EVALUATION OF HEAVY METAL CONCENTRATIONS AND PUBLIC HEALTH RISK OF FISH SPECIES OF *VIMBA VIMBA*, *TINCA TINCA*, *SCARDINIUS ERYTHROPHTHALMUS* IN SAPANCA LAKE, TURKEY

SAPANCA GÖLÜ, TÜRKİYE'DE *VİMBA VİMBA*, *TİNCA TİNCA*, *SCARDİNİUS ERYTHROPHTHALMUS* BALIK TÜRLERİNİN AĞIR METAL YOĞUNLUKLARI VE HALK SAĞLIĞI RİSKİNİN DEĞERLENDİRİLMESİ

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ÖZET

Bu çalışma Sapanca Gölü, Türkiye'den toplanan *Vimba vimba*, *Tinca tinca*, *Scardinius erythrophthalmus* balık türlerinde ağır metallerin yoğunluklarını ve halk sağlığı risklerini belirlemeyi amaçladı. Bu amaçla farklı mevsimlerde (sonbahar, kış, ilkbahar ve yaz) elde edilen üç balık türünün kas bakır, çinko, kurşun, kadmiyum ve arsenic yoğunlukları atomik absorpsiyon spektrometresi ile belirlendi. Metal yoğunlukları bazı balık türlerinde mevsimsel farklılıklar gösterdi ve ayrıca belirli balık türleri ile değişti. Bu metallerin yoğunluklarının izin verilen sınırlar içinde olduğu bulundu. Sonuçlar üç balık türünde ağır metal yoğunluğunun önemli halk sağlığı riski oluşturmadığını gösterdi.

Anahtar Kelimeler: Sapanca Gölü, Ağır metaller, Balık, Kirlilik, Sağlık riski

ABSTRACT

This study aimed to determine the concentrations of heavy metals in *Vimba vimba*, *Tinca tinca*, *Scardinius erythrophthalmus* fish species, collected from Sapanca Lake, Turkey and public health risks. For this purpose, the muscle copper, zinc, lead, cadmium and arsenic concentrations of three fish species obtained in four different seasons (autumn, winter, spring and summer) were determined by atomic absorption spectrometer. The metal concentrations showed seasonal variations in some fish species and also varied with respect to particular fish species. The concentrations of these metals were found to be within the permissible limits. The results showed that there was no important public health risk of heavy metal concentration in three fish species.

Keywords: Sapanca Lake, Heavy metals, Fish, Pollution, Health risk

Note: *This study was presented as oral presentation in 3rd International Water and Health Congress, 12-15 November, 2019, Antalya.*

1. INTRODUCTION

Heavy metals such as arsenic (As), copper (Cu), cadmium (Cd), zinc (Zn) and lead (Pb) are elements of earth's crust (Singh, 2017). These metals tend to accumulate in plants via soil that can result in increased metal load in humans and animals (Wuana and Okieimen, 2011). In addition, exposure to these metals through water resources is possible (Chowdhury et al., 2016; Kamunde et al., 2002). However, increasing of industrial activities, use of metals in many commercial products, discharge of plant wastes to environment can lead to increased metal contamination in soil and waters (Dang et al., 2019; Omwene et al., 2018; Wang et al., 2018; Withanachchi et al., 2018; Yousaf et al., 2016). Therefore, health concerns with exposure of heavy metals can occur. Health concerns are gastro-intestinal problems, cardiovascular disorders, neurological damage, kidney injury, cancer and diabetes (Rehman et al., 2018).

Cu and Zn are essential elements which are normally found in certain amounts in the body tissues (Aggett, 1997; Chan et al., 1998; Ekmekcioglu, 2001; Kaplan and Maryon, 2016; Livingstone, 2015). Cu is also structural component of some enzymes (superoxide dismutase, cytochrome c oxidase, metallothionein, ceruloplasmin etc.) (Linder and Hazegh-Azam, 1996; Milne, 1994) and is an essential element for thyroid hormone metabolism (Rasic-Milutinovic et al., 2017). Zn, on the other hand, plays an important role in protein synthesis, cell growth and DNA synthesis (Giugliano and Maillward, 1987; Ohashi et al., 2015). However, long term high level intake of these metals can result in toxicities (Gaetke et al., 2014; Pal, 2014; Yoshida et al., 2019).

