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Research Article

Evaluation of Some Biomarkers in Carp (*Cyprinus carpio* Linnaeus, 1758) Depending on Water and Sediment Pollution of Atatürk Dam Lake

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Abstract
In this study, some environmental pollution parameters of Atatürk Dam Lake were evaluated with some biochemical data of carp living in the lake and consumed economically. Water, sediment and fish samplings were done simultaneously from Kahta and Bozova districts, where the Atatürk Dam Lake is located. Residue analyzes of various metals in water, sediment and muscle of carp samples were carried out together with some physicochemical parameters in the water. Total antioxidant capacity (TAC) and total oxidant scavenging capacity (TOSC) levels in the liver, and activities of Na^+/K^+ATPase, Mg^{2+}ATPase, Ca^{2+}ATPase were determined in the gill of the carp. As a result of the study, it was observed that Cd, Cr and Cu levels in the water, Cd and Cu levels in sediment and Pb and Cd levels in carp exceeded the maximum acceptable concentrations. Among the biochemical parameters, oxidative stress index and TOSC level were found significantly higher in the liver of the fish in Kahta compared to those in Bozova. Na^+/K^+ATPase activity was significantly inhibited in the gill of the fish in Kahta. When all these pollution parameters and biochemical data are evaluated together, it can be said that the water, sediment and carp of Kahta are more contaminated with toxic metals than those in Bozova, and the carp are under oxidative stress, so they may be a threat to the health of the consumers hunted from this region.

Keywords: Atatürk Dam Lake, total antioxidant capacity, ATPase, *Cyprinus carpio.*

Atatürk Baraj Gölü Su ve Sediment Kirliliğine Bağlı Olarak Sazanlarda (*Cyprinus carpio* Linnaeus, 1758) Bazı Biyobelirteçlerin Değerlendirilmesi

Öz
Bu çalışmada, Atatürk Baraj Gölü'nün bazı çevre kirliliği parametreleri, gölde yaşayan ve ekonomik olarak tüketilen sazanların bazı biyokimyasal verileri ile değerlendirildi. Atatürk Baraj Gölü'nün kıyısının olduğu Kahta ve Bozova ilçelerinden eş zamanlı su, sediment ve balık örneklemeleri yapıldı. Suda bazı fizikokimyasal parametrelerle birlikte su, sediment ve sazanların kas örneklerinde çeşitli metallerin kalıntı analizleri yapıldı. Sazanların karaciğer dokusunda toplam antioksidan kapasitesi (TAC) ve toplam oksidan süpürme kapasitesi (TOSC) seviyeleri, solungaç dokusunda ise Na^+/K^+ATPaz, Mg^{2+}ATPaz ve Ca^{2+}ATPaz aktiviteleri tayin edildi. Çalışmanın sonucunda, suda Cd, Cr ve Cu seviyelerinin, sedimentte Cd ve Cu seviyelerinin, sazanda ise Pb ve Cd seviyelerinin maksimum kabul edilebilir konsantrasyonları aştığı gözlendi. Biyokimyasal parametrelerden oksidatif stres indeksi ile TOSC seviyesi, Kahta'daki balıkların karaciğerinde Bozova'dakilere göre önemli derecede yüksek bulundu. Na^+/K^+ATPaz aktivitesi, Kahta'daki balıkların solungacında önemli oranda inhibisyona uğradı. Tüm bu kirlilik parametreleri ile biyokimyasal veriler birlikte değerlendirildiğinde, Kahta'nın su, sediment ve sazanlarının Bozova'dakilere göre toksik metallerle daha fazla kontamine olduğu ve sazanların oksidatif stres altında olduğu, dolayısıyla bu bölgeden avlanan tüketicilerin sağlığı için bir tehdit unsuru olabileceği söylenebilir.

