JAEHR Journal of Advances in Environmental Health Research
Environmental Health Research Center

Bioaccumulation of metals in silver carp and stone moroko from Zarivar Wetland in Kurdistan Province, Iran

Borhan Mansouri[1], Behroz Davari[2,3], Namamali Azadi[4], Mohammad Amin Pordel[1]

1 Student Research Committee, Kurdistan University of Medical Sciences, Sanandaj, Iran
2 Environmental Health Research Center, Kurdistan University of Medical Sciences, Sanandaj, Iran
3 Department of Entomology, School of Medicine, Hamadan University of Medical Sciences, Hamadan, Iran
4 Biostatistics Department, School of Public Health, Iran University of Medical Sciences, Tehran, Iran

Original Article

Abstract

This research aims to monitor the trace elements content (Cr, Cu, Pb, Cd, Ag, Al, Mn, Mg, Zn and Fe) in the tissues of the muscle and liver of silver carp (*H. molitrix*) and stone moroko (*P. parva)* from Zarivar Wetland in western Iran. This research was cross-sectional. The research specimen was fish caught from Zarivar Wetland. Metal concentration analysis was carried out utilizing an ICP. Findings indicate presence of Fe and Pb in the liver, Zn and Cd in the muscle hadthe highest and lowest metal concentration accumulated, respectively. The trace elements content in the liver tissue was higher than those in the muscle tissue of *H. molitrix* and *P. parva*. Moreover, the Hazard Quotients for an adult with mean of 71.5 kg was below 1 based on trace elements levels. Though, the mean concentrations of trace elements in the muscle of *H. molitrix* and *P. parva* was lower than international standards. according to the uptake and distribution, these elements require periodic monitoring in the human body.

KEYWORDS: Liver, Muscles, Carps, Trace Elements, Lead.

Date of submission: 31 Oct 2016, ***Date of acceptance:*** 03 Dec 2016

Citation: Mansouri B, Maleki A, Davari B, Azadi N, Pordel MA. **Bioaccumulation of metals in silver carp and stone moroko from Zarivar Wetland in Kurdistan Province, Iran.** J Adv Environ Health Res 2016; 4(4): 227-233

Introduction

The contamination of aquatic environments by trace elements has raised major concerns in local, regional, and global scales due to their persistence in theecosystemacute and chronic toxicity, non-biodegradable nature, and ability to be accumulated and transfered into aquatic food web.[1,2] Metals fall into one of the two important groups; essential and nonessential groups. Some of the trace elements such as Zn,Cu, and Fe are essential elements or micronutrients to living organisms and have important roles in biological functions, but can be toxic at higher concentrations; whereas other trace elements like Ag, Pb, and Cd even at low level are nonessential elements for physiological and biochemical processes in organisms and can result in severe health effects.[3]. The finding of Eisler[4] indicates that the Cd is a known teratogen and carcinogen, and has been reported as the cause of several deleterious effects on fish and wildlife. Pb accumulation in aquatic environment occurs mainly through the gills of fish and uptake of Pb that causes several adverse effects like blood chemistry, reduced survival, impaired reproduction and heme synthesis, reduced growth, and high bioconcentration for aquatic biota.[4,5] Thus, it is expedient to monitor freshwater ecosystems polluted by trace elements and disseminate information on the content of trace elements in the tissues of fish for ecosystem monitoring and human consumption. In recent years in diverse areas of Iran, several studies have reported contents of trace elements in the aquatic environment in

