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Assessment of Pollution in Ataturk Dam Lake (Adiyaman, Turkey) Using Several Biochemical Parameters in Common Carp, *Cyprinus carpio* L.

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Abstract Ataturk Dam Lake, the largest impounded lake in Turkey, has been contaminated by domestic, industrial and agricultural effluents coming from Adiyaman city. In this study, we investigated the possible effects of pollutants on several biochemical parameters in the cyprinid fish, *Cyprinus carpio*, by comparing the parameters in fish collected from a polluted area (Sitilce) to a relatively clean area (Samsat) in August 2011. The activities of alanine aminotransferase, aspartate aminotransferase, alkaline phosphatase and lactate dehydrogenase and levels of cortisol, glucose, and K increased while total protein, cholesterol, Ca, Na and Cl levels decreased in fish from the Sitilce site when compared to the Samsat site. The observed alterations in these biochemical parameters indicate that the Ataturk Dam Lake is affected by untreated wastewater discharges.

Keywords Ataturk Dam Lake · Pollution · *Cyprinus carpio* · Blood parameters

The release of industrial, domestic, and urban wastes generated by anthropogenic activities into aquatic ecosystems may affect the water chemistry of rivers and/or lakes and be deleterious to aquatic organisms. The impact of contaminants on these ecosystems can be assessed by measurement of biochemical parameters in fish that respond specifically to the degree and type of contamination (Petrivalsky et al. 1997). Fish blood parameters have been used in environmental monitoring programs as valuable indicators of physiological changes in the presence of toxicants (Oliveira Ribeiro et al. 2006). Measurements of blood serum chemistry parameters have been used as a diagnostic tool in fish toxicology and biomonitoring (Adams et al. 1996).

The Ataturk Dam Lake is situated on the Euphrates River on the border of Adiyaman Province and Şanliurfa Province in the southeastern Anatolia Region of Turkey, and has importance in irrigation and electrical energy production. The dam is one of the world's largest, with an embankment 169 m high and 1,820 m long. The surface areas and total water deposits of the lake are, respectively, about 817 km^2 and 48.7 billion m^3, thus the lake is the biggest artificial reservoir in Turkey. The Ataturk Dam Lake is an abundant source of food for local people and also provides opportunities for recreational fishing. *Cyprinus carpio*, *Liza abu*, *Capoeta trutta*, *Chondrostoma regium*, *Acanthobrama marmid*, *Chalcalburnus mossulensis*, *Barbus rajonorum*, *Mastacembelus simack*, *Cyprinion macrostomus*, and *Tor grypus* have high market value and are the main fish resources in the lake.

Adiyaman city, which is located to the north of the Ataturk Dam Lake, has an approximate population of 400,000. The city has vast areas of agricultural land and some industrial plants (textile, cement, chemical, machinery, paper and pulp, petrochemicals, fertilizers, plastics, etc.). However, the city has no wastewater purification facilities which results in municipal, agricultural, and industrial wastewater discharges directly into the lake. Pollutants entering this reservoir may affect not only this region, but also Syria and Iraq via the Euphrates River (Karadede et al. 2004). To assess the pollution load in aquatic ecosystems resulting from pollutants of anthropogenic activities, biochemical biomarkers have been used at other locations (Bucher and Hofer 1990; Zutshi et al.

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2010). To our knowledge, no reports are available on biochemical responses of fish to pollutants in Ataturk Dam Lake. Only a few studies have been carried out to determine the heavy metal levels in tissues (gill, liver, muscle etc.) of fish species including *C. carpio* in the lake (Karadede and Ünlü 2000; Karadede et al. 2004; Mol et al. 2010). Therefore, in the present study, our objective was to evaluate the possible effects of pollutants in Ataturk Dam Lake by measuring selected biochemicals in the serum of *C. carpio* collected from polluted and unpolluted areas in the reservoir.