Anahtar kelimeler: Atatürk Baraj Gölü, toplam antioksidan kapasite, ATPaz, *Cyprinus carpio.*

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1. Introduction

Atatürk Dam Lake is the largest dam lake of our country, built on the Euphrates River, with a surface area of 81700 ha, and is among the world's largest dams [1]. It was built for energy and irrigation purposes and economically important fish species have a very important place in meeting the nutritional needs of fisheries and local people [2]. The shores of Atatürk Dam include Adıyaman and Şanlıurfa provinces which have large agricultural areas and a dense population. The distances of Atatürk Dam Lake to Şanlıurfa and Adıyaman provinces are 65 km and 42 km, respectively. Kahta is the largest district of Adıyaman and has eastern and southeastern borders to the Euphrates River. Bozova is the district of Şanlıurfa, which is on the shore of Atatürk Dam and has the highest human activity around the dam [3]. Aquatic environments are heavily contaminated by pollution released from domestic, industrial and other man-made activities. Some pollutants can have a serious impact on the ecological balance of the aquatic environments [4]. Exposure of aquatic organisms to pollutants can affect not only the biological competencies of the organism but also human health, which depends on the organisms as a major source of protein [5]. Therefore, it is necessary to analyze some pollution-related biomarkers in aquatic organisms in order to fully evaluate the impact of environmental pollutants on the ecosystem [4, 6, 7].

Two approaches are proposed to evaluate the extent of the stress caused by environmental pollutants in organisms. The first relates to measuring the integrated state of total antioxidant capacity (TAC) [8, 9]. TAC is a measure of the amount of free radicals scavenged by a test solution used to find the total antioxidant capacity in biological samples [10]. The second parameter related to stress is the measurement of the total oxyradical scavenging capacity (TOSC). TOSC is a parameter used to measure the ability of the entire antioxidant system to scavenge free oxygen radicals. TAC and TOSC are useful biomarkers in predicting the biological responses of organisms against oxidative stress caused by xenobiotics [11]. In aquatic toxicology studies, changes in antioxidant enzyme activities are usually evaluated in the liver, an important organ involved in the detoxification of xenobiotics [12]. Adenosintriphosphatases (ATPases) are responsible for ion homeostasis in the cell, maintenance of the electrochemical gradient, and regulation of cell volume [13, 14]. Gills are responsible for osmoregulation in fish and have direct contact with contaminants in the water [15].

Atatürk Dam Lake is polluted by human activities, agricultural and industrial pollutants from the surrounding provinces. Common carp (*Cyprinus carpio* Linnaeus, 1758) is an important commercial species that appeals to large populations worldwide and is consumed economically. It is used as a bioindicator species in most studies associated with pollution in aquatic environments [16].

In this study, water samples were taken from the shore of Atatürk Dam Lake to Kahta and Bozova districts and their physicochemical parameters were measured. Besides, various metal residues were analyzed in water, sediment and muscle of fish samples taken from these regions. The pollution of these two regions was evaluated by TAC and TOSC analyzes in the liver, and ATPase analysis (Na^{+}/K^{+}ATPase, Mg^{2+}ATPase, Ca^{2+}ATPase) in the gill of the carp caught there.

2. Material and method

2.1. Sampling sites and sample collection

Kahta district within the borders of Adıyaman of the Atatürk Dam and Bozova districts within the borders of Şanlıurfa were selected as the sampling points (Figure. 1). These sites were determined considering the high population density compared to other districts, high human activities, and the mixing of domestic, agricultural and industrial wastes into the Atatürk Dam Lake. Fish, sediment and water samples were collected from these sites and taken to the laboratory. Eight fish from each area were caught by the fishermen in the region using the gill nets. Fish with an average length of 50 cm and a weight of 700 g were selected by eye decision and used in the experiments. Plastic gallons impregnated with 100 mg L^{-1} MS 222 were used to anesthetize the fish. Fish brought to the laboratory were dissected and their muscle, liver and gill tissues were separated and kept at -80 until analysis. Ethical approval document regarding all procedures to be applied to fish was approved by Adıyaman University Ethics Committee (Permissions no. 2021/007).