Corresponding Author:
Behroz Davari
Email: davaribehroz@yahoo.com

different species of fish in Qanats of Birjand,[6] Zabol Chahnimeh Reservoirs,[7] Sanandaj Gheshlagh Reservoir,[8] Qeshm Island,[9] Zarivar Wetland,[1] and Anzali Wetland.[10] Fish is a rich source of omega-3, polyunsaturated fatty acids for human health and contribute to immune system health, cardiovascular disease, brain, and inflammatory conditions. [11,12] Fish samples have been utilized as excellent indicators for the estimation of the levels of trace element contamination in aquatic environments and may receive large amounts of some trace elements from surrounding waters, because they occupy higher trophic levels of food web and are responsible for the adverse effects in the aquatic system.[13,14] Fishes in aquatic ecosystems in Zarivar Wetland near Marivan City in Kurdistan Province are often subjected to contamination with trace elements because the runoff from villages and farmlands enters the wetland and sometimes these discharges are deliberate. Therefore, the aim of the present study was to assess the distribution of selected trace elements concentrations of Ag, Mn, Cr, Fe, Pb, Zn, Cu, Cd, Mg, and Al in the liver and muscle of silver carp (*H. molitrix*) and stone moroko (*P. parva*) in Zarivar wetland, Iran, and to identify the potential public health risk from these trace elements related to the consumption safety of the muscle of fishes.

Materials and Methods

Zarivar Wetland is located in western Iran (Fig. 1) with an average area and water depth of 720 ha and 4-5 m respectively, it is a main source of water supply for Marivan City and other agricultural areas. In terms of contamination, the quality of Zarivar Wetland water is influenced by the waste water discharged from adjacent populated areas, mainly Marivan City. Furthermore, in recent years, Zarivar Wetland has become one of the important tourist resorts in westernIran and that releases substantial amount of contamination into wetland waters.

Specimens were gathered from random catches in Zarivar wetland from August to December, 2015. The specimens were transported to the laboratory in ice chambers. The collections included *Hypophthalmichthys molitrix* and *Pseudorasbora parva*. Thereafer, fish tissue samples were dissected while wearing clean plastic gloves and prepared for chemical digestion. Fish muscle tissue was extracted from below the dorsal fin without skin.[10]

For each digestion procedure, one gram of liver and muscle was weighed out for analysis, transferred into 150-mL Erlenmeyer flasks, and mineralized with mixture of nitric acid (10 ml) and perchloric acid (5 ml). The samples were digested on a bain-marie (water bath) at 100 ºC until the solutions were clear and digestion solution was diluted to 25 ml with deionized water. Thereafter, sample solutions were stored in polyethylene bottles at room temperature until the assessment of trace elements concentrations by ICP-OES. The limits of detection were as follows: Cd (0.01), Pb (0.2), Cr (0.2), Cu (0.3), Ag (0.2), Al (0.1), Mn (0.2), Mg (0.3), Fe (0.2), and Zn (0.75) µg g^{-1}. Results for Zn, Pb, Cd and Cu gave a mean recovery of 96 to 99%.

The data were analyzed statistically using SPSS statistical package (version 16; SPSS, Chicago, IL). ANOVA test (one-way) was used for finding the difference among the concentrations of heavy metals in fish tissues. Moreover, Pearson correlation test was employed for the analysis of correlations among trace elements, size and weight of the fish . The concentration of metals in tissues of fish was expressed as µg/g (ww). In addition, data were presented in mean (±standard deviation) and level of statistical significance was designated as p <0.05.

As reported by Ariayee et al. , daily consumption limits were calculated[7]:

$$CR_{lim} = \frac{RfD \times BW}{C_m}$$

CR_{lim} is maximumallowable fish consumption rate (kg/d); RfD is reference dose (1 for Cd, none set for Pb, 5 for Cr, 30 for Zn, 40 for Cu, 140 for Mn, 5 for Ag, and 360 for Al µg/kg/day); BW is body weight (kg) of consumer; and Cm is contents of trace elements *m* in fish species (mg/kg). A 0.227 kg average fish meal size was assumed.[6]

CRmm is the maximum allowable fish consumption rate (meals per month); CRlim is the maximum allowable fish consumption rate (kg/d); MS is the average fish meal size (0.227

$$CR_{mm} = \frac{CR_{lim} \times T_{ap}}{MS}$$

kg fish/meal); and Tap is the time averaging period (365.25 days/12 months=30.44 days/month).

