Asian Journal of Water, Environment and Pollution, Vol. 18, No. 2 (2021), pp. 1–8.
DOI 10.3233/AJW210013

Assessment of Heavy Metal Concentrations and Public Health Risk in Fish Species of Sakarya River, Turkey

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Received August 10, 2020; revised and accepted February 9, 2021

Abstract: In this study, heavy metal concentrations including cadmium, lead, zinc, copper and arsenic concentrations were determined in five fish species (*Capoeta sieboldii, Capoeta tinca, Scardinius erythrophthalmus, Squalius pursakensis* and *Barbus escherichii*) obtained from the Sakarya River. The metal concentrations of fish supplied in four different seasons (winter, spring, summer and autumn) were determined by using atomic absorption spectrophotometry. Although 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. In addition, it was concluded that the concentration of metal contamination in the evaluated fish species would not pose a risk for human consuming fish species obtained from Sakarya River by considering estimated daily intake (EDI), target hazard quotient (THQ), hazard index (HI), and target cancer risk (TCR) values.

Key words: Heavy metal, fish, Sakarya River, pollution, health risk.

Introduction

A number of studies on metal contamination in fish species of freshwater ecosystems in Turkey have been published, indicating that heavy metal contamination is generally within the permissible limits (Agtas et al., 2007; Alhas et al., 2009; Yilmaz and Dogan, 2008). However, continuing surveillance of heavy metals in fish species important for human consumption is needed to evaluate the risk of public health and to assess the degree of environmental pollution particularly in regions with heavy industrial and agricultural activities (Bosch et al., 2016). Sakarya River is one of the important freshwater resources located around the heavily populated and industrialised cities. Arsenic (As), copper (Cu), zinc (Zn), cadmium (Cd) and lead (Pb) are some heavy metals that are frequently utilised in today's industrialised life (Chen et al., 2016; Vareda et al., 2019; Weissmannova et al., 2019). Upon taken up, they are quickly bound to the sulfhydryl groups of proteins in the body (Bandyopadhyay et al., 1997; Jomova and Valko, 2011; Valko et al., 2016), leading to a reduction in the activities of many enzymes (Bal et al., 2017; Banci et al., 2002; Hanahisa and Yamaguchi, 1998). Zn and Cu

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are trace elements that play various important roles in the regulation of vital functions (Bosch et al., 2016). Cu is transported with the help of ceruloplasmine and accumulated in the skin and hair in higher amounts (Lech, 2002; Valko et al., 2016). Zn is also known to be accumulated in high levels in muscle and hair. Furthermore, Zn and Cu are structural components of some vital enzymes such as SOD, tyrosine hydroxylase, carbonic anhydrase and alkaline phosphatase (Hanahisa and Yamaguchi, 1998; Kunikowska and Jenner, 2002; Szabolcs, 1990). Long term exposure to high levels of these metals can result in acute, subacute and chronic toxications (Fischer and Skreb, 2001; Rehman et al., 2018; Saleh and Awadin, 2017; Sonmez et al., 2002; Tchounwou et al., 2012). Therefore, it is important to know the concentrations of metal contamination in fish species important for human consumption to manage the toxicity problems caused by these metals. Living organisms are intensely exposed to heavy metals due to their living environment and dietary habits and accumulate metals in much greater concentrations in their body compared to the environment (Zaqoot et al., 2017). Fish are organisms widely used in the evaluation of the quality of aquatic ecosystems as bio-indicator for environmental pollutants also including heavy metals. This study aimed to determine the concentrations of metal contamination in some fish species living in the Sakarya River and to evaluate whether the potential risk to humans consuming these fishes would occur.

Materials and Methods

Supplying Sample

This study was carried out in some fish species (*Capoeta sieboldii*, *Capoeta tinca*, *Scardinius erythrophthalmus, Barbus escherichii* and *Squalius pursakensis*) in autumn, winter, spring and summer seasons. The fish samples were supplied from fishermen who collected fish in different locations (Bilecik, Osmaneli, and Pamukova areas) in the Sakarya River. Six fish were collected from each location in each season, and three locations were used in this study, thus, each group consisted of 72 fish. After the fish samples were obtained from fishermen, they were stored in a deep freeze for the metal analysis.