Especially As, Cd, Cu and Pb are among the most frequently used metals for industrial purposes (in manure production, battery, plastic, glass, paper and ceramic industry) (Burgess et al., 2000; Chu et al., 2019; Moreira, 1996; Yue et al., 2019). Environmental pollution due to these metals is of increasing concern around the heavily industrialized regions (Omwene et al., 2018; Otansev et al., 2016; Zou et al., 2018).

Sapanca Lake is located in a region close to the heavily populated and industrialized cities. In this study, it was aimed to determine the concentrations of metal contamination in *Vimba vimba*, *Tinca tinca*, *Scardinius erythrophthalmus* fish species of Sapanca Lake, Turkey and to evaluate whether the potential risk to humans consuming these fishes would occur.

2. MATERIALS AND METHODS

2.1. Sampling of fish

The fish samples were supplied from fishermen. The fish sampling area in Sapanca Lake is showed in Figure 1. In this study, the concentrations of Cd, As, Zn, Cu and Pb were determined in 4 different seasons (autumn, winter, spring and summer seasons) in fish species of *Vimba vimba, Tinca tinca* and *Scardinius erythrophthalmus*. Ten fish samples were obtained from each season and each fish species, thus, each group consisted of 40 fish. After the fish samples were obtained from fishermen, they were stored in a deep freeze for the metal analysis.

2.2. Heavy metal analysis

The metal concentrations of fish muscles were determined by the method of Salisbury and Chan (Salisbury and Chan, 1985). The muscle parts of fish samples were removed. Approximately 2 grams of muscle parts were weighed accurately and were digested with nitric acid (65%) and hydrogen peroxide (30%) in microwave acid digestion unit (Milestone Mega1200). Cd, Pb, and As concentrations in these digested samples were analyzed with atomic absorption spectrometer (AAS) (Varian SpectraAA 30/40) equipped with graphite furnace (Varian GTA-96). Calibration curves were produced with Cd, Pb and As atomic absorption standard solutions at AAS. Then, the concentrations of metals were calculated in the digested samples with these calibration curves at AAS. Measurements were repeated twice. Cu and Zn concentrations in these digested samples were analyzed with flame atomic absorption spectrometer (AAS) (Varian SpectraAA 30/40). Acetylene and air mixture was used as flame. Calibration curves were produced with Cu and Zn atomic absorption standard solutions at AAS. Then, the concentrations of these metals were calculated in the digested samples with these calibration curves at AAS. Measurements were repeated twice. All reagents and laboratory ware were atomic absorption spectrometry quality.

2.3. Assessment of health risks

Formulae with regard to public health risks are presented as follows: Estimated daily intake (EDI) (Keshavarzi, 2018), EDI = C_{metal} × [DC fish/BW], C_{metal} (mg/kg) is the concentration of heavy metals in the fish muscle, DC fish is an amount of consumed fish (20 g/person/day), BW is considered 70 kg for adults (Varol and Sünbül, 2018).

Target hazard quotient (THQ) (Keshavarzi, 2018), THQ = [EDI/RfD] × 10^{-3}, RfD is the metal reference dose, 1.0 × 10^{-3} mg/kg/day for Cd, 4.0 × 10^{-3} mg/kg/day for Pb, 3.0 × 10^{-4} mg/kg/day for As, 4.0 × 10^{-2} mg/kg/day for Cu, 3 × 10^{-1} mg/kg/day for Zn (USEPA, 2011). Hazard index (HI) = ΣTHQs, s represents different elements (USEPA, 2006).

Target cancer risk (TCR), TCR = EDI × CPSo × 10^{-3}, CPSo is 1.5 mg/kg/day for As (USEPA, 2006).