Hazard Quotients:

$$HQ = (\{MTC \times CR) / BW\} / RFD)$$

Where HQ is assessment of health risks of fish consumption by people; RfD is reference dose (1 for Cd, none set for Pb, 5 for Cr, 30 for Zn, 40 for Cu, 140 for Mn, 5 for Ag, and 360 for Al µg/kg/day); BW is body weight (kg) of consumer; and MTC is the content of trace elements *m* in a given species of fish (mg/kg), CR is the average fish meal size (0.003 kg fish/meal). A HQ less 1 means the population is not exposed with serious health risks.[7]

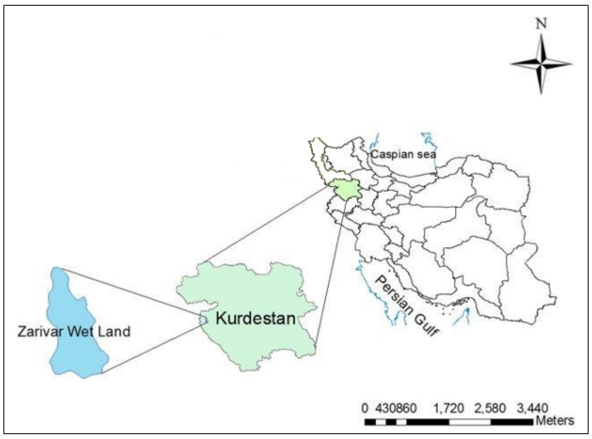

Figure 1.The map of Zarivar wetland in western Iran

Results and Discussion

Trace elements contents in the liver and muscle of *H. molitrix* and *P. parva* are presented in Tables 1 and 2. The element accumulation in liver had the following trend: Al > Fe > Zn > Cu > Mg > Mn > Cd > Ag > Pb > Cr in *H. molitrix*; and Fe > Al > Zn > Mn > Mg > Cu > Fe > Cr > Ag > Pb > Cd in *P. parva*; Furthermore, the tendency of accumulation of elements in the muscle was: Al > Zn > Mg > Mn > Cu > Fe > Cr > Ag > Pb > Cd in *P. parva*;and Al > Zn > Mg > Cu > Mn > Fe > Cr > Ag > Pb > Cd in *H. molitrix*. Findings of our research showed that element contents in liver were higher than muscle. In addition, results of statistical studies illustrated that trace element levels (except Cr and Pb) in liver tissue of *H. molitrix* and *P. parva* were significant ($p < 0.05$; Table 1); while, only Fe, Al, Mg, and Mn levels in muscle tissue were significant ($p < 0.05$; Table 2). Correlation of elements in muscle tissue of fish caught in Zarivar Wetland are shown in Table 3. The results of HQ in *H. molitrix* and *P. parva* were below 1 (Table 4). Moreover, based on our findings, the maximum allowable fish consumption rate for an adult person with mean body weight of 71.5 kg was 18-37, 31-40, and 28-150 g/day according to Cr, Cd, and Pb concentrations, respectively.

According to our results, the content of trace elements in liver of *H. molitrix* were higher than those of the muscle and contents of Zn, Fe, and Cu were higher than Pb and Cd in tissues of *P. parva* and *H. molitrix*. As the low contents of trace elements in the muscle of two fish species are due to the fact that the muscle tissue in comparison to liver involves lower metabolic activities to the elements accumulation and proved to be a good source of vital elements at small levels.[15] Furthermore, in this study, results of statistical analysis show that the metal contents in the liver tissues of *H. molitrix* were significant; while, only some metal levels in muscle tissue were significant Because of the health aspects of fish consumption by humans, toxic chemical accumulation from aquatic systems by muscle tissue is more important than those of the liver. Majnoni et al.[1], Ariyaee et al.[7] and Ahmed et al.[15] illustrated that the element levels in the muscle tissue were lower than those of other tissues such as liver. The literature shows that in many cases, the liver also plays a vital role in trace elements transformation or detoxification, redistribution, and active site of

Table 1. Trace elements concentration (Mean and SD) in the liver of two fish in Zarivar wetland