Heavy Metal Analysis

The metal concentrations of tissues were determined by the method of Salisbury and Chan (1985). The muscle parts of fish samples were removed. Approximately 2 gms of muscle parts were weighed accurately and digested with nitric acid (65%) and hydrogen peroxide (30%) in microwave acid digestion unit (Milestone Mega 1200). The Cd, Pb, and As concentrations in these digested samples were analysed using an atomic absorption spectrometer (AAS) (Varian SpectraAA 30/40) equipped with a graphite furnace (Varian GTA-96). Calibration curves were produced with Cd, Pb and As atomic absorption standard solutions at AAS. Then, the concentrations of these metals were calculated in the digested samples with these calibration curves at AAS. The measurements were repeated twice. Cu and Zn concentrations in these digested samples were analysed using a flame atomic absorption spectrometer (AAS) (Varian SpectraAA 30/40). A mixture of acetylene and air 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.

Estimated Daily Intake (EDI) of Heavy Metals

The estimated daily intake of heavy metals such as Cd, Cu, Pb, As and Zn was analysed as follows (Keshavarzi et al., 2018): EDI = C_{metal} × DC/BW. Here C_{metal} (mg/kg) represents the concentration of heavy metals in fish muscle. DC is the fish consumption amounts in a day (g/person/day), average fish consumption is 20.0 g, BW is body weight, and is assumed 70 kg for adults (Varol and Sünbül, 2018).

Target Hazard Quotient

Target hazard quotient (THQ) is calculated as follows (Keshavarzi et al., 2018):THQ = [EDI/RfD]×10^{-3}. If the THQ value is less than 1 in fish, there is no health hazard (USEPA, 2011). RfD means the metal reference dose. Metal reference doses are as follows: 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, and 3 × 10^{-1} mg/kg/day for Zn (USEPA, 2011).

Hazard Index

Hazard index (HI) is calculated using HI= ΣTHQs. S means different elements (USEPA, 2006). If HI values are greater than unity, there is a public health problem.

Target Cancer Risk

Target cancer risk is measured as follows (USEPA, 2006).TCR= EDI × CPSo× 10^{-3}.

CPSo means the carcinogenic potency slope and CPSo value for As is 1.5 mg/kg/day (USEPA, 2006).

Statistical Analysis

Analysis of variance (ANOVA) was used for the statistical analysis of data. Pair-wise comparisons were done using Duncan test. Differences were considered significant if the p value was less than 0.05.

Results and Discussion

The tissue concentrations of Cd, Cu, Pb, As and Zn as well as the live body weights and the lengths of five different fish species supplied from Sakarya River are presented in Tables 1-5. In addition, estimated daily intake (EDI), target hazard quotient (THQ), target cancer risk (TCR), and hazard index (HI) are presented in Tables 6 and 7.

Cadmium concentrations determined in fish samples obtained from Sakarya River showed variations with respect to fish species. In this study, Cd concentrations ranged from 1.68 to 5.35 ng/g. The muscle Cd concentrations found in this study were lower than those of other studies (Ahmed et al., 2018; Ngumbu et al., 2016). While there was a seasonal variation

Table 1: Metal concentrations, live weights and lengths in *Barbus escherichii*

Parameter	*Autumn season*	*Winter season*	*Spring season*	*Summer season*
Cadmium (ng/g)	3.26±0.58	3.08±0.29	3.08±0.31	3.10±0.42
Lead (ng/g)	41.70±4.13	46.40±5.29	44.00±6.48	45.30±6.30
Zinc (µg/g)	6.08±0.59	5.85±0.59	5.76±0.61	6.09±0.73
Copper (µg/g)	0.97±0.21^{a}	1.11±0.24 ^{a}	1.31±0.22 ^{b}	1.06±0.17 ^{a}
Arsenic (ng/g)	33.30±6.56 ^{a}	34.00±6.94 ^{a}	37.00±4.61 ^{ab}	41.50±11.30 ^{b}
Live weight (g)	201.90±78.77 ^{b}	542.60±142.57 ^{c}	110.20±68.35 ^{a}	237.05±96.34 ^{b}
Length (cm)	27.20±4.49 ^{b}	37.45±3.68 ^{c}	21.40±2.30 ^{a}	28.25±4.90 ^{b}