Materials and Methods

Two sites (Sitilce and Samsat) in Ataturk Dam Lake were selected for study (Fig. 1). The Sitilce site is known to have pollution that is mostly contributed through the wastewater discharges from Adiyaman city (especially untreated municipal and industrial effluents). The Samsat site was selected as a relatively clean area of the lake. It is approximately 70 km from Adiyaman city, and is therefore less affected by effluents from this city. Water and fish samples were taken from Sitilce and Samsat sites in August 2011. Some physico-chemical parameters of water were measured at each sampling site. Water temperature, dissolved oxygen concentrations, and pH were recorded in the field using portable meters. For laboratory chemical analyses, samples were taken from the same sites using 5-L dark-colored bottles and were transported to the laboratory in a cooler box in order to avoid sample deterioration owing to biological activity. At the laboratory, all sample bottles were stored in the refrigerator prior to analysis. The other water quality parameters such as ammonia, nitrite, nitrate, sulphate, phosphate content were measured according to the methods described in Standard Methods (APHA 1998).

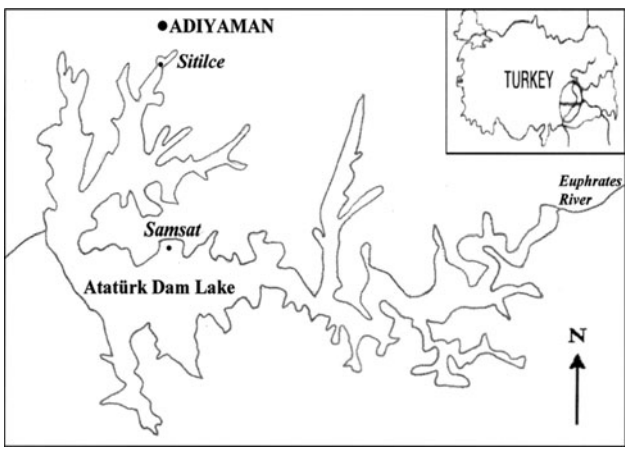

Fig. 1 Location map of sampling sites in the Ataturk Dam Lake, Turkey

Ten specimens from each sampling site were caught using fishing nets. All fishes were collected from a single fisherman in order to assure regularity in fishing methods. The body weights of *C. carpio* from Sitilce site ranged from 755 to 1,080 g, with total lengths of 37–42 cm. Fish from the Samsat site had body weights in the range 810–1,140 g and total lengths between 39 and 45 cm. Blood samples were taken from the caudal vein of each fish into anticoagulant-free centrifuge tubes in the field, and were immediately transported on ice to the laboratory. Serum was obtained by centrifugation of the blood at 3,000 rpm for 10 min. The serum samples were stored at −80°C until analysis.

Biochemical parameters in the serum samples were analyzed using biochemical analyzers (Architect ci-16200, Architect i-2000 SR, Abbott Laboratories, Diagnostic Division, Abbott Park, IL, USA). Reactants for all the measurements were supplied from Abbott diagnostics (Wienna, Austria) for the analyses. The following procedures were used for measurements of serum parameters: UV test technique for alanine aminotransferase (ALT), aspartate aminotransferase (AST) and lactate dehydrogenase (LDH) activities and glucose level; colorimetric assay for alkaline phosphatase (ALP) activity and total protein and Ca levels; electrochemiluminometric technique for cortisol level; enzymatic colorimetric test for cholesterol level, and ion-selective electrodes technique for Na, Cl and K levels. Data are presented as the mean ± standard error. For statistical analysis, the Student *t* test was used to compare study sites. Differences were considered significant if $p < 0.05$.

Results and Discussion

When compared with water taken from Samsat, it was observed that the values of pH, ammonia, nitrite, nitrate, sulphate, and phosphate were higher, whereas the dissolved oxygen level was lower for water taken from the Sitilce site (Table 1). In agreement with the present results, Kazi et al. (2009) reported that high pH (8.02–8.35), ammonia (6.82–8.48 mg/L), nitrite (2.68–3.37 mg/L), sulphate (150.4–186.1 mg/L) and phosphate (0.42–0.52 mg/L) and low dissolved oxygen levels (3.7–5.2 mg/L) were found in water from polluted sites of Manchar Lake (Pakistan) due to agricultural, municipal, and industrial wastes.

The activities of enzymes, other biochemicals and ions levels in serum of *C. carpio* collected from the Ataturk Dam Lake are presented in Tables 2, 3, and 4, respectively. In recent review (Groff and Zinkl 1999) and research (Tripathi et al. 2003) articles, various serum chemical

Table 1 Values of some physical and chemical parameters of water from Ataturk Dam Lake

Site	pH	Temperature (°C)	Dissolved oxygen (mg/L)	Ammonia (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Sulfate (mg/L)	Phosphate (mg/L)
Samsat	8.15	28.21	7.23	0.03	0.01	0.08	25.00	3.00
Sitilce	8.37	28.13	4.09	0.11	0.10	0.55	35.00	8.00

Table 2 Enzyme activity in serum of *C. carpio* collected from two sites in Ataturk Dam Lake

Enzyme activity (U/L)	Samsat site	Sitilce site
ALT	36.00 ± 3.58	95.90 ± 5.50*
AST	168.6 ± 15.6	429.5 ± 28.9*
ALP	13.50 ± 1.55	81.00 ± 7.85*
LDH	766 ± 43.9	1707 ± 49.7*

Values are expressed as mean ± standard error ($N = 10$)

* $p < 0.05$; (Student's t test) statistical differences between sites

Table 3 Biochemical level in serum of *C. carpio* collected from two sites in Ataturk Dam Lake

Metabolite	Samsat site	Sitilce site
Cortisol (ng/dL)	9.77 ± 0.60	27.51 ± 2.17*
Glucose (mg/dL)	78.83 ± 5.52	216.6 ± 15.1*
Total protein (g/dL)	3.02 ± 0.12	2.07 ± 0.08*
Cholesterol (mg/dL)	249.6 ± 19.2	148.3 ± 4.5*

Values are expressed as mean ± standard error ($N = 10$)

* $p < 0.05$; (Student's t test) statistical differences between sites

Table 4 Ion level in serum of *C. carpio* collected from two sites in Ataturk Dam Lake

Ion	Samsat site	Sitilce site
Ca (mg/dL)	13.17 ± 0.32	9.05 ± 0.26*
Na (mmol/L)	130.7 ± 2.2	105.9 ± 3.1*
Cl (mmol/L)	98.10 ± 2.15	71.37 ± 1.38*
K (mmol/L)	3.17 ± 0.21	7.38 ± 0.41*

Values are expressed as mean ± standard error ($N = 10$)

* $p < 0.05$; (Student's t test) statistical differences between sites

parameters were reported for clinically healthy *C. carpio* taken from a fish culture farm. In these works, the reference ranges were 31 ± 8 U/L for ALT, 11 ± 4 U/L for ALP, 48 ± 10 mg/dL for glucose, 3.0 ± 0.3 g/dL for total protein, 164 ± 24 mg/dL for cholesterol, 10.2 ± 0.7 mg/dL for Ca, 140 ± 4 mmol/L for Na, 113 ± 2 mmol/L for Cl and 2.4 ± 0.9 mmol/L for K. The values of biochemical parameters in fish from Samsat site selected as control area were generally in agreement with the findings of Tripathi et al. (2003).

When compared with fish taken from the Samsat site, it was observed that the activities of ALT, AST, ALP and LDH and levels of cortisol, glucose, and K were higher, whereas the total protein, cholesterol, Ca, Na and Cl levels were lower for the fish taken from the Sitilce site. These results indicate that the Sitilce site should be considered as an area polluted by the wastewater discharges from Adiyaman city. We studied the concentrations of Cd, Pb, Cr, Co, Ni, Cu, Zn, Fe, Mn, Ca, Mg, Na, and K in water and the gill, liver, and muscle tissues of fish species, *C. carpio* and *C. trutta*, taken from Ataturk Dam Lake in August 2009, and found that due to municipal and industrial effluents all metal levels in water and fish samples were significantly higher at the Sitilce site than at the Samsat site (Fırat et al. 2010). These results suggest that pollutants, especially heavy metals, discharged into the lake cause significant alterations in the above-mentioned biochemical parameters, and thus may pose a serious threat to the environment and quality of life in the reservoir.

Several soluble serum enzymes have been considered as relevant stress indicators. The serum enzymes ALT, AST, ALP, and LDH have been used to determine pollution exposure in animals and in monitoring of water pollution for heavy metals and pesticides (Lavanya et al. 2011). Higher levels of these enzymes in circulation may result from leakage out of cells, as well as from the release to peripheral fluids following cell damage. Harvey et al. (1994) concluded that blood levels of ALT, AST and ALP increased due to cellular damage in the liver, and that high levels of these enzymes in the serum were usually indicative of disease and necrosis in the liver of animals. Therefore, in the present investigation, the significant increase in activities of the aforementioned enzymes in fish from the Sitilce site may indicate hepatic damage caused by pollutants at this site, which in turn caused the release of these enzymes into bloodstream. The obtained results were in agreement with the findings of Fırat et al. (2011) who found that an increase in activities of serum ALT, AST, ALP and LDH of *Oreochromis niloticus* in response to pesticide and metal stress. Also, an increase in both AST and ALT activity was observed in experiments in which brown trout, *Salmo trutta*, were acutely exposed to domestic wastewater (Bucher and Hofer 1990).

Among the biochemical profiles, serum glucose has been used as a sensitive parameter to study stress and also

used as a sensitive indicator of environmental stress in fish (Kavitha et al. 2010). Cortisol plays an important role in mobilizing fuels such as glucose for the maintenance of homeostasis in response to stress (Sepici-Dinçel et al. 2009). The stress hormone cortisol has been shown to increase glucose production in fish, by both gluconeogenesis and glycogenolysis, and likely plays an important role in the stress-associated increase in serum glucose concentration (Iwama et al. 1999). The serum cortisol and glucose levels of *C. carpio* caught at the Sitilce site elevated perhaps to maintain the increased energy demand of the pollutant-stressed fish. Increases in these parameters were also reported in serum of *O. niloticus* exposed to toxicants (Fırat et al. 2011). Changes in the level of serum total protein, synthesized mainly in the liver, can be observed due to liver damage or reduced absorption. Protein loss may thus be a good indicator of the health status of fish (Öner et al. 2008). Total protein is used as an indicator of liver impairment. Decreased concentrations in fish sampled from a polluted site may occur due to a failure of protein synthesis. Lavanya et al. (2011) reported that protein, an important biochemical parameter has been used to understand the general state of health and biological mechanism of metabolism under toxicant stress. The significant decrease in serum protein in fish of our study may have resulted from impaired protein synthesis due to liver disorder. Cholesterol is known to be an essential structural component of membranes, as well as a precursor of all steroid hormones. In the present work, the serum cholesterol level was observed to decrease in fish collected from the Sitilce site when compared to those from the Samsat site, indicating hypocholesteremia. This response may be due to the inhibitory effects of pollutants on cholesterol synthesis. The present results are in agreement with the findings of Zutshi et al. (2010), who reported a decline in total protein and cholesterol levels in serum of *Labeo rohita* from Hebbal and Chowkalli lakes (India) polluted by anthropogenic activities, when compared to levels in fish from a reference site.

Serum ion levels are significant biomarkers in ecotoxicology because their levels can be altered sensitively due to reduced branchial ion extrusion, reduced intestinal fluid absorption, and changes in morphological structure of cells (Öner et al. 2008). These ions are very sensitive to environmental stressors, and are commonly altered in response to pollutants (Suvetha et al. 2010). In comparison to fish from the clean site, observed changes in levels of serum ions of *C. carpio* collected from the Sitilce site may be attributed to pathological changes in tissues such as gills and kidney, which are involved in the exchange of ions between the fish and the surrounding water; as well as to a reduction in Na^+/K^+-ATPase activity, which plays a central role in whole body ion regulation. Similar to the results of the present study, Öner et al. (2008) showed that Na^+, Cl^-, and Ca^{2+} levels decreased in the serum of *O. niloticus*, and the K^+ level increased following exposure to metals. Also, a decline in levels of plasma sodium and chloride was observed in arsenic trioxide exposed fish, *Catla catla* (Lavanya et al. 2011). The researchers concluded that toxic contaminants entering the gills may cause damage to gill structure, resulting in alterations in electrolyte levels and osmoregulatory dysfunction.

In the present investigation, several biomarkers in *C. carpio* were used to evaluate the pollution in Ataturk Dam Lake. The alterations in serum biochemical parameters of fish samples collected from the Sitilce region indicate that this reservoir is significantly affected by untreated wastewater discharges from Adiyaman city. These parameters can be used as rapid and sensitive indicators to assess the impact of contaminants in aquatic ecosystems. Finally, our study indicates that effective measures must be taken to control the quantity and concentration of input pollutants for a reduction in the pollution load into this lake. Furthermore, these measures for the improvement in water quality of the lake are needed for the maintenance of healthy aquatic biota in this reservoir.

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