	No.	Fe	Zn	Ag	Cu	Al	Cr	Mn	Cd	Mg	Pb
H. molitrix	24										
Mean		10.1	6.7	1.3	3.96	10.88	1.1	2.41	2.1	3.1	1.17
SD		1.2	1.8	0.4	0.8	2.5	0.2	0.4	0.4	0.7	0.7
P. parva	16										
Mean		23.57	13.34	2.45	4.37	14.0	1.8	5.9	2.53	5.21	1.64
SD		5.5	1.1	0.6	0.7	4.0	0.3	0.4	0.6	0.9	0.4
P value		<0.05	<0.05	<0.05	<0.05	<0.05	NS	<0.05	<0.05	<0.05	NS

NS – not significant

Table 2. Trace elements (Mean and SD) in the muscle of two fish in Zarivar wetland

	No.	Fe	Zn	Ag	Cu	Al	Cr	Mn	Cd	Mg	Pb
H. molitrix	24										
Mean		0.89	2.56	0.53	1.51	5.11	0.71	1.35	0.21	1.52	0.24
SD		0.3	0.4	0.1	0.3	1.1	0.1	0.6	0.1	0.4	0.1
P. parva	16										
Mean		1.39	3.15	0.66	2.19	9.11	0.79	2.71	0.22	2.62	0.38
SD		0.5	0.3	0.2	0.5	2.52	0.1	0.6	0.1	0.9	0.1
P value		<0.05	NS	NS	NS	<0.05	NS	<0.05	NS	<0.05	NS

NS – not significant

pathological effects induced by pollutants.[10,7,16] Producing metallothionein is a reaction of fish to trace elements exposure, particularly in liver.[17] Hence, the liver tissues in fish when pollution. According to correlation compared to any other fish tissues are more often suggested as bioindicators of watercoefficients of trace elements in muscles of two fish species, most of them were highly correlated and this shows that the metals with high positive correlations are possibly from the same pollution source and vice versa.

Table 3. Correlation coefficients of trace elements contents in the muscle tissue of two fish species caught in Zarivar Wetland

Species	Metals	PC*	Sig.**
H. molitrix			
	Pb=Mn	0.84	0.01
	Cd=Zn	0.84	0.01
	Mn=Cr	0.76	0.04
P. parva			
	Pb=Mg	-0.72	0.04
	Mg=Mn	0.97	0.01
	Cd=Fe	0.71	0.04

*Pearson Correlation coefficients;
**significant: 0.05 and 0.01 levels

Among the trace elements in this study, it is understood that the toxicity of Cd and Pb is very important, because both metals are non-essential metals and toxic[1]. Chronic exposure to Cd and Pb cause some problems in the body such as circulatory system, kidney and liver failure and nerve tissue deficiency. Hanaa et al.[18] demonstrated that high levels of Pb lead to some damage in the body such as death or the central nervous system, brain, and kidney deterioration. Pb levels in the muscle tissues of *H. molitrix* and *P. parva* (0.24 to 0.38 µg/g) were lower than the maximum acceptable content (2.0 µg/g) published by UK Food Standards Agency,[19] Spanish legislation,[20] EC,[21] and Australian National Health and Medical Research Council.[22] The contents of Cd obtained from *H. molitrix* and *P. parva* (0.21 to 0.22 µg/g) muscle tissues were lower than the maximum acceptable content set by Spanish legislation (1.0 µg/g)[20], ANHMRC (2.0 µg/g), and Western Australian authorities (5.5 µg/g).[23]

