, it was observed that the accumulation level of Cu metal was high.

CONCLUSION

Although the Turkish Food Codex does not set a specific maximum limit value for the metals included in the study in fish meat, general food safety principles require that the concentration of metal accumulation should be at a concentration that does not harm human health. By keeping fish consumption at an appropriate concentration with a balanced and varied diet, it can be prevented from harming human health with substances such as Cu, Fe, Ni, Zn and As for which limit levels have not been determined yet. Atatürk Dam Lake, located on the Euphrates River, is home to various aquatic creatures and meets the fish and water needs of the people of the region. Monitoring of dam lake pollution is extremely important for environmental and public health. Considering all anthropogenic activities, the risk of metal accumulations in Atatürk Dam increasing in the future is quite high. Repetition of this study in Ataturk Reservoir at regular intervals is important for aquatic balance and human health.

Conflict of interest: The authors have no conflicts of interest to report.

Authors' Contributions: FT and OA contributed to the project idea, design and execution of the study. FT, OA and ZG contributed to the acquisition of data. FT and OA analysed the data. FT, OA and ZG drafted and wrote the manuscript. FT, OA and ZG reviewed the manuscript critically. All authors have read and approved the finalized manuscript.

Ethical approval: This study was carried out at Harran University Reserch Animals Application Center. This research was approved by The Ethics Committee of the Faculty of Veterinary Medicine, Harran University (HRUHADYEK, Ref No: 229988, Tarih: 07/2023)

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