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

Table 2: Metal concentrations, live weights and lengths in *Capoeta tinca*

Parameter	*Autumn Season*	*Winter Season*	*Spring Season*	*Summer Season*
Cadmium (ng/g)	1.68±0.53 ^{a}	1.89±0.43 ^{b}	1.71±0.42 ^{a}	1.98±0.55 ^{a}
Lead (ng/g)	39.50±7.94	44.30±6.88	41.10±5.76	44.60±7.84
Zinc (µg/g)	7.57±0.85	7.58±0.74	7.74±0.73	7.64±0.61
Copper (µg/g)	1.76±0.54	1.60±0.38	1.64±0.42	1.70±0.35
Arsenic (ng/g)	34.20±7.98	34.70±6.09	36.40±5.98	35.40±6.11
Live weight (g)	146.20±30.73	170.60±23.63	145.50±15.34	137.40±15.82
Length (cm)	23.10±1.62 ^{b}	23.15±0.94 ^{b}	22.25±1.03 ^{ab}	21.75±1.13 ^{a}

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

Table 3: Metal concentrations, live weights and lengths in *Squalius pursakensis*

Parameter	*Autumn season*	*Winter season*	*Spring season*	*Summer season*
Cadmium (ng/g)	2.16±0.41	1.93±0.51	1.99±0.38	2.19±0.65
Lead (ng/g)	54.50±8.07	54.90±8.31	55.70±7.31	48.60±7.39
Zinc (µg/g)	8.84±1.08 ^{ab}	9.02±1.03 ^{b}	8.85±0.80 ^{ab}	7.98±0.76 ^{a}
Copper (µg/g)	1.27±0.30	1.37±0.26	1.37±0.34	1.56±0.27
Arsenic (ng/g)	24.80±5.90	26.40±4.64	28.90±4.60	25.70±5.71
Live weight (g)	206.30±17.51	190.30±22.05	192.60±16.99	195.90±36.91
Length (cm)	27.65±0.74	27.20±0.71	27.20±0.71	27.55±1.46

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

Table 4: Metal concentrations, live weights and lengths in *Capoeta sieboldii*

Parameter	*Autumn season*	*Winter season*	*Spring season*	*Summer season*
Cadmium (ng/g)	3.25±0.48 [a]	5.35±0.92 [c]	5.17±1.21 [c]	4.06±0.70 [b]
Lead (ng/g)	50.50±9.99	53.00±8.31	52.60±8.74	50.80±8.17
Zinc (µg/g)	6.91±1.17	7.01±1.05	7.27±0.71	7.03±0.70
Copper (µg/g)	1.33±0.35	1.19±0.31	1.42±0.28	1.46±0.25
Arsenic (ng/g)	40.30±8.02 [a]	34.60±9.27 [ab]	46.80±7.84 [b]	47.00±6.66 [b]
Live weight (g)	274.40±48.24 [b]	200.90±50.12 [a]	211.50±45.38 [a]	240.90±47.03 [ab]
Length (cm)	30.15±1.87 [b]	26.00±2.65 [a]	27.15±2.68 [a]	29.95±2.55 [b]

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

Table 5: Metal concentrations, live weights and lengths in *Scardinius erythrophthalmus*

Parameter	*Autumn season*	*Winter season*	*Spring season*	*Summer season*
Cadmium (ng/g)	2.02±0.42	1.95±0.55	2.05±0.50	2.12±0.42
Lead (ng/g)	80.50±17.48 [b]	66.10±8.07 [a]	69.20±11.03 [ab]	73.60±13.14 [ab]
Zinc (µg/g)	8.32±1.40	7.91±1.47	8.10±0.68	8.31±1.22
Copper (µg/g)	1.41±0.39	1.53±0.47	1.68±0.24	1.71±0.41
Arsenic (ng/g)	43.20±10.88	40.10±7.80	42.20±7.48	42.10±9.58
Live weight (g)	145.60±22.04	134.40±13.70	128.55±30.25	126.00±19.10
Length (cm)	23.50±1.13 [b]	22.75±0.67 [b]	21.65±1.05 [a]	21.30±1.03 [a]

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

Table 6: Estimated daily intake (mg/kg/day) of fish obtained from Sakarya River

Fish species	*Cd*	*Pb*	*Zn*	*Cu*	*As*
Barbus escherichii	0.93×10^{-3}	13.25×10^{-3}	1.74	0.37	11.85×10^{-3}
Capoeta tinca	0.56×10^{-3}	12.74×10^{-3}	2.21	0.50	10.4×10^{-3}
Squalius pursakensis	0.62×10^{-3}	15.91×10^{-3}	2.57	0.44	8.25×10^{-3}
Capoeta sieboldii	1.52×10^{-3}	15.14×10^{-3}	2.07	0.41	13.42×10^{-3}
Scardinius erythrophthalmus	0.60×10^{-3}	23×10^{-3}	2.37	0.48	12.34×10^{-3}

Table 7: THQ of fish obtained from Sakarya River, HI and TCR values

Fish species	*THQ*					*HI*	*TCR*
	Cd	*Pb*	*Zn*	*Cu*	*As*		
Barbus escherichii	0.093×10^{-2}	0.331×10^{-2}	0.58×10^{-2}	0.9×10^{-2}	3.95×10^{-2}	5.85×10^{-2}	1.77×10^{-5}
Capoeta tinca	0.056×10^{-2}	0.318×10^{-2}	0.73×10^{-2}	1.2×10^{-2}	3.46×10^{-2}	5.76×10^{-2}	1.50×10^{-5}
Squalius pursakensis	0.062×10^{-2}	0.397×10^{-2}	0.85×10^{-2}	1.1×10^{-2}	2.75×10^{-2}	5.15×10^{-2}	1.23×10^{-5}
Capoeta sieboldii	0.152×10^{-2}	0.378×10^{-2}	0.69×10^{-2}	1.0×10^{-2}	4.47×10^{-2}	6.69×10^{-2}	2.01×10^{-5}
Scardinius erythrophthalmus	0.060×10^{-2}	0.575×10^{-2}	0.79×10^{-2}	1.2×10^{-2}	4.11×10^{-2}	6.73×10^{-2}	1.85×10^{-5}

in *Capoeta tinca and Capoeta sieboldii,* no seasonal difference was observed in other fish species analyzed. However, the concentrations of Cd in fish species were found to be within allowed limits. Recently, several studies have reported that increased Cd concentrations are determined in the muscles of fish samples in Enne Dam Lake, Turkey (Uysal et al., 2009), and in the Black Sea (Alkan et al., 2016). The Cd concentration is known to be used frequently in industrial areas (Zhang and Reynolds, 2019). Hence, the Cd overload in the environment can indirectly raise the Cd concentration in water resources, and can lead to increased metal concentrations of living organisms in these waters. Variations in metal concentrations of fish species can depend on differences in the Cd accumulation capacity of the particular fish species. Turkish Food Codex (2011) allows Cd concentrations of 50 ng/g for fish. Thus, in the present study, the maximum Cd concentration in fish was far below allowable levels. EDI values for Cd varied between 0.56×10^{-3} and 1.52×10^{-3} mg/kg/day and not exceeded provisional maximum tolerable daily intake (0.008 mg/day)(Ysart et al., 2000).

Pb is not found naturally in the body, but it is usually taken up and accumulated in the body tissues due to various reasons. Pb pollution has been increasing in many ecosystems due to the increasing rate of industrialization. Thus, Pb is one of the important metals for the environment. Consistent with this statement, Dundar and Altundag (2007) have reported that the highest Pb concentration in water samples of Sakarya River is around industrial area discharges. The concentrations of Pb showed seasonal variations in only *Scardinius erythrophthalmus* which had also the highest Pb concentration. In another study conducted in Van Lake, Turkey, Bilgili et al. (1995) reported that Pb concentrations in *Chalcalburnus Tarichi, Pallas 1811* can pose a risk for humans due to higher contamination of Pb. Feeding habit and physiology of the *Scardinius erythrophthalmus* could play a role in these variations as compared to other species. Similarly, it has been reported that fish can accumulate heavy metals according to fish behaviour, feeding habits, and surrounding environment (Tyokumbur, 2016) and that heavy metal accumulation in fish can vary to fish species and tissues (Sobihah et al., 2018). Pb concentrations of fish muscles in this study were lower than those of other studies (Ahmed et al., 2018; Jithesh and Radhakrishnan, 2017). However, the fish muscle Pb concentrations in river Jhelum were lower than those of this study (Mehmood et al., 2019). The maximum allowable Pb level via fish meat is 0.3 mg/kg according to the regulation on contaminants in Turkish Food Codex (2011) and European Community (EEC, 2001). In this study, EDI values for Pb varied between 12.74×10^{-3} and 23×10^{-3} and did not exceed provisional maximum daily intake values (0.03 mg/day) (Ysart et al., 2000).