The mean Al values in fish varied from 14 to 23 µg/g in liver and 5 to 9 µg/g in muscle. The Al values are similar to the values of *Merlangius merlangus*, *Sadra sarda*, *Engraulis encrasicolus*, and *Pamatomus saltarix* (7 to 9 µg/g) in West Black Sea, Sakarya,[24] and higher than *Cyprinus carpio* (5 to 11 µg/g in liver and 2 to 4 µg/g in muscle) in Pansky and Klucenicky Ponds, Czech Republic.[25] The mean contents of Cr (0.71 to 0.79 µg/g) in fish in present research were lower than the 5.5 µg/g limit of Cr set by the Western Australian Food and Drug regulations.[23] In a similar study by Rahman et al.,[21] maximum value of Mn in *Corica soborna*, was shown as 51.2 µg/g, but our maximum value from this study (1.35 to 5.9 µg/g) was far below their result. Mn as manganese-activated enzymes plays beneficial roles for humans including digestion, a cellular antioxidant, regulation of reproduction, blood sugar, and bone growth[24] and chromium as an essential mineral, is involved in insulin action and it has effects on the metabolism of carbohydrate, protein and lipid. For daily intake of Fe, FAO[26] suggests a value of 48 µg/g is safe for human consumption on the basis of body weight. Our findings of Fe in liver in this study (10-23 µg/g) were lower than Fe levels reported by Mendil et al.[27] in different fish species (ranged between 25.5 and 41.4 µg/g) and Waheed et al.[28] in the muscle and liver tissues of herbivorous (HF) and carnivorous (CF) edible fish (42 and 45 µg/g in liver and muscle of HF; and 95 and 33 µg/g in liver and muscle of CF).

According to the proposed ANHMRC and

Table 4. HQ and CR indexes for two fish species in Zarivar Wetland

Species		HQ	CR (g)
H. molitrix			
	Zn	0.0040	100.57
	Cu	0.0015	255.42
	Cr	0.0061	39.11
	Cd	0.0115	34.76
	Pb	0.0107	37.54
	Ag	0.0034	117.33
	Mn	0.0004	912.60
	Al	0.0005	715.94
P. parva			
	Zn	0.0046	86.11
	Cu	0.0025	157.10
	Cr	0.0072	150.59
	Cd	0.0098	40.81
	Pb	0.0145	27.60
	Ag	0.0061	14.79
	Mn	0.0009	423.91
	Al	0.0009	411.10

FAO guidelines, a maximum permissible concentration of Cu is 30 µg/g fresh weight[29] and the UK food Standard Agency has recommended Cu of up to 20 per ww[19] (in this study, it was 2.10 µg/g for *H. molitrix*). The Cu contents in muscle of two fish species in this research were similar to those of other areas reported in Iskenderun Bay in Turkey,[30] Zabol Chahnimeh Reservoirs in Iran,[7] and Yangtze River in China.[31] The Zn and Cu contents in the muscle tissue of fish in Zarivar Wetland were below the specified content of concern for human health as defined by the FAO.[26] The Cu and Zn contents in the muscle and liver of *H. molitrix* from this research were lower than those in *C. idellus*, and *P. fluviatilis* from Anzali wetland from Iran,[10] and *C. carpio* and *H. molitrix* from Sanandaj Gheshlagh Reservoir from Iran.[32]. The levels of Ag in the muscle of *H. molitrix* was higher than the findings of Ahmad et al.[15] in four native fish species collected from river Kabul in Pakistan. To estimate the potential health risks from consuming metal-contaminated fish as well as to humans who consume them, the HQ and CR of trace elements were calculated according to consumption of fish captured in Zarivar Wetland. The estimated HQ for trace elements indicated that the Pb and Cd's HQ were the highest values and Mn and Mg were the lowest values in two fish species. In this study, HQ values of Pb (0.010 to 0.214) and Cd (0.009 to 0.012) for *H. molitrix* were higher than comparable values for Pb (0.033) and Cd (0.031) from the consumption of fish by the general population in the Taihu lake, China.[33] Yu et al.[33] quantified mean THQ values of 0.29–0.45 for Pb for common carp by local residents at Fandong village from Dabaoshan mine, South China, and, similarly, Yi et al.[31] obtained mean THQ values of 0.29, 0.34, 0.11, and 0.16 for Cd, Pb, Cu, and Zn, respectively in the Yangtze River. Both were considerably greater than HQ values in fish from Zarivar wetland. The daily intake of trace elements from fish depends on some elements like trace elements contents in food source and level of food consumed.[34] According to our result, all the HQ contents were lower than 1 for two fish species in Zarivar Wetland that implies the consumers of fish will not be exposed to health risks.[14]