2.4. Statistical analysis

Data were expressed as mean ± SD. Differences among seasons were tested by one-way ANOVA which was followed by Duncan's post-hoc multiple comparison test using SPSS Version 10.0 for Windows (SPSS Inc., Chicago, IL). Differences were considered significant if the P value was less than 0.05.

3. RESULTS

The mean highest and lowest weights of fish were 151.00 g and 84.9 g, respectively. The mean highest and lowest lengths of fish were 22.50 cm and 17.5 cm, respectively. The concentrations of Pb, Zn, Cu and As in *Vimba vimba* species showed significant differences with respect to seasons ($p<0.05$, Table 1). In addition, there were also significant seasonal variations in Cd, Cu and As concentrations in *Tinca tinca* species ($p<0.05$, Table 2). In samples from *Scardinius erythrophthalmus* species, only As concentrations showed significant seasonal variations ($p<0.05$, Table 3). Health risk parameters such as EDI, THQ, HI, and TCR were found within allowable limits (Tables 4 and 5).

4. DISCUSSION

Cadmium is one of the metals that can lead to intense environmental pollution in industrialized areas (Li et al., 2017) and mining areas (Palutoglu et al., 2018). In the current study Cd concentrations showed variations in terms of fish species. No seasonal differences in Cd concentrations were found in *Vimba vimba* and *Scardinius erythrophthalmus* species. The highest accumulation of Cd was found in *Tinca tinca* and *Scardinius erythrophthalmus* species. Cadmium concentrations in this study were lower than the study of Sobihah et al. (2018) that cadmium concentrations in the muscles of fish supplied from Pulau Ketam, Malasia are found to be 0.007-0.012 mg/kg. However, cadmium concentrations in fish samples of Enne Dam Lake, Turkey were determined to be high compared to permissible limits (Uysal et al., 2009). The Cd concentration of fish muscle in this study is below maximum allowable Cd concentrations (50 ng/g) set by Turkish Food Codex (2011). EDI values for Cd in this study are much lower than provisional maximum daily intake (PMDI) (0.08 mg/day).

Pb is one of the most important metals causing environmental pollution (Frank et al., 2019; Yan et al., 2019). While *Vimba vimba* species showed seasonal variations for Pb concentrations, no difference was observed seasonally in *Tinca tinca* and *Scardinius erythrophthalmus*. Seasonal variations of Pb found in *Vimba vimba* species may not solely be attributed to seasonal variations in environmental pollution since no difference was observed in other fish species obtained from the same Lake. Lead concentrations in *Chalcalburnus tarichi*, *Pallas 1811* obtained from Van Lake, Turkey were reported to be above allowed limit and to be of concern for humans (Bilgili et al., 1995). In another study, Dundar and Altundag (2007) have showed that the industrial area discharges lead to the highest Pb concentration in water samples of Sakarya River. The fish muscle Pb concentrations in this study were lower than those of the studies of Sobihah et al. (2018) and Rather et al. (2019). According to World Health Organization (1989), maximum allowed daily limit of Pb is 3.57 µg/kg/day. In addition, provisional maximum tolerable daily intake (PMTDI) for Pb is 0.03 mg/day (Ysart et al., 2000) and in this study EDI value for Pb did not exceed PMTDI value.

The concentrations of As can be higher in marine species as compared to other species (WHO, 1995). As consistent with this report, Keshavarzi et al. (2018) have reported high As contamination in the muscles of fish species analyzed at Musa Estuary and Mahshahr Harbour in Iran and health risk for humans consuming fish. In a study carried out in Turkey, Bilgili et al. (1999) reported that the As concentrations in *Chalcarburnus tarichii*, Pallas 1811 collected in Van Lake, Turkey were below the allowed levels. However, Durmaz et al. (2017) have revealed that the weekly risk for As is high according to the tolerable levels in carp in Büyük Menderes River, Turkey. It was reported that humans could be exposed to As-contaminated food. European Community guidelines (EEC, 2001) permit 2 µg/g maximum arsenic levels in marine fish. In this study, As concentrations of fish muscle were varied between 29.60±5.60 and 63.90±16.25 ng/g. The muscle As concentrations in fish obtained from Sakarya River were below European Community guidelines (EEC, 2001). EDI values by consuming fish from Sapanca Lake were between 13.6×10^{-3} and 18.25×10^{-3}. PMTDI for As is 0.12 mg/day (Ysart et al., 2000). In this study, EDI values for As in fish from Spanca lake were much lower than PMTDI value.

Zn is a metal which is normally found in the body as an essential element. It has functions in cell communication, proliferation, differentiation and survival (Livingstone, 2015; Sanna et al., 2018). Küpeli et al. (2014) have revealed that heavy metal risk is no concern in Sapanca Lake. In this study, the concentrations of Zn in *Vimba vimba* species were found to be varied in different seasons. In other study carried out in fish of different aquatic areas, increased Zn concentrations have been determined compared to this study (Rather et al., 2019). Turkish Food Codex (2002) maximally allowed Zn intake 50 µg/g for fish. Minimum and maximum concentrations of Zn found in fish muscles were 7.30 and 9.38 µg/g, respectively and were within allowable levels by Turkish Food Codex (2002). In addition, maximum daily intake for Zn is 300 µg/kg/day allowed by USEPA (2005). EDI values for Zn in this study were far below this value for Zn intake by fish, suggesting that there was no risk for human consumption.

Cu is also a metal normally present in the body. It has functions as cofactor of several enzymes and proteins, and several biological processes, especially respiration, protection from oxidative damage (Giampietro et al., 2018). This metal can only cause toxicities at doses higher than the amount found in the body (Gaetke et al., 2014; Scheiber et al., 2013). Negligible Cu contamination in sediments of lower Sakarya River and the lower accumulation of Cu in fish of Porsuk Stream were reported (Dundar et al., 2012; Köse et al., 2015). In the present study, Cu concentrations in *Tinca tinca* and *Vimba vimba* species showed seasonal variations. However, no variation was observed in *Scardinius erythrophthalmus*. Maximum Cu concentrations of fish muscle in this study were found to be 1.88 µg/g. Turkish Food Codex (2002) set at 20 µg/g allowable Cu intake. Maximum Cu concentrations of fish muscle in this study were much lower than values set by Turkish Food Codex (2002). Moreover, maximum daily intake value is 500 µg/kg/day allowed by WHO (WHO, 1989). In this study, EDI values were much lower than value reported by WHO (WHO, 1989).

Moreover, in this study, health risk parameters due to heavy metal contamination of fish supplied from Sapanca Lake were evaluated. If THQ (Wang et al., 2005) and HI (USEPA, 2006) values in fish edible parts are equal or above unity, fish consumption leads to public health concerns. TCR for carcinogens such as As is evaluated and acceptable risk values are between 10^{-4} and 10^{-6} (FAO, 2014). In this study, THQ and HI were below 1 and TRC levels were within 10^{-4} and 10^{-6}.

In conclusion, the results of the current study suggested that heavy metal accumulation in three fish species in Sapanca Lake, Turkey was within allowable limits. In addition, it was concluded that the consumption of fish species from Sapanca Lake would not conceivably cause adverse effects on human health considering EDI, THQ, HI and TCR.

Conflicts of Interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Table 1. Metal concentrations, live weights and lengths in *Vimba vimba* in different seasons.

Parameter	Autumn	Winter	Spring	Summer
Cadmium (ng/g)	2.39±0.78	2.24±1.11	2.02±0.62	2.61±1.10
Lead (ng/g)	79.90±21.20[a]	96.90±15.3[a]	102.60±18.11[ab]	98.80±20.22[b]
Zinc (µg/g)	7.56±1.98[a]	8.44±1.57[ab]	7.98±1.93[ab]	9.38±1.39[b]
Copper (µg/g)	0.93±0.35[a]	1.11±0.58[a]	1.41±0.52[ab]	1.79±0.64[b]
Arsenic (ng/g)	39.10±7.06[a]	39.60±7.79[a]	46.40±9.85[a]	61.00±18.62[b]
Live weight (g)	84.90±13.23[a]	90.75±11.95[b]	103.16±4.16[a]	100.48±3.31[a]
Length (cm)	18.45±1.25	18.50±0.94	18.70±1.51	17.75±0.54

Note: Means with different superscripts are significantly different ($p<0.05$).

Table 2. Metal concentrations, live weights and lengths in *Tinca tinca* in different seasons.

Parameter	Autumn	Winter	Spring	Summer
Cadmium (ng/g)	2.89±0.89[a]	2.98±1.04[a]	1.88±0.58[b]	2.27±0.64[ab]
Lead (ng/g)	88.80±32.82	98.70±38.61	95.10±19.04	84.30±16.95
Zinc (µg/g)	7.30±1.73	8.70±2.02	8.41±2.20	8.42±1.66
Copper (µg/g)	0.90±0.34[a]	0.71±0.32[ab]	0.51±0.30[b]	0.77±0.25[ab]
Arsenic (ng/g)	29.60±5.60[a]	39.60±8.65[a]	63.90±16.25[b]	53.70±14.59[b]
Live weight (g)	151.00±9.77[a]	149.30±12.08[ab]	136.60±14.68[bc]	135.50±18.13[c]
Length (cm)	21.70±0.88	22.50±1.05	21.85±1.56	22.01±1.41

Note: Means with different superscripts are significantly different ($p<0.05$).

Table 3. Metal concentrations, live weights and lengths in *Scardinius erythrophthalmus* in different seasons.

Parameter	Autumn	Winter	Spring	Summer
Cadmium (ng/g)	2.47±0.70	2.98±1.06	2.84±0.68	2.81±0.58
Lead (ng/g)	100.40±17.79	90.40±14.65	89.00±6.78	95.60±11.06
Zinc (µg/g)	9.04±1.74	8.20±0.66	8.85±0.95	8.14±0.84
Copper (µg/g)	1.88±0.59	1.46±0.54	1.84±0.61	1.86±0.71
Arsenic (ng/g)	40.10±10.55[ab]	47.60±7.66[b]	37.00±9.93[a]	46.30±9.55[b]
Live weight (g)	138.70±36.78	116.10±26.00	129.85±32.05	116.55±23.69
Length (cm)	21.10±1.96	20.85±1.24	21.55±1.42	20.70±1.39

Note: Means with different superscripts are significantly different ($p<0.05$).

Table 4. Estimated daily intake (EDI) of heavy metals in fish species from Sapanca Lake.

Fish Species	Cd	Pb	Zn	Cu	As
Vimba vimba	0.74×10^{-3}	29.31×10^{-3}	2.68	0.51	17.42×10^{-3}
Tinca tinca	0.85×10^{-3}	28.2×10^{-3}	2.48	0.25	18.25×10^{-3}
Scardinius erythrophthalmus	0.85×10^{-3}	28.68×10^{-3}	2.58	0.53	13.6×10^{-3}

Table 5. THQ, HI and TCR values of fish species from Sapanca Lake.

Fish Species	THQ					HI	TCR
	Cd	Pb	Zn	Cu	As		
Vimba vimba	0.074×10^{-2}	0.732×10^{-2}	0.89×10^{-2}	0.012	5.80×10^{-2}	7.50×10^{-2}	2.61×10^{-5}
Tinca tinca	0.085×10^{-2}	0.705×10^{-2}	0.82×10^{-2}	0.006	6.08×10^{-2}	7.69×10^{-2}	2.73×10^{-5}
Scardinius erythrophthalmus	0.085×10^{-2}	0.717×10^{-2}	0.86×10^{-2}	0.013	4.53×10^{-2}	6.20×10^{-2}	2.04×10^{-5}

Fig. 1. The fish sampling area in Sapanca Lake, Turkey.