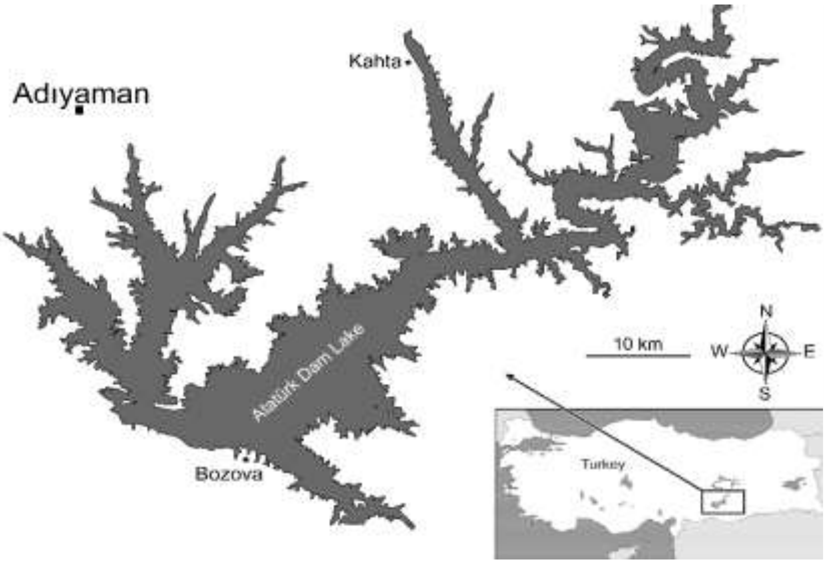

Figure 1. Map of the study area

2.2. Water quality and metal analyses

The temperature, pH, dissolved oxygen and conductivity of the water were measured with field type portable probe devices (YSI Pro20). All remaining analyses were conducted in Adıyaman University Central Research Laboratory. Ammonium, nitrite, nitrate, phosphate and sulphate levels in water were measured with commercial kits in a kit compatible spectrophotometer (DR/2010 Hachlange). Lead (Pb), nickel (Ni), mercury (Hg), chromium (Cr), zinc (Zn), cadmium (Cd) and arsenic (As) concentrations in muscle, sediment and water samples were measured using an inductively coupled plasma mass spectrometer (ICPMS) (NexION 350X, PerkinElmer, USA). The ICPMS operating conditions were the following: RF power, 1150 W; plasma gas f1ow rate, 18 L/min; auxiliary gas flow rate, 1.2 L/min; nebulizer gas flow rate, 0.84 L/min; sample uptake rate, 1 mL/min; integration time, 600 ms, triple cone interface material, nickel; spray chamber, glass cyclonic; nebulizer, mainhard; mode of operation, STD/KED Mode Collision (using hellium gas).

2.3. Biochemical analyses

Liver and gill samples were weighed and then homogenized in potassium phosphate buffer using a homogenizer (Ika T25 D). Homogenates were centrifuged at 16000×g for 20 min at 4 °C (Hettich 460 R) and the supernatant was separated. Total protein and enzyme activity measurements were performed in a microplate reader (Thermo, Varioscan Flash 2000). The total protein concentration was determined using the Bradford method [17].

The modified methods of Atlı and Canlı (2011) [18] for microplate reader were used to determine ATPase activities in gill tissue. 5 µL of gill sample and 60 µL of incubation medium were pipetted into each microplate well and incubated at 37 °C for 5 minutes. 10 µL of 3 mM ATP was added to this mixture and the reaction was initiated by incubating at 37 °C for 30 minutes. Then, 35 µL of distilled water at a temperature of +4 °C was added to these wells and the reaction was stopped. By measuring the absorbance of the main reagent at a wavelength of 390 nm, the value of inorganic phosphate was calculated [19]. 190 µL of the main reagent was added to the mixture of 60 µL of incubation medium, 5 µL of supernatant and 35 µL of cold distilled water in the wells, then it was incubated at 25 °C for 10 minutes and their absorbance at a wavelength of 390 nm was measured. The results were calculated according to the standard curve prepared from different concentrations of KH_2PO_4 solution.