Conclusion

Metal concentration in the liver was higher than the muscle and the maximum allowable fish consumption rate for an adult person with mean body weight of 71.5 kg was 31-40, 18-37, and 28-150 g/day based on Cr, Pb, and Cd levels, respectively. According to our findings, the trace elements contents in fish muscle of Zarivar wetland were less of concern for human consumption. Although our research shows that element concentrations in edible muscle of two fish species were lower than international standards, but according to the bioaccumulation and toxicity of these metals in the body, periodic monitoring is essential.

Acknowledgements

Kurdistan University of Medical Sciences supported this research [Grant number 14/15074].

References

1. Majnoni F, Mansouri B, Rezaei MR, Hamidian AH. Contaminations of metals in tissues of Common crap, Cyprinus carpio and Silver crap, Hypophthalmichthys molitrix from Zarivar wetland, western Iran. Arch Polish Fish 2013; 21:9-18.
2. Zhuang P, Li Z, McBride MB, Zou B, Wang G. Health risk assessment for consumption of fish originating from ponds near Dabaoshan mine, South China. Environ Sci Pollut Res 2013; 20: 5849-5854.
3. Tchounwou PB, Yedjou CG, Patlolla AK. Heavy metals toxicity and the environment. EXS 2012; 101:158-164.

4. Eisler R. Zink Hazards to fish, Wildlife and Invertebrates: a synoptic review. US Fish Wildlife Serv. Biol Rep 1993; pages:85.
5. Sánchez-Martín FJ, Fan Y, Lindquist DM, Xia Y, Puga A. Lead induces similar gene expression changes in brains of gestationally exposed adult mice and in neurons differentiated from mouse embryonic stem cells. PLoS ONE 2013; 8:80551-80558.
6. Mansouri B, Majnoni F, Rezaei Z, Gharibi F. Bioaccumulation of mercury in some organs of two fish species from the Sanandaj Gheshlagh Reservoir, Iran. J Adv Environ Health Res 2014; 2:151-156.
7. Ariayee M., Azadi N., Majnoni F., Mansouri B. Comparison of metal concentrations in organs of two fish species from the Zabol Chahnimeh reservoirs, Iran. Bull. Environ. Contamin. Toxicol. 2015; DOI 10.1007/s00128-015-1529-1
8. Mansouri B., Ebrahimpour M., Babaei H. Determine of trace elements in different tissues of black fish (Capoeta fusca) in central part qanats of Birjand. Veter. J. (Pajouhesh & Sazandegi). 89, 52, 2011. [In Persian].
9. Nowrouzi M, Mansouri B, Hamidian AH, Zarei I, Mansouri A. Metal contents in tissues of two fish species from Qeshm Island, Iran. Bull Environ Contamin Toxicol 2012; 89:1003-1008.
10. Baramaki R, Ebrahimpour M, Mansouri B, Rezaei MR, Babaei H. Contamination of metals in tissues of Ctenopharyngodon idella and Perca fluviatilis, from Anzali Wetland, Iran. Bull Environ Contamin Toxicol 2012; 89:830-835.
11. Daviglus M, Sheeshka J, Murkin E. Health benefits from eating fish. Comments on Toxicology 2002; 8:369-374.
12. Patterson J. Introduction comparative dietary risk: balance the risks and benefits of fish consumption. Commen Toxicol 2002; 8(4-6):337- 343
13. Vinodhini R., Narayanan M. Bioaccumulation of trace elementss in organs of fresh water fish Cyprinus carpio (Common carp). Int. J. Environ. Sci. Tech. 5, 182, 2008.
14. Bidar G., Pruvot C., Garçon G., Verdin A., Shirali P., Douay F. Seasonal and annual variations of metal uptake, bioaccumulation, and toxicity in Trifolium repens and Lolium perenne growing in a trace elements-contaminated field. Environ. Sci. Pollut. Res. 16, 53, 2009.
15. Ahmad H, Yousafzai AM, Siraj M, Ahmad R, Ahmad I, Nadeem MS, et al. Pollution problem in river Kabul: Accumulation estimates of trace elementss in native fish species. BioMed Res Int 2015; 2015:1-7.
16. Al-Bairuty GA, Shaw BJ, Handy RD, Henry TB. Histopathological effects of waterborne copper nanoparticles and copper sulphate on the organs of rainbow trout (Oncorhynchus mykiss). Aquat Toxicol 2013; 126:11-115.
17. Kargin F. Metal concentrations in tissues of the freshwater fish Capoeta Barroisi from the Seyhan River (Turkey). Bull Environ Contamin Toxicol 1998; 60:821-828.
18. Hanaa M, Eweida A, Farag A. Heavy metals in drinking water and their environmental impact on human health. In: International conference on environmental hazards mitigation, Cairo University, Egypt, 556, 2000.
19. Cronin M, Davies IM, Newton A, Pirie JM, Topping G, Swan SC. Trace metal concentrations in deep sea fish from the North Atlantic Marine. Environ Res 1998; 45:31-38.
20. Demirak A, Yilmaz F, Tuna AL, Ozdemir N. Heavy metals in water, sediment and tissues of Leuciscus cephalus from a stream in southwestern Turkey. Chemosphere 2006; 63:1452-1458
21. Rahman MS, Molla AH, Saha N, Rahman A. Study on trace elementss levels and its risk assessment in some edible fishes from Bangshi River, Savar, Dhaka, Bangladesh. Food Chem 2012; 134(4):1849-1854
22. Rahman MS, Molla AH, Saha N, Rahman A. Study on trace elementss levels and its risk assessment in some edible fishes from Bangshi River, Savar, Dhaka, Bangladesh. Food Chem 2012; 134(4):1849-1854
23. Storelli MM, Garofalo R, Giungato D, Giacominelli-Stuffler R. Intake of essential and non-essential elements from consumption of octopus, cuttlefish and squid. Food Addit Contam Part B Surveill. 2010;3(1):14-8.
24. Küpeli T, Altundağ H, İmamoğlu M. Assessment of Trace Element Levels in Muscle Tissues of Fish Species Collected from a River, Stream, Lake, and Sea in Sakarya, Turkey. Sci World J 2014; 7:1-11.
25. Slaninova A, Machova J, Svobodova Z. Fish kill caused by aluminium and iron contamination in a natural pond used for fish rearing: a case report. Veteri Med 2014; 59:576-581.
26. FAO. Compilation of legal limits for hazardous substances in fish and fishery product. FAO. Fish. Circ. 464, 100, 1983.
27. Mendil D, Demirci Z, Tuzen M, Soylak M. Seasonal investigation of trace element contents in commercially valuable fish species from the Black sea, Turkey. Food Chem Toxicol 2010; 48:863-870.

28. Waheed S, Kamal A, Malik RN. Human health risk from organ-specific accumulation of toxic metals and response of antioxidants in edible fish species from Chenab River, Pakistan. Environ Sci Pollut Res 2013; 21:4411-4417.
29. Dural M, Goksu LZM, Ozak Derici B. Bioaccumulation of some trace elementss in different tissues of Dicentrachus labrax L, 1758, Sparus aurata L, 1758 and Mugil cephalus, L, 1758 from the Camlik Lagoon of the eastern cost of Mediterranean (Turkey). Environ Monit Assess 2006; 18:68-74.
30. Turkmen A, Turkmen M, Tepe Y, Akyurt L. Heavy metals in three commercially valuable fish species from İskenderun Bay, Northern East Mediterranean Sea, Turkey. Food Chem 2015; 91:167-172.
31. Yi Y, Yang Z, Zhang S. Ecological risk assessment of heavy metals in sediment and human health risk assessment of heavy metