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Short Communication

Boron and Arsenic Levels in Water, Sediment, and Tissues of *Carassius Gibelio* (Bloch, 1782) in a Dam Lake

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Abstract

The Seydisuyu River one of the tributaries of Sakarya River which is the third largest river system in Turkey. The Seydisuyu Basin includes one of the most important boron mines in world. Boron sources in the Seydisuyu Basin, fertilizers, and pesticides used in agricultural applications; geological structure of the basin and mining applications are resources important for boron and arsenic. Kunduzlar Dam Lake, which is one of the most important reservoirs of the Seydisuyu basin, was constructed for the Seyitgazi Plain in 1983. Boron and arsenic values were the two important contaminants determined around the region. B and As levels were determined in water and sediment of Kunduzlar Dam Lake and also B levels were identified in tissues of *Carassius gibelio*. Water and sediment samples were collected seasonally between 2011-12. Also, muscle, gill, and liver tissues of *Carassius gibelio* (Bloch, 1782) were examined in spring 2012. Arsenic and boron levels in water were found higher than permissible levels. In all tissues of *Carassius gibelio* bioaccumulation factors (BAFs) for boron were remarkably high and boron accumulation levels in the muscle were lower than other tissues.

Keywords: boron, arsenic, Kunduzlar Dam Lake, sediment, *Carassius gibelio*

Introduction

Boron is a non-metallic element ubiquitous in the environment, existing naturally in over 80 minerals [1]. The natural borate content of groundwater and surface water is usually small. Economic borate deposits are rare in the world, but the last center of borate industry active since 1968 is Kırka, a town in Seyitgazi County, Eskisehir. The Kırka-Sarıkaya borates line extending to the west is the world's largest deposit that has ever been discovered [2].

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The borate content of surface water can be significantly increased as a result of waste water discharges. However, arsenic is one of the significant pollutants in terms of environmental and human health, and permissible levels of arsenic in drinking and surface water systems are limited in WHO and Turkish Regulations.

Arsenic has been classified as group I carcinogens based on human epidemiological data [3, 4]. There are studies related to the presence of arsenic in the boron-rich region [5-7]. Bioaccumulation of metal contaminants in aquatic food webs varies by metal and with ecological factors such as tropic level, the feeding strategy of an organ-

ism, and organism abundance within a tropic level. Fish are significantly used as bioindicator organisms in aquatic environments. Much of element variability in fish tissues has been attributed to variability of age, life cycle, and feeding habits of species [8-11].

Boron and arsenic accumulation is not often studied together for aquatic ecosystems. Boron and arsenic contaminations are a serious environmental problem affecting both aquatic ecosystems and human activities. So the present paper aims to investigate boron and arsenic concentrations in water and sediment of Kunduzlar Dam Lake on Seydi Stream, and also boron levels in different tissues in *Carassius gibelio* biotic and abiotic samples from Kunduzlar Dam Lake were collected seasonally 2011-12.

Materials and Methods

Study Areas

Kunduzlar Dam Lake is located within the boundaries of Seyitgazi town of Eskişehir. Kunduzlar Dam Lake, which is one of the most important reservoirs of the Seydisuyu basin, was constructed for the purpose of irrigation to Seyitgazi Plain in 1983. Sampling stations on Kunduzlar Dam Lake were shown on the map (Fig. 1). Water and sediment samples were collected seasonally from Kunduzlar Dam Lake in autumn 2011-summer 2012. *Carassius gibelio* (Bloch, 1782) species were collected respectively in spring 2012.

Measurements of temperature, pH, dissolved oxygen and electrical conductivity and salinity values in water of Kunduzlar Dam Lake were performed with a multi-measuring device in the samples sites.

Boron and Arsenic Analysis

To minimize contamination, all the materials used in the experiments were previously washed in ultra-pure water, and a stainless steel knife was used to cut the tissues.

Water samples of 0.5 liter in volume were taken at each sampling point and adjusted to pH 2 with HNO_3 being added to each. Sediment samples were collected from all stations using a sediment dipper and Ekman grab and kept in suitable bottles (2 kg). Bottom sediment samples were dried at 105ºC for boron and arsenic analysis and after 0.5 g sample was taken from homogenized each sediment samples. Sediment samples were digested with $HClO_4$:HNO_3 acids of 1:3 proportions and added to a CEM Mars Xpress microwave digestion unit. Afterward, the samples were filtered in such a way as to make their volumes to 100 ml with ultra-pure distilled water.

The fish samples used in the experiment were collected from Kunduzlar Dam Lake and the fish were first wrapped into polyethylene plastic, put into an isolated container, and brought to the laboratory. After biometric measurements, the fish were immediately frozen and stored at -20ºC until dissection. Before analysis the fish were thawed and a 0.25 g sample was taken from each tissue (muscle, gill, and liver). Fish samples were dried for 24 h at 105ºC. Three thawed 0.25 g homogenates from each tissue were taken and $HClO_4$:HNO_3 acids of 1:3 proportions were inserted in the reactors, respectively. Samples were digested in a microwave digestion unit. Afterward, the samples were filtered in such a way as to make their volumes to 100 ml with ultra-pure distilled water.

Arsenic and boron levels in water, sediment, and tissues of fish were determined by a high-resolution continuum source atomic absorption spectrometer (Analytikjena

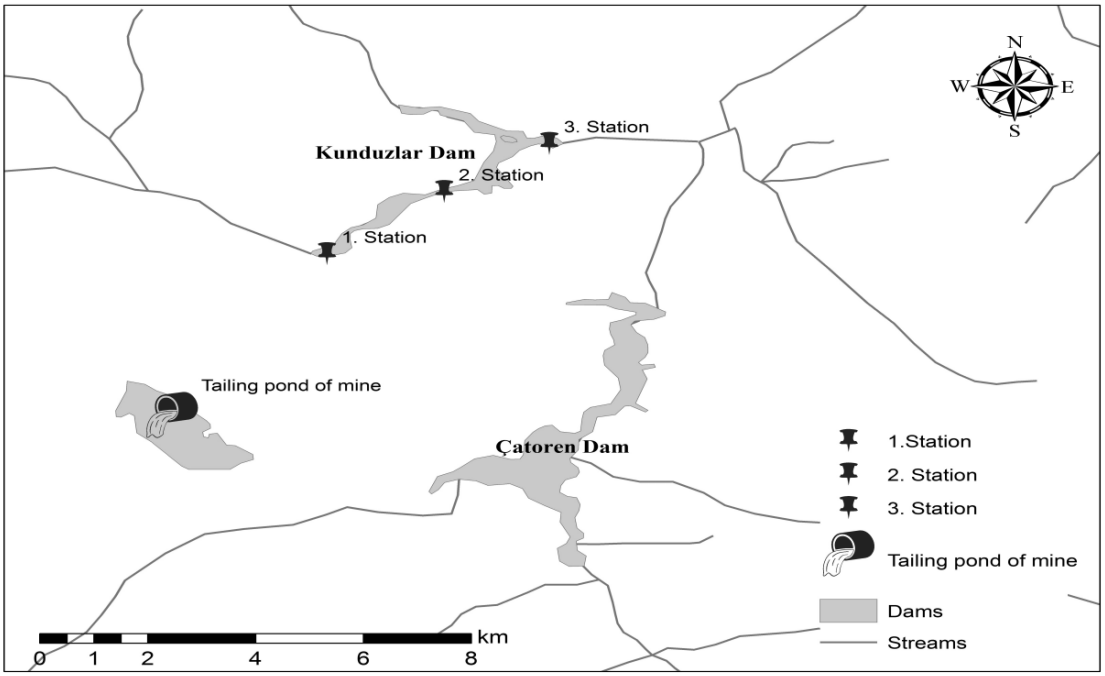

Fig. 1. Study area and sampling sites.

ContrAA 700) by triplicate measurements [12-14]. Atomic absorption spectrometer analysis, the following wavelength lines were used: As 193.696 nm and B 249.77 nm.

Bioaccumulation Factor (BAF)

The bioaccumulation factor (*BAF*) was calculated according to the equation:

$$BAF = CB/CWT$$

...where *CB* is the concentration of the heavy metals in the fish, *CWT* is the concentration of the heavy metals in the water [15].

Results and Discussion

The seasonal concentrations of temperature, pH, salinity, conductivity, arsenic, and boron values in water of Kunduzlar Dam Lake are shown in Fig. 2. Due to rains and melting snow, the depth of Dam Lake was increased and so the water and sediment samples were unable to be collected from station 3 in Dam Lake in spring. Water quality values in Kunduzlar Dam Lake were evaluated in accordance with Turkish Regulations, 2004. Water quality regulations in Turkey separate inland waters into four classes. Class I refers to high-quality water that can be used for high potential for drinking water, recreation the production of trout, and other purposes. Class II refers to less contaminated

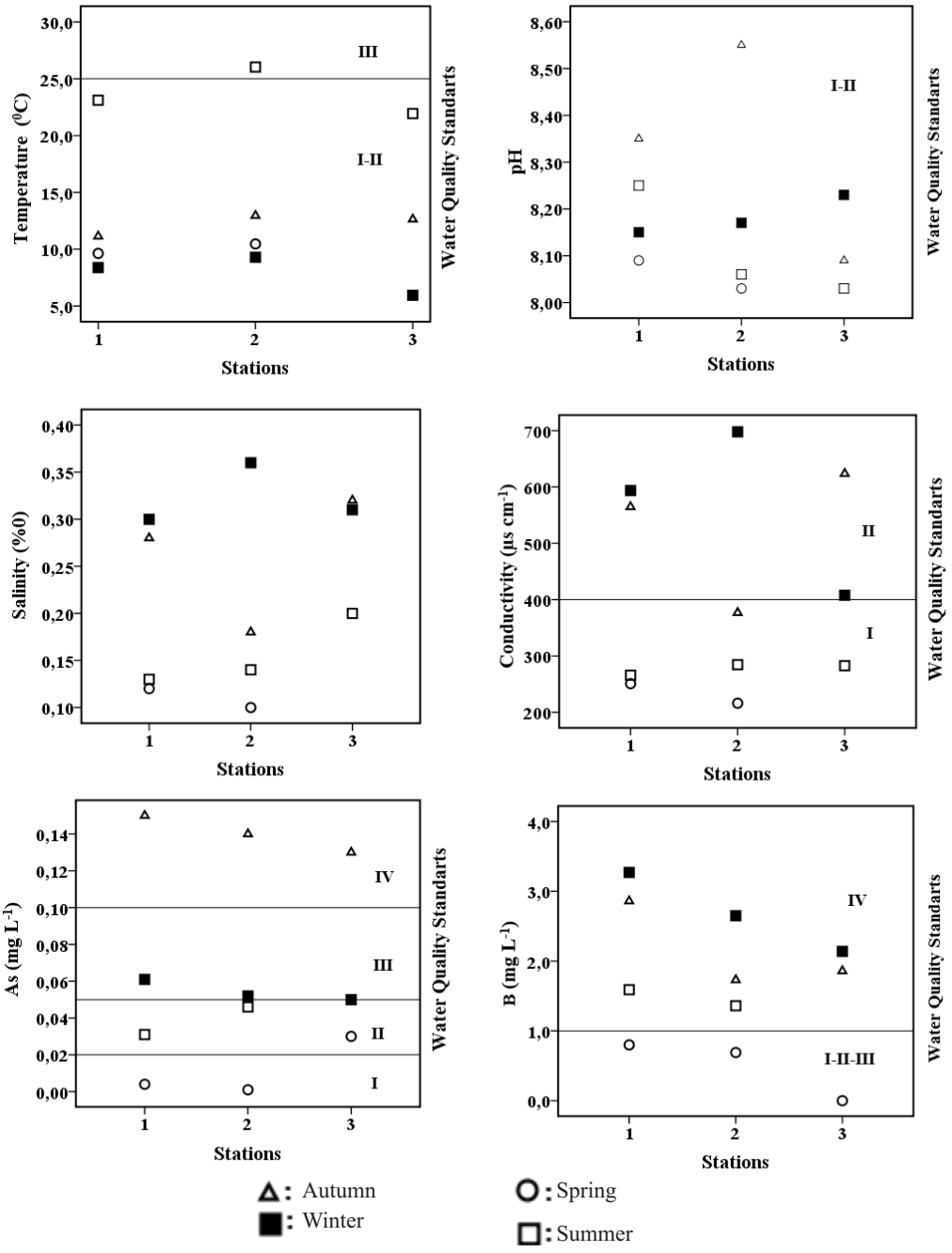

Fig. 2. Seasonal physical and chemical parameters in water of Kunduzlar Dam Lake.

water that can be used as surface water is to become potential for drinking water outside of trout production and for all uses other than class I. Class III includes polluted water, which can only be used as industrial water after treatment. Class IV refers to heavily polluted water that should not be used at all [16].

Dissolved oxygen levels in Kunduzlar Dam Lake were changed between 8.02-9.39 mg·L^{-1}. The highest conductivity and salinity values were determined in winter and autumn seasons for all stations. According to Türkish Regulations 2004, conductivity values were found to be second class for Kunduzlar Dam Lake. The highest temperature value was found in station 2 (26.04ºC) in summer. Abiotic factors such as dissolved oxygen and temperature can also influence the distribution of aquatic species, studying biological and physico-chemical factors of water is necessary for finding suitable water quality improvement [4].

Arsenic levels were not detected in stations 1 and 2 in spring. The highest As level were found in station 1 in autumn, and fourth class according to Turkish Regulations [16].

The accumulation order of annual mean As levels of Kunduzlar Dam Lake were found 3>2>1. Also according to annual mean As level were class III.

B levels were not detected in station 3 in spring (Fig. 2). The highest B levels were found in winter season for all stations and according to Turkish Regulations; B levels were class IV (except spring season). Emiroğlu et al. [2], indicated boron concentrations in Seydisuyu and they reported average B content as 3.45 mg·L^{-1}. Also, they found that the highest boron concentrations were identified in Kırka station and also high boron values in our studies identified the input of Kunduzlar Dam Lake and the station nearest to the Kırka. Our results were similar with this data.

In a study conducted by Tübitak in 1992 [17], it was determined that Kunduzlar Dam Lake was affected by water collection pond of mining application. And especially the boron levels increased in rainy seasons. Our results in water supported this judiciary. Because boron levels were increased especially in autumn season.

Ünlü et al. [5] investigated boron and arsenic pollution of underground water in Kütahya – Emet Region and they identified that boron and arsenic levels in the region were higher than permissible levels and affected the geographical characteristics of the region. Especially during the rainy seasons, the arsenic and boron levels in groundwater were increasing by snow and rain waters that were draining water from surface lands. Our results were parallel with this data.

In a study performed in Emet Stream, As and B accumulations greatly exceeded the limit values for drinking water, especially around the close stations to the boron mine (maximum As: 1 mg/L and maximum B: 74 mg/L) [18]. In another study performed in groundwater of the Emet-Hisarcık districts (Turkey), arsenic levels in the region (0.01-0.56 mg/L) and boron levels in close stations to the boron mine (0.59-4.34 mg/L) exceeded the limit values for drinking water [19].

Tokatlı et al. [20] reported that arsenic concentrations in groundwater of some regions in Türkmen Mountain (located in the Seydisuyu Stream Basin) have exceeded the limit values for drinking an average of 3-4 times. In another study conducted in the same area as our study (Seydisuyu Stream Basin), maksimum boron value was reported as 12.99 mg/L in groundwater [21]. These results are quite a bit higher than the data detected in the present study.

The average boron concentrations in sediment samples taken from the three stations of Kunduzlar Dam Lake are given in Fig. 3. There is no information about maximum permissible boron in sediment quality guidelines. In sediment samples, the highest boron levels in station 3 in summer (265.40 mg·kg^{-1}). Emiroğlu et al. [2] found that the highest boron concentration was at Kırka station (maximum 36 mg·kg^{-1}). Boron concentrations in sediments of Kunduzlar Dam Lake were lower than those detected in Kırka. These results show that boron concentrations in the region substantially increased.

MacDonald et al. [22] reported the toxic limits of As levels in sediment quality guidelines for freshwater sediments. As levels in the sediment of Kunduzlar Dam Lake were compared with these sediment quality guidelines (LEL – lowest effect levels; MET – minimal effect threshold; TET – toxic effect thresholds). The highest arsenic value was observed in station 3 (22.39 mg·kg^{-1}) in autumn. The detected As levels in station 1 in autumn and winter were approximately higher than the limit values of TET, while the least in spring (Fig. 3).

Boron concentrations in tissues of *C. gibelio* were determined. The mean B level in liver was also higher than in other tissues. The accumulation order of boron was found in the tissues of *C. gibelio* as liver>gill>muscle. Boron values in tissues were found between 85.14-222 mg·kg^{-1}. The BAF is a number that describes the bioaccumulation as the ratio of the concentration of a chemical in an organism to that in the surrounding environment [9, 15]. According to BAF values of muscle, gill, and liver tissues of *C. gibelio* calculated by using water accumulation data; BAF values were remarkable for muscle, about 50 times higher than 1 for muscle and 100 times higher than 1 for gill and liver tissues.

The highest BAFs in sediment were determined in the liver of *C. gibelio* (2.60). Also, BAF according to sediment were found for muscles higher than 1. There is no information about maximum permissible boron limits in fish tissues in the Turkish standards. Therefore, our results could not have been compared with the levels of Turkish Food Codex Standard [23].

Emiroğlu et al. [2] studied boron contents in muscles, gill, liver, head and of *Leuciscus cephalus* in Seydisuyu Stream. In muscle of *L. cephalus*, boron levels were detected between 7.85-100.71 mg·kg^{-1} and the highest mean boron concentrations were determined in heads of fish. If we compare the present study data with the bioaccumulations in *L. cephalus*, boron concentrations in muscle of *C. gibelio* generally were found to be higher than tissues of the *L. cephalus*.

Özkurt [24] determined the boron contents in tissues of *C. carpio* in Kunduzlar Dam Lake. Boron levels in muscle, liver, and head of *C. carpio* were detected between 80.81-427.26 mg·kg^{-1} (2-5 ages).

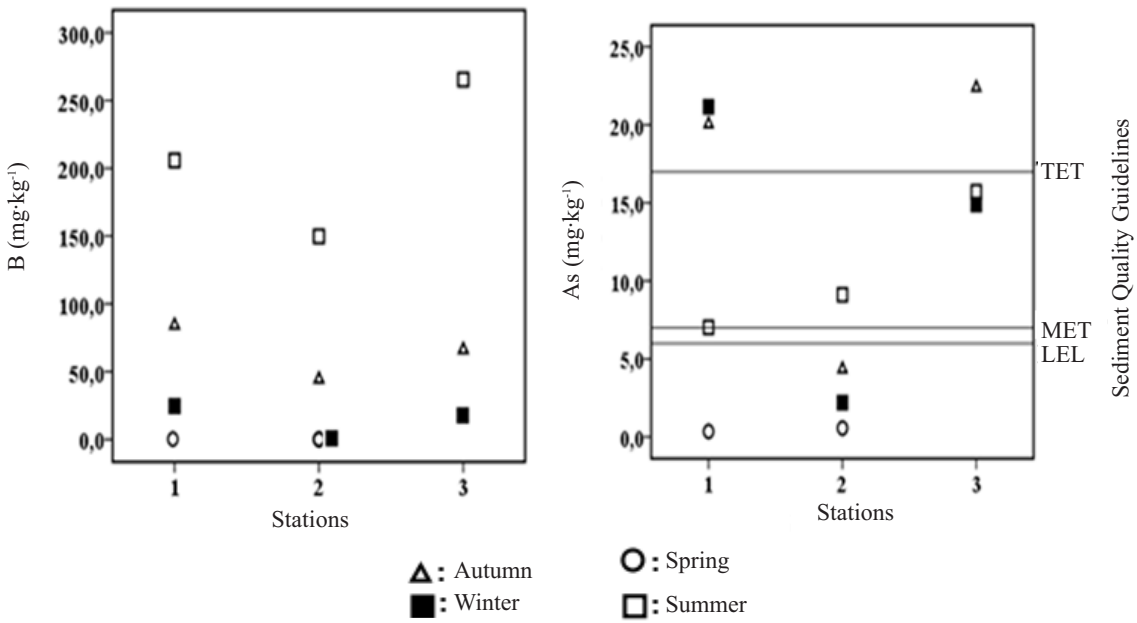

Fig. 3. Seasonal boron and arsenic levels in sediment of Kunduzlar Dam Lake.

Fish from Seydi Stream and Kunduzlar and Çatören Dam Lakes serve as a source of animal protein and means of livelihood for the population in surroundings of both Seyitgazi and Kırka [2]. But high boron levels in water and sediments in this region caused high rates of toxic element accumulations in fish and aquatic organisms in aquatic ecosystems. Our results showed that the average level of boron in edible parts of fish is quite high and may be an important risk factor for human health.

Conclusion

Boron occurs naturally in rocks, some soils, and coal. The boron content of surface water of Kunduzlar Dam Lake can be significantly increased and from the geological structure of the region and especially as a result of waste-water discharges. The results of our study indicate that boron content is significantly higher in water, sediment, and fish. If this bioaccumulation in the biotic and abiotic environments of Kunduzlar Dam Lake and in its near region continues to increase, this condition will create a negative effect in all the environment and on human health. As a result, water of Kunduzlar Dam Lake is higher than the Turkish Environmental Guidelines standard (1 $mg \cdot L^{-1}$). Also, boron and arsenic contents in sediment of Kunduzlar Dam Lake were found to bhigher than other studies in the region (for boron content) and Sediment Quality Guidelines (for arsenic content).

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