Total antioxidant context (TAC) and total oxyradical scavenging capacity (TOSC) assays were performed by using commercial test kits (Rel Assay Diagnostics) following the instructions of the kit. The analysis of TAC is based on the antioxidants in the sample reducing the dark blue-green ABTS radical ($ABTS^{•+}$: 2,2'-azinobis (3- ehylbenzothiazoline-6-sulfonate) to the colorless reduced ABTS form. The total antioxidant level of the sample is calculated by measuring the absorbance change at 660 nm. The principle of the TOSC test is that the oxidants present in the sample oxidize the ferrous ion-chelator complex to the iron ion. The total amount of oxidant molecules in the sample is correlated with the spectrophotometric reading of the color intensity formed by the ferric ions with the chromogen in an acidic medium. The following formula was used to calculate the OSI (arbitrary unit: AU) and expressed as a percentage [20]. OSI=TOS/(TAS*10)

2.4. Statistical analyses

In the statistical analysis of the data, the computer software package SPSS 22 was used. One-way ANOVA test was used for this purpose. Then, Tukey HSD test was performed for group comparisons. The results were presented as mean±standard error. P values < 0.05 were considered significant.

3. Results and discussion

3.1. Water quality

Data on water quality parameters are shown in Table 1. In Bozova, the water temperature was found to be higher and dissolved oxygen value lower than Kahta. Conductivity and pH values were close to each other in both regions. Ammonium level was higher in Bozova, while nitrate value was higher in Kahta. Nitrite levels were the same. Phosphate and sulphate levels were higher in Bozova than Kahta. When these values are evaluated in general, the water quality in Bozova is lower than Kahta. We can think that this may be due to the excess of agricultural and domestic wastes in Bozova. Similar to our results, the values of phosphate, nitrite**,** ammonia, nitrate and sulphate were found higher in water from the polluted area (Sitilce) than relatively clean area (Samsat) of Atatürk Dam Lake [21, 22]. Yoloğlu et al. (2018) [23] reported that the levels of phosphate, nitrite, ammonia, nitrate and sulphate were higher in water of Karakoç and in Sitilce than Sarısu and Taşpınar in Atatürk Dam Lake.

Table 1. Water quality parameters

	Kahta	Bozova
Temperature (˚C)	26.50	28.90
Dissolved oxygen (mg/L)	8.20	6.80
Conductuvity (ISI/cm)	365	367
pH	7.70	7.50
NH_4 (mg/L)	0.06	0.12
NO_2 (mg/L)	0.02	0.02
NO_3 (mg/L)	1.14	0.86
PO_4^{-3} (mg/L)	0.04	0.08
SO_4 (mg/L)	18.50	23.50

3.2. Metal residues in fish, sediment and water

Data on metal residues in fish, sediment and water samples are shown in Table 2. The amounts of Pb, Cd, Cr, Ni and Cu in the water were significantly higher in Kahta than in Bozova. The amount of Hg in the water could not be determined in either region. Concentrations of metals in water were compared with the limit values of Environmental Quality Standard-Annual Average (EQS-AA) and Environmental Quality Standard-Maximum Average (EQS-MA) specified in Turkey's Surface Water Quality Regulation [24] (Table 3). Pb level was found below both EQS-AA and EQS-MA limits in waters sampled from Kahta and Bozova. Cd and Cr levels in the water of Kahta (0.3±0.02 µg/L and 2.18±0.2 µg/L) was found above EQS-AA limit (0.2 µg/L for Cd, and 1.6 µg/L for Cr). Concentrations of Co and Ni remained below the limit values in both regions. Cu level exceeded both EQS-AA and EQS-MA limits in both regions. In summary, when all metal levels in waters were evaluated, it was found that Cd and Cr levels were above the EQS-AA limit only in Kahta, while the Cu level was above the EQS-AA and EQS-MA limits in Kahta and Bozova.

In sediment, the concentration of all metals except Hg were higher in Kahta than in Bozova. Zn level was higher in the sediment of Bozova. There are currently no criteria for the evaluation of freshwater sediment quality in our country [25]. Therefore, the data obtained from this study were evaluated according to the sediment quality criteria published by MacDonald et al. (2000) [26], and the average heavy metal content of the earth's crust reported by Krauskopf (1979) [27]. According to the effect levels of sediment quality criteria; LEL (Lowest Effect Level); Below this limit, no adverse effects are generally observed in the organisms in the sediment. TEL (Threshold effect level); Adverse effects are rarely observed in organisms in sediments below this limit. MET (Minimal effect threshold); Below this limit, adverse effects are generally not observed in most of the creatures in the sediment. TET is expressed as (Toxic effect threshold) and above this limit, adverse effects are generally observed in most of the organisms in the sediment [26] (Table 4). The Pb level exceeded the LEL and TEL values in Kahta, but it did not exceed these limits in Bozova. The natural concentration of Pb in the earth's crust ranges from 15 to 20 mg/kg [28]. The Pb concentration detected in the Kahta sediment is above the earth's crust average, but it is a less effective threat to the lake ecosystem as it is below the MET and TET limits. The Cd level exceeded the LEL and TEL limits in both regions. The average Cd value in the earth's crust is in the range of 0.1-0.5 mg/kg [29]. The Cd levels we determined in the sediments of Kahta and Bozova are well above the average in the earth's crust, therefore it poses a threat to the lake ecosystem. While the Cr level was above the LEL, TEL and MET limits in Kahta, it was only above the LEL limit in Bozova. The Cr values in both regions are considerably lower than the average value (100 mg/kg) of Cr found naturally in the earth's crust. However, since it slightly exceeds the MET limit in the Kahta sediment, it may create a toxic effect here. Co amounts were below the SAV limit. While Cu level was above the limit values of LEL, TEL, MET and SAV in Kahta, it was above the limit values of LEL, TEL and MET in Bozova. The fact that the Cu level exceeds the limit values in both regions indicates that the lake sediments are exposed to significant copper pollution. Cu is a micronutrient element essential for aquatic life in freshwater and sediments, but at high levels, it has a toxic effect on the ecosystem [25].

Concentrations of Pb, Cd and Cr were significantly higher in muscle tissue of fish sampled from Kahta than those from Bozova. Co, Hg, Ni and Cu levels are close to each other in the fish of both regions and there is no statistically significant difference between them. FAO/WHO (2011) [30] determined the maximum permissible limit of metals in fish muscles as 0.5, 0.05, 80, 0.5, 30 mg/kg for Pb, Cd, Ni, Cr and Cu, respectively. In the Turkish guideline, Pb, Cd and Cu limits were reported as 1, 0.1 and 20 mg/kg, respectively [31]. In our study, Pb and Cd levels in fish exceeded the limits of both FAO/WHO and Turkish guideline while Ni and Cu levels did not. The Cr level of fish was above the limit of FAO/WHO in Kahta and below it in Bozova. Pb is a naturally-occurring and industrially-produced element that is very toxic to the human, especially children [32]. As a result of chronic exposure of fish to Pb, hematological [33], neurological [34] and renal [35] disorders occur. Food consumption is the main source of exposure cadmium (Cd) in the human body. Cd is known as an endocrine disturbing substance and it is well documented that Cd can cause to develop breast cancer and prostate cancer in humans [36]. Oymak et al. (2009) [37] determined the Pb, Ni, Cr and Cu levels in the muscle of *Tor grypus*, which they caught from Atatürk Dam Lake, as 1.23, 0.16, 0.22 and 0.56 μg/g, respectively. Almost all of these values are lower than the values we set. The reasons for this difference may be that the type of fish used, sampling points and sampling time are different from ours. Karadede and Ünlü (2000) [38] could not detect the levels of Pb, Cd, Co and Ni in the muscle of *Acanthobrama marmid*, *Chalcalburnus mossulensis*, *Chondrostoma regium*, *Carasobarbus luteus*, *Capoetta trutta* and *Cyprinus carpio*, which they sampled from Atatürk Dam Lake, they only determined the Cu levels in these species as 0.81, 2.41, 2.29, 1.14, 1.68 and 2.23 mg/kg, respectively. These Cu values found are well below the values we set for *Cyprinus carpio*. The biggest reason for the occurrence of this difference may be that a period of as long as twenty years has passed. Since there is no up-to-date study on metal residue in Atatürk Dam Lake fish lately, we cannot compare our results with this time. The reasons for these increases in metals may be increases in industrial, agricultural and anthropogenic activities over time.

Table 2. Metal concentrations of water, sediment and fish samples

	Pb	Cd	Cr	Co	Hg	Ni	Cu
Water-Kahta (µg/L)	0.07±0.002*	0.3±0.02*	2.18±0.2*	0.08±0.003	ND	2.15±0.03*	6.45±0.03*
Sediment-Kahta (mg/kg)	35.72±3.06*	0.86±0.07*	57.15±3.45*	2.62±0.55*	0.02±0.001	97.50±5.52*	57.87±4.83*
Fish-Kahta (mg/kg)	2.18±0.5*	0.75±0.04*	0.68±0.02*	0.06±0.003	0.002±0.005	1.42±0.15	14.43±1.85
Water-Bozova (µg/L)	0.04±0.003	0.05±0.001	0.17±0.03	0.06±0.002	ND	1.27±0.04	4.86±0.05
Sediment-Bozova (mg/kg)	28.56±1.05	0.68±0.05	28.95±2.34	1.23±0.12	0.01±0.002	68.36±5.65	36.55±2.36
Fish-Bozova (mg/kg)	1.07±0.3	0.43±0.03	0.32±0.05	0.07±0.002	0.002±0.001	1.35±0.43	12.82±1.12

Asteriks indicate significant differences between water/sediment/fish from the two sites (p<0.05)

Table 3. Environmental quality standards of Turkey's surface water quality regulation (µg/L)

	Pb	Cd	Cr	Co	Hg	Ni	Cu
AA-EQS	1.2	0.2	1.6	0.3	ND	4	1.6
MA-EQS	14	1.5	142	2.6	ND	34	3.1

AA-EQS: Annual Average-Environmental Quality Standard MA-EQS: Maximum Average-Environmental Quality Standard

Table 4. Sediment quality criteria limit values (mg/kg)

GV	Pb	Cd	Cr	Co	Hg	Ni	Cu
LEL	31	0.6	26	-	-	-	16
TEL	35	0.6	37.3	-	-	-	35.7
MET	42	0.9	55	-	-	-	28
TET	170	3	100	-	-	-	86
SAV	20	0.3	100	8	-	-	50

GV: Guidelines Values, LEL (Lowest Effect Level), TEL (Threshold effect level), MET (Minimal effect threshold), TET (Toxic effect threshold), SAV (Shale Average Value)

3.3. Biochemical markers

TAC and TOSC values in liver and ATPases values are shown in Table 5. When the liver TAC and TOSC values were compared, it was found that the TAC value was higher in Bozova's fish, while the TOSC value was higher in Kahta's fish. These differences between the TAC and TOSC values of the two regions were statistically significant (p<0.05). Oxidant-antioxidant balance is disrupted by common inflammatory processes and free radicals. The oxidative stress is a result of disruption in this balance. It can induce dysfunction of organs [39]. Recently, TAC and TOSC markers have been used in environmental pollution studies. TOSC analysis measures biological resistance against a variety of oxyradicals, thus providing useful indicators for predicting the negative effects of oxygen radicals on the health status of organisms [11]. In this study, the reason for the lower TOSC level in the fish in Kahta compared to the ones in Bozova may be due to the oxidative stress effect created by the high metal concentration in the Kahta waters. This shows that the fish in Kahta is under more oxidative stress, so their capacity to neutralize reactive oxygen species is lower. Similar to our findings, in a study comparing TOSC levels in the digestive gland of mussels collected from polluted and clean areas, it was observed that the TOSC level was lower in mussels in the polluted area [11]. The researcher associated this low TOSC level with the insufficient capacity of the organism against oxidative stress caused by the high metal content in the water of the polluted area. It is assumed that TAC is the sum of enzymatic and nonenzymatic antioxidants [40]. In this study, the TAC level was found approximately twice as high in Kahta than in Bozova. The reason for the low TAC level in Kahta compared to Bozova can be explained as the energy consumption in response to the oxidative stress caused by the high metal content in the samples taken from Kahta. In parallel with our study, Hamed et al. (2020) [41] observed that TAC level decreased as the dose increased in *Oreochromis niloticus*, which they exposed to microplastics. Oxidative stress index (OSI) is an indicator showing the degree of relationship between free radicalforming agents that cause oxidative stress in the organism and antioxidant defense systems against them [42]. In our study, OSI value was significantly higher in Kahta than in Bozova. In another study, the OSI was found to be high in goldfish treated with arsenite [43].

Na^+/K^+ATPase plays a central role in ion transport across cellular membranes in fish and is responsible for whole body ion regulation [44]. In our study, Na^+/K^+ATPase activity was significantly inhibited in the gills of fish caught from Kahta compared to those in Bozova ($p<0.05$). This decrease in Na^+/K^+ATPase activity indicates the destruction of cellular ion regulation in the gill tissues of fish [45]. In aquatic organisms, especially in the gills of fish, the Na^+/K^+ATPase enzyme plays an important role in maintaining the ion balance, and the increase or decrease in its activity has proven to be a vital index for the levels of environmental pollutants as well as as a potential indicator of toxic stress [46]. ATPases are known to be the target enzymes of xenobiotics in the cell, heavy metals and other xenobiotics can bind to the phospholipid part of the cell membranes, causing inhibition of these enzymes [47]. Pollutants in the water can interact with the enzyme directly, altering the gill Na^+/K^+ATPase activity [48]. Based on this idea, in our study, we can attribute the inhibition of the Na^+/K^+ATPase in fish caught from the Kahta to the toxic effect created by the metal density in this region. Similar to our findings, the Na^+/K^+ATPase activity is decreased in the gills of the silver catfish (*Rhamdia quelen*) exposed to the Zn effect [49]. Morga et al. (1997) [50] determined that gill Na^+/K^+ATPase activity of *Oncorhynchus mykiss*, which was exposed to 10 µg/L silver for 48 hours, was inhibited by 85%. Mg^{2+}ATPase and Ca^{2+}ATPase activities were higher in Bozova than in Kahta however, these differences were not statistically significant ($p>0.05$). Yoloğlu (2019) [51] reported that Ca^{2+}ATPase activity was significantly inhibited in freshwater mussels (*Unio mancus*) when exposed to the pesticide penconazole for 96 hours compared to the control. Uçkun and Öz (2020a, 2020b) [52, 53] observed dose-dependent inhibitions of Mg^{2+}ATPase and Ca^{2+}ATPase in the muscle and gill of freshwater crayfish (*Astacus leptodactylus*) which were exposed to penconazole and azoxystrobin for 96 hours, separately. They attributed the inhibition of these enzymes to the reactive oxygen radicals released as a result of oxidative stress caused by damage to tissues by the pesticides they applied.

Table 5. Biochemical markers in liver and gill tissues

	Kahta	Bozova
TAC (µmol trolox Equiv./L ± mean standard error)	1.13±0.15*	2.25±0.18
TOSC (mmol H_2O_2 Equiv./L± mean standard error)	4.67±0.32*	2.98±0.20
OSI (arbitrary unit: AU ± mean standard error)	0.41±0.03*	0.13±0.02
Na^+K^+ATPase (nmol P_i min^{-1} mg $protein^{-1}$ ± mean standard error)	16.23±0.25*	23.56±0.32
Mg^{2+}ATPase (nmol P_i min^{-1} mg $protein^{-1}$ ± mean standard error)	25.42±0.12	26.66±0.55
Ca^{2+}ATPase (nmol P_i min^{-1} mg $protein^{-1}$ ± mean standard error)	39.67±0.85	41.22±0.93

Asteriks indicate significant differences between organisms from the two sites ($p<0.05$)

4. Conclusion

In this study, it was determined that the Cd, Cr and Cu levels in the waters sampled from Kahta and the Cu level in Bozova were above Turkey's surface water quality regulation limits. We foresee that the Cd and Cu ratios in both Kahta and Bozova sediments may pose a threat to the ecosystem of the Atatürk Dam Lake, as they exceed the minimal effect threshold limit. Since Pb and Cd levels in fish are above the maximum permissible values determined by FAO/WHO (2011) [30] and Turkish guidline [31] in fish muscles in both Kahta and Bozova, it can be a threat to both the lake ecosystem and fish consumers. From the biochemical data measured in the liver and muscles of fish, it can be concluded that the fish in Kahta are more affected by pollution and are under more stress than those in Bozova.

Authors' Contributions

The contributions of Aysel ALKAN UÇKUN and Miraç UÇKUN to this article is equal (50%: 50%).

Statement of Conflicts of Interest

The authors declare that they have no conflict of interest.

Statement of Research and Publication Ethics

The author declares that this study complies with Research and Publication Ethics.

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