The concentration of Zn showed seasonal variations in *Squalius pursakensis*, whereas the amounts of Zn residues were found to be similar among the fish species. Other studies reported higher muscle Zn concentrations compared to those of this study (Jitnesh and Radhakrishnan, 2017; Velusamy et al., 2014). Jiang et al. (2016) have stated that metal concentrations of fish samples obtained from Heilongjiang River, China correlate with fish length, but this study did not reveal this event. The maximum allowable Zn concentration for fish meat is 50 µg/g set by the Turkish Food Codex (2002). Therefore, it could be suggested that Zn intake through the fish muscle would not pose a risk for humans consuming fish supplied from the Sakarya River. In addition, USEPA (2005) reports a maximum daily Zn intake of 300 µg/kg/day. The EDI value in this study ranged from 1.74 to 2.57 mg/kg/day and the consumption of fish from the Sakarya River was found to be safe for human consumption.

Marine species may have higher Cu levels than other organisms. The maximum daily intake of Cu is determined as 500 µg/kg/day set by WHO (1989), and is 20 µg/g set by Turkish Food Codex (2002). It can be suggested that the EDI for Cu in fish samples supplied from the Sakarya River varied between 0.37 and 0.50, which is far below the allowable limits. Similarly, Dundar et al. (2012) have shown that Cu contamination may be negligible in sediments of the lower Sakarya River. In other studies carried out in Turkey, Cu appeared to be in the border levels with respect to allowed limits in *Carasobarbus luteus* in Orontes River (Yilmaz and Dogan, 2008) and to be lower in Porsuk Stream than the FAO (1983) and Turkish Food Codex 2004 guidelines (Köse et al., 2015). In this study, Cu concentrations in fish ranged from 0.76 to 2.30 µg/g. Similar results were determined in the other studies such as in the muscle of *Anodontostoma chacunda* in the Persian Gulf as 1.37-3.14 mg/kg (Keshavarzi et al., 2018), in the muscle of *T. lepturus* and *T. savala* as 2.23 and 2.53 µg/g, respectively (Ahmed et al., 2018). However, higher concentrations compared to this study were revealed in the study of Jitnesh and Radhakrishnan (2017). Lower concentrations of muscle Cu compared to this study were revealed in the study of Mehmood et al. (2019), which was performed in the trans-Himalayan freshwater ecosystem.

It is possible to encounter organic arsenic (arsenobetain) in marine fish products at concentrations of 1-100 mg/kg (WHO, 2001a). European Community guidelines (EEC, 2001) allow 2 µg/g maximum arsenic levels in marine fish. The muscle As concentrations showed significant seasonal variations in *Barbus escherichii and Capoeta sieboldii.* The lower and upper concentrations observed in all fish species analyzed were determined to be 24.80±5.90 and 46.80±7.84 ng/g, respectively. These levels are below the range of the aforementioned levels that are normally found in marine species. In this study, EDI values varied between 8.25×10^{-3} and 13.42×10^{-3} mg/kg/day and did not exceed the provisional maximum tolerable daily intake value of 0.12 mg/day (Ysart et al., 2000). These results suggest that As concentrations in fish species would not pose a risk for human health in terms of As pollution. In a study, Bilgili et al. (1999) have reported that As concentrations are found to be between 0.009 and 0.347 ppm in *Chalcarburnus tarichii*, Pallas 1811 obtained from Van Lake, Turkey, indicating that the concentrations for As are below the allowed levels. Another study has revealed that As concentrations are higher in fish muscles than the standard value in the Persian Gulf via anthropogenic contamination, particularly industrial wastewater discharge and heavy metal pollution in this area may cause human health concerns (Keshavarzi et al., 2018).

Moreover, health risk on humans from fish consumption is assessed using THQ, HI, and TCR in this study. The results of THQ and HI were determined to be less than 1, indicating that the metal exposure concentrations via fish consumption did not cause adverse health concerns (Şasi et al., 2018). TCR values for As were determined to be a range of 10^{-4} to 10^{-6} and indicating permissible risk levels for fish consumption (USEPA, 2011).

Conclusions

Heavy metal pollution in the aquatic environment is not a concern for fish species supplied from the Sakarya River. In addition, this study showed that heavy metal accumulations in five fish species in Sakarya River, Turkey were within allowable limits and EDI values of heavy metals were lower than values of maximum daily intake and that THQ, HI and TCR values did not cause risk on human via consumption of 20 g/day fish.

Acknowledgement

The authors thank the fishermen for supplying fish.

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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