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Blood serum IgE and muscle element levels in *Cyprinus carpio* infested by *Argulus foliaceus* in Lake Çavuşçu (Konya/Turkey): Assessment of their impact on human health

by

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Abstract

Fish with the metazoan parasite *Argulus foliaceus* (Crustacea: Branchiura) infestation observed in carp (*Cyprinus carpio*) were caught between September and October 2018 in Lake Çavuşçu. The objective of this study was to determine the concentrations of selected heavy metals (Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Se, Zn) in the muscle tissue of individuals of this fish species. The levels of heavy metals were studied and assessed for their effects on human health. The results obtained in the study were compared with the limit values set by national and international quality criteria. In addition, blood serum IgE levels were examined in fish. IgE is considered part of the parasite-specific immune defense system called allergic antibody. The results were compared with serum IgE levels in non-parasitized carp. It was found that serum IgE levels of infested fish were higher than serum IgE levels of non-parasitized carp. The recommendation for consumers is that although the target hazard quotient (THQ) and total target hazard quotient (TTHQ) were well below 1, they should be mindful of the risk in their daily fish intake.

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1. Introduction

Freshwater quality is deteriorating every day due to rapid development of industry and technology, and the growth of the world's population and urbanization. Freshwater bodies are among the most susceptible to pollution (Tokatlı et al. 2014).

Contamination by heavy metals is a very serious problem for the environment, as they cannot be biologically digested and are toxic to organisms. These metals cause even more health problems once they enter the human body (Jyothi, Farook 2020). Heavy metals reach natural waters from both domestic and industrial water sources, as well as from surface runoff containing fertilizers and pesticides used in agriculture, and reach humans, i.e. the last link in the food chain, through water and aquatic products. Fish absorb heavy metals by eating organisms such as plankton, crayfish and mussels contaminated with metals, or directly from the water through their gills (Saha et al. 2016).

Fish contain high levels of protein and vitamins and low levels of saturated fat and omega fatty acids. Due to these characteristics, they are an important food source for humans and are recommended for consumption (Javed, Usmani 2019; Parvin et al. 2013). Research on the concentration of metals in organisms collected from their natural habitats is important for monitoring ecosystem pollution that occurs as a result of anthropogenic impact (Uçar 2019). Heavy metals tend to accumulate in higher organisms through their biomagnification effects in the food chain. In this way, they can enter the human body and accumulate in human tissues, causing chronic toxicity (Amirah et al. 2013). Many researchers have extensively studied the carcinogenic effects of edible parts of fish on human health (Aissioui et al. 2021; Yap, Al-Mutairi 2022; Zhu et al. 2015; Gu et al. 2015).

Bacterial, viral, fungal and parasitic diseases occur in fish due to climatic or anthropogenic pressures. In order to treat a disease, it is necessary to identify the pathogen causing it. However, there is not sufficient information on the immune response triggered in fish by parasites. IgE plays a key role as a mediator of defense against parasitic diseases (Tepecik 2006).

Fish are one of the indicators of pollution in freshwater systems, and toxic levels in fish can be used to estimate the potential risk for human consumption (Mahamood et al. 2023). Therefore, the impact of heavy metal concentrations on fish should be monitored regularly to better understand the effects of these pollutants on fish growth and the corresponding state of population dynamics (Bat et al. 2019).

According to the United Nations Environmental Protection Agency, heavy metals generally cause two types of health effects, i.e. carcinogenic and non-carcinogenic (Varol, Sünbül 2019). Both effects can be measured in terms of the target hazard quotient (THQ) and the total target hazard quotient (TTHQ), and assessed for the amount and frequency of fish consumption (USEPA 2018). The THQ should not exceed a value of 1; if this limit is exceeded, the non-carcinogenic risk to human life increases. Human health risk assessment is a process that requires defining, collecting and integrating information on health risks from toxins and chemicals, human exposure to chemical substances, and the relationship between exposure, dose and adverse health effects in a contaminated environment (Sobhanardakani et al. 2018).

The purpose of this study was to determine the concentrations of heavy metals in carp (*Cyprinus carpio*) infested with *Argulus foliaceus* (Crustacea: Branchiura) collected from Lake Çavuşçu, and to assess whether this poses a risk to human health.

2. Materials and methods

2.1. Study area

Lake Çavuşçu is located 6 km south of the Ilgin district of Konya Province, at coordinates 38°20'N and 31°52'E (Fig. 1). The lake has an area of 27 km^2 and is a tectonic freshwater lake surrounded by reeds and marshes (Aşıkkutlu et al. 2014). In the vicinity of the lake there is an active lignite pit operated as an open-pit mine (Erdoğan, Manisa 2016).

Fish were caught using gill nets in September and October 2018. Length and weight relationships in the fish are given in Table 1. Parasites taken

Figure 1

Satellite image of Lake Çavuşçu.

Table 1

Metric characteristics of fish.

	Weight (g)	Length (cm)		
		Standard	Fork	Total
(n = 40)				
min.	172	19.2	22.7	23.9
max	217	23.2	26.6	28.3
mean	191.8	25.1	28.9	30.3
SD	7.2	1.83	1.62	1.37

n – number of samples; SD – standard deviation

from the collected fish were fixed in 70% alcohol for observation under a light microscope (LM). Various studies and publications have contributed to determining the morphometric properties of this parasite (Bray et al. 2008). The *Argulus foliaceus* parasite on cyprinid fish is shown in Figure 2.

2.2. IgE analysis

For blood analysis, the heart was punctured with an insulin injector, and blood samples were placed in vacuum biochemistry tubes (BD Vacutainer Systems). The tubes were then immediately put in a cool container and brought to the laboratory. After being left at ambient temperature for 30 min, samples were centrifuged for 10 min at 4000 rpm. The serum was separated using a Beckman Coulter Access 2 immunoassay analyzer. The separated serum was placed in eppendorf tubes and stored at –80°C until analysis. The calibrated test kits were checked with two-level control sera before reading the samples.

2.3. Analysis of heavy metals in fish

Samples of 0.2 g were collected from the muscle tissue of fish, 5 ml of 65% nitric acid (HNO_3) and 2 ml of pure water were added to each tube, and after discharging the gas, samples were put in a microwave (CEM Mars 6) and the dissolution process was conducted. Samples were then cooled and filtered through 100 mm blue band filter paper. After that, they were transferred to falcon tubes and their volume was increased to 25 ml with deionized water. Samples prepared for analysis were measured with an inductively coupled plasma-optic absorption spectrophotometer (ICP-OES; Varian-Vista, Australia). The accuracy of the method was checked by comparing the measured element concentrations to the element concentrations obtained from the TORT-2 (Lobster Hepatopancreas Reference Material for Trace Metals, National Research Council of Canada) fish reference item.

The fish standard reference material was tested with TORT-2 to verify the validity of the analytic method of the measurement device. The results for the reference material are presented in Table 2.

The wavelengths of the elements measured in the devices were Cd 214.439 nm, Co 238.892, Cr 267.716 nm, Cu 327.395 nm, Fe 238.204 nm, Mo 202.032 nm, Mn 257.610 nm, Ni 231.604 nm, Pb 220.353 nm, Se 203.985 nm, and Zn 213.857 nm.

2.4. Human health risk assessment

The estimated daily intake (EDI) of the metals obtained from carp muscles was calculated, as the

Figure 2

Appearance of *Cyprinus carpio* infested by *Argulus foliaceus*.

Table 2

Concentrations of metals found in certified and observed reference material TORT-2 from the National Research Council Canada.

Elemental Concentrations (mg kg^{-1})	Certified value	Observed value	Recovery (%)
Cd	26.7 ± 0.6	25.08	94
Cr	0.77 ± 0.15	0.74	97
Co	0.51 ± 0.09	0.53	104
Cu	106 ± 10	104.9	99
Fe	105 ± 13	106	101
Pb	0.35 ± 0.13	0.34	98
Ni	2.50 ± 0.19	2.37	95
Se	5.63 ± 0.67	5.57	99

EDI of metals varies depending on the concentration of metals in fish muscles and the amount of daily fish consumption. Several methods were used in this study to assess human health risks. The estimated daily intake value for adults was calculated using the following equation (Varol et al. 2018):

$$EDI = \frac{MC \times IRd}{BW}$$

where MC is the metal concentration in fish (mg kg^{-1}, wet weight), IRd is the daily consumption of fish (g day^{-1}), and BW is the average body weight (70 kg) for adults (Korkmaz et al. 2019). According to the Turkish Minister of Agriculture and Forestry (TMAF 2019), the daily fish consumption amount per person in Turkey is approximately 15 g/person/day.

The non-cancer health risks caused by heavy metals due to human consumption of fish were calculated using the target hazard quotient (THQ). This risk estimation method developed by USEPA (2018) was derived from the following equation:

$$THQ = \frac{EF \times ED \times IRd \times MC}{RfD \times BW \times AT} \times 10^{-3}$$

where EF is the frequency of exposure (365 days year^{-1}), ED is the duration of exposure (70 years)(WHO 2015), RfD is the oral reference dose of each metal (mg kg^{-1} day^{-1}) (USEPA 2018), and AT is the average time of the resulting impact, except for cancer (365 days/year × ED) (Kamunda et al. 2016).

The total target hazard quotient (TTHQ) calculated in this study shows the total THQ value of each metal. TTHQ was calculated with the following equation:

$$TTHQ = THQ\ (metal\ 1) + THQ\ (metal\ 2) + THQ\ (metal\ 3) + \ldots + THQ\ (metal\ n)$$

If the TTHQ is lower than 1, no adverse health effects are likely to occur as a result of exposure. If TTHQ is higher than 1, adverse health effects are possible.

In this study, the average values of eight metals detected in the muscles of the fish species under consideration were used to calculate the EDI and THQ.

3. Results

The average concentrations (wet weight, ww) of the heavy metals determined in the fish muscle tissues are given in Table 3. There is no statistical difference in terms of the ANOVA results. Various world institutions have set an upper limit for the permissible amount of heavy metals in foodstuffs. The results of this study were compared with the quality criteria of the Turkish Food Codex (TFC 2011), the European Commission (EC 2006), the International Atomic Energy Agency (IAEA 2003) and the World Health Organization (FAO/WHO 1989); they are listed in Table 4. As shown in Table 4, the average concentrations of Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Se and Zn are below the upper limits set by TFC (2011), EC (2006), IAEA (2003) and FAO/WHO (1989).

The average concentrations of heavy metals determined in the muscle tissues were. While the most accumulated element in the muscle tissues was Fe, Se and Pb were below the limits of analysis. Similar results were reported by many researchers (Ali et al. 2020; Dökmeci et al. 2019; Makedonski et al. 2017).

Heavy metals are important components of hormones, enzymes and enzyme activators. Heavy metals exist as natural components of the Earth's crust and have the property of remaining in the environment for a long time. The presence of trace elements in water can be linked to both natural and anthropogenic sources (Vetrimurugan et al. 2017).

4. Discussion

Since Pb is not an essential element for aquatic organisms, its low concentrations can even cause toxic effects. High concentrations of Pb in humans cause many adverse effects, such as liver and brain damage, cardiovascular diseases, infertility in men, and anemia and miscarriage in women (Kankılıç et al. 2013). The concentration of Se in the aquatic environment varies depending on the O_2 level in the water, the trophic status, water temperature, age of organisms,

Table 3

Comparison of heavy metal concentrations in carp muscles determined in this study with those reported in carp from other freshwater bodies; min.–max (mean).

Location	Karasu Stream[a] mg kg^{-1} ww	Lake Beyşehir[b] mg kg^{-1} dw	Lake Eğirdir[c] mg kg^{-1} dw	Lake Nansi[d] (China) µg g^{-1} ww	Lake Sakarya[e] µg g^{-1} dw	Keban Dam Lake[f] mg kg^{-1} dw	Lake Suğla[g] mg kg^{-1} dw	Lake Mogan[h] µg g^{-1} ww	This study
Cd	0.031 – 0.045	2.06 – 2.32 (2.17)	0.0016 – 3.19 (0.22)	0.12 – 0.35		1.2			0.01 – 0.04 (0.03)
Pb	0.22 – 0.29	1.68 – 4.02 (2.84)	0.01 – 0.11 (0.04)	0.28 – 0.65		3.1		4.15	BAL
Cu	1.32 – 1.61	1.09 – 2.68 (1.62)	1.38 – 98.14 (14.21)	1.47 – 5.67	1.12		0.31		0.33 – 0.74 (0.59)
Zn	8.4 – 12.3	9.32 – 15.92 (12.49)	18.06 – 394.49 (90.93)	11.43 – 28.23	23.1		9.83	33.24	10.43 – 22.2 (14.46)
Ni	–	0.5 – 2.17 (1.43)	0.12 – 7.76 (1.47)	0.84 – 3.12	0.52	2.6			0.001 – 0.027 (0.009)
Cr		10.6 – 13.02 (12.11	0.06 – 3.85 (0.74)		0.08	0.1	0.03	1.19	0.088 – 0.125 (0.1)
Fe		< BAL – 3.37 (3.03)	11.28 – 533.02 (85.06)	8.73 – 35.81	22.3		9.43	57.2	12.961 – 26.724 (18.13)
Mn		8.76 – 9.76 (9.35)	0.01 – 3.23 (0.96)	1.48 – 4.62	0.38	5.3	0.22	1	0.89 – 1.34 (1.17)
Mo			0.003 – 1.99 (0.27)						0.02 – 0.16 (0.06)
Se			0.21 – 3.20 (1.21)						BAL
Co		2.50 – 3.14 (2.85)							0.14 – 0.18 (0.165)

ww – wet weight; dw – dry weight; BAL – Below Analysis Limit; [a] (Bat et al. 2019); [b] (Ozparlak et al. 2012); [c] (Kaptan, Tekin-Özan 2014); [d] (Zhu et al. 2015); [e] (Küpeli et al. 2014); [f] (Danabas et al. 2020); [g] (Akköz, Çağlar 2014); [h] (Benzer et al. 2013)

Table 4

Limit values of selected heavy metals in fish muscles according to national and international quality standards (mg kg^{-1}, wet weight).

	Cd	Pb	Ni	Cr	Cu	Fe	Zn	Mn
Turkish Food Codex TFC (2011)	0.1	0.2			20	50	50	20
EC (2006)	0.05	0.3						
IAEA (2003)	0.19	0.12	0.6	0.73	3.28	146	67.1	3.52
FAO/WHO (1989)	0.5	0.5			30		40	
This study	0.03	BAL*	0.009	0.103	0.594	18.137	14.466	1.167

*BAL – Below Analysis Limit

nutritional status and body size. Products from agricultural fields contaminated with selenium infect humans through the food chain (Kaptan, Tekin-Ozan 2014). Pb and Se levels in sampled individuals of the analyzed carp species were below detectable limits, including the results from Lake Sugla (Özparlak et al. 2016), Lake Sapancı (Küpeli et al. 2014), Lake Işıklı (Tekin-Ozan, Aktan 2012), Lake Nansi (Zhu et al. 2015) and Lake Šalek (Al Sayegh Petkovšek et al. 2012).

Fe occurs in large quantities worldwide and is a biologically essential compound for every organism, including as a component of proteins that transport oxygen from the lungs to tissues in other parts of the body. High Fe intake, however, can increase the risk of chronic diseases (Tao et al. 2012). Fe occurs with the highest concentrations among the metals analyzed. Similar results were obtained in Lake Karataş Başyiğit, Tekin-Özan (2013), Lake Taihu (Tao et al. 2012) and Gökçekaya Dam Lake (Akın et al. 2011). Although Fe was the most abundant element in this study, it did not exceed international limits.

Cu is also an essential element. Excessive exposure to Cu can cause anemia, liver and kidney damage, developmental toxicity and immunotoxicity (Atsdr 2004). The average Cu level in fish muscles was 0.594 mg/kg. The data obtained in this study were found to be in line with the results obtained for the dams and natural lakes of Turkey, including 0.56 mg kg^{-1} (Oymak et al. 2009) in the muscles of fish collected from Ataturk Dam Lake, 0.378 mg/kg from Keban Dam Lake (Varol et al. 2018) and 0.67 mg kg^{-1} (Özparlak et al. 2016) from Lake Sugla.

Nickel is one of the hardest heavy metals due to its resistance to chemical corrosion. An increase in nickel in the body increases the risk of various diseases, including lung cancer or other respiratory cancers, asthma, bronchitis, pneumonitis and allergic skin diseases (Öztürk et al. 2014). The average Ni concentration in this study was determined to be 0.009 mg kg^{-1}. Although the Ni values were low, they were similar to those found in previous studies, for example for Lake Beysehir (0.05 mg kg^{-1}; Aktümsek, Gezgin 2011), a lake in China (0.014 mg kg^{-1}; Jiang et al. 2016) and a lake in Iran (0.0985 mg kg^{-1}; Fallah et al. 2011).

Zinc is an essential element present in all organs, tissues and body liquids. Zn is an important micronutrient present in almost every cell and is the second most abundant trace element after Fe. High-dose intake of zinc is rare and inhibits copper function in the body (Hedera et al. 2009). The average Fe concentration in this study was 14.466 mg kg^{-1}. In previous studies, it was detected at the following values: 17.7 mg kg^{-1} in Lake Mogan (Benzer et al. 2013), 26.4 mg kg^{-1} in Karakaya Dam Lake (Ural et al. 2012), and 16.9 mg kg^{-1} in Borcka Dam Lake (Gedik et al. 2018); these values are consistent with the results of this study.

Cadmium is a very rare element and is not a main element for living organisms. It generally occurs in nature as a result of industrial activities (paint and chemical industries, fertilizer and drug production, plastics, mining, and oil refining). Cadmium as a toxic heavy metal enters the food chain through direct ingestion of water and aquatic organisms from aquatic ecosystems or through epithelial tissue (Burger 2008). Cadmium was found at a level of 0.03 mg kg^{-1} in this study, close to the value of EC (2006), where 0.05 mg kg^{-1} is the limit value. In previous studies, contamination with cadmium was determined at 0.16 mg kg^{-1} in Lake Egirdir (Kaptan, Tekin-Ozan 2014) and 0.05 mg kg^{-1} in Lake Isikli (Tekin-Ozan, Aktan 2012), which may be due to agricultural fertilizers.

Cobalt is a naturally occurring element in sediments, rocks and soil, found in trace amounts in zinc, ferrous, copper, argent, and arsenic ores as a byproduct of mining these metals. Cobalt forms the basic structure of vitamin B12. In the case of excessive intake, however, cobalt has toxic effects on terrestrial and aquatic plants, animals, and humans (Kankılıç et al. 2013). In this study, it was found at a level of 0.165 mg kg^{-1}. In previous studies, the concentration of Co was found at 2.85 mg kg^{-1} in Lake Beysehir (Özparlak et al. 2012) and 1.57 mg kg^{-1} in Lake Sugla (Özparlak et al. 2016). The value obtained in this study is higher than the values reported in the literature.

Manganese does not occur naturally as a pure element, but is found in compounds with more than a hundred elements. Manganese is toxic if it enters the human body in high concentrations. The average concentration of Mn in fish muscles in this study was 1.167 mg kg^{-1}. Other studies reported that it was 0.22 mg kg^{-1} in Lake Sugla (Akköz, Çağlar 2013) and 0.58 mg kg^{-1} in Lake Kovada (Kayrak, Tekin-Ozan 2018). The value determined in this study is higher than that found in other studies, but it is below the IEAE (2003) limit value.

Molybdenum is an essential trace element with relatively low toxicity. It is added to fertilizers to provide stimulation to plant growth because it is an easily soluble element. Molybdenum in small amounts is essential for all living organisms, but in large amounts it is highly toxic (Jyothi, Farook 2020; Shrivas et al. 2009; Varol et al. 2019). While the average concentration of Mo in this study was calculated at 0.062 mg kg^{-1}, other studies reported it at 0.11 mg kg^{-1} in Lake Kovada (Kayrak, Tekin-Ozan 2018) and 0.27 mg kg^{-1} in Lake Egirdir (Kaptan, Tekin-Ozan 2014). The value obtained in this study was lower than that calculated in other studies.

Chromium is an essential element and an important enzyme cofactor, but can be toxic to living organisms. Cr is the seventh most abundant element on Earth but it rarely occurs in elemental form and appears in the structure of various minerals (Tekin-Ozan, Aktan 2012). The average Cr value in fish muscles in this study was 0.103 mg kg^{-1}, which is lower than that determined in other studies, for examples 0.22 mg kg^{-1} in Lake Marmara (Yabanlı et al. 2014), 0.122 mg kg^{-1} in Batman Dam Lake (Kaçar et al. 2017) and 0.132 mg kg^{-1} Ataturk Dam Lake (Oymak et al. 2009).

Fish living in contaminated waters tend to accumulate heavy metals in their tissues. Carp is one of the most frequently caught and consumed fish in the world and is a good bioindicator for determining the effects of different pollutants on aquatic organisms (Bat et al. 2019). This study examined for the first time the concentration of heavy metals in common carp in Lake Çavuşçu. Various studies have shown differences in heavy metal concentrations in cyprinid fish in rivers, streams and lakes.

4.1 Human health risk assessment

The EDI values of the metals as a result of fish consumption by adults are shown in Table 5. The EDI values for the examined carp samples were well below the TDI limits indicating that there is no health risk regarding the intake of the examined heavy metals through consumption of the examined fish samples. While Cr and Cu have the highest TDI/EDI ratio

(> 3000) among the metals, Ni has the lowest TDI/EDI ratio (< 10).

It is not possible to make a decision on the safety of food resources based on EDI analysis alone. Therefore, a broader risk analysis was conducted to determine the carcinogenic effects of each metal ion. For this purpose, THQ values were calculated, and THQ values of heavy metals in relation to fish consumption are presented in Table 5. THQ values could not be calculated for Se and Pb because Se and Pb concentrations in the muscle tissues of the studied fish species were below the measurable limit values. None of the THQ values (< 0.01) for any metal ion exceeded the hazard quotient threshold of 1. These values mean that the daily intake of every examined metal ion was lower than the related reference dose for adults. Thus, based on the assumption that people receive all their fish resources from Lake Çavuşçu and food processing has no impact on the amounts of heavy metals found in fish, it can be concluded that the exposure levels of people to the analyzed metals will have no harmful effect on their lives. In this study, the TTHQ value (0.0369) was also less than 1 (Table 5), and this shows that the intake of metals in cyprinid fish poses no health risk to adults in Turkey. Similar results have been reported by many researchers (Bat et al. 2019; Kamunda et al. 2019; Korkmaz et al. 2019; Makedonski et al. 2017; Özparlak et al. 2012; Petkovšek et al. 2012; Varol et al. 2018; Varol, Sünbül 2019). Zn, Cr and Fe are the three main factors contributing to TTHQ due to their low RfD values compared to their concentrations.

4.2. IgE levels

IgE was determined with the development of the metazoan parasite *Argulus foliaceus* (Crustacea: Branchiura) observed in carp individuals with fin atrophy (Table 6). The immune system of the fish activated to protect them from the harmful effects of the parasite. Fish attempt to prevent the migration and settlement of the parasite with this immunity. Five classes of immunoglobulins (Ig) were identified in humans and higher vertebrate animals: IgA, IgD, IgE, IgG, and IgM. IgE plays a role in the pathogenesis of many allergic diseases in defense against parasitic diseases.

The purpose of this study was to compare IgE serum levels in the infested fish collected from the lake with the healthy carp individuals collected from the same lake. The average IgE level in the healthy fish was 6.82 (IU ml^{-1}). All values remained below the measurement range of the device (< 2 IU ml^{-1}) in the control fish.

Blood serum IgE levels of infested fish were found to be consistent with blood serum IgE levels that are highly elevated in humans with parasitic and allergic diseases (Ramadani et al. 2019). These results indicate that blood serum IgE levels can also be used to study the immunity that develops in fish with parasites.

Table 5

EDI, THQ, and TTHQ values calculated for eight metals in *Cyprinus carpio*, and TDI and Rfd values determined for these metals.

Metal	Mean	EDI	TDI (µg/kg/body weight /day)	Rfd (mg/kg/bw/day)[a,b]	THQ
Co	0.165	0.35	8.6	0.003	0.0011
Cd	0.03	0.0016	0.8	0.001	0.0078
Cr	0.103	0.0221	300	0.003	0.0073
Cu	0.594	0.1273	500	0.04	0.0031
Fe	18.137	3.886	800	0.7	0.0055
Mn	1.167	0.2502	140	0.14	0.0017
Ni	0.009	1.96	12	0.02	0.0001
Zn	14.466	3.0998	300	0.3	0.0103
TTHQ					0.0369

[a] (Korkmaz et al. 2019); [b] (USEPA 2018)

Table 6

Blood serum IgE levels in parasitized and non-parasitized fish from Lake Çavuşçu.

	IgE (IU ml^{-1})						
	I	II	III	IV	V	VI	VII
Parasitic examples	7.73	7.24	6.87	5.89	7.02	6.26	6.74
Normal examples	< 2	< 2	< 2	< 2	< 2	< 2	< 2

5. Conclusion

The objective of this study was to reveal the impact of bioaccumulation and consumption of carp as freshwater fish collected from Lake Çavuşçu, which is commonly sold in local markets and consumed by the public, on human health. The results of the health risk assessment (EDI, THQ and TTHQ) of the average concentrations of the analyzed heavy metals in the muscle tissue constituting the consumable part of the caught fish showed no risk to human health. The low health risk may result from the low consumption of fish (15 g/day). In addition, the results obtained for the analyzed elements in the fish species in question are within acceptable limits for human consumption. Furthermore, the effects of environmental pollutants in lakes can be exacerbated in an uncontrolled way by factors such as river inflows, drainage, and industrial discharges. For this reason, it is crucial to monitor and control pollutants, such as heavy metals, which negatively affect human health by leaving residues in fish. Potentially dangerous situations may occur in the future depending on the development of agriculture and lignite mining in this region. With the use of the lake's water for agricultural activities, the lowering water level is causing fish infestation. Increased infestation can cause swimming disorders in fish, discoloration of fins, molting, redness of the skin and hemorrhagic symptoms, as well as the death of weak juvenile fish. Therefore, it is necessary to ensure that the fish consumed by the public is inspected and precautions are taken for its consumption if necessary.

Disclosure statement:

The author declares that he has no conflict of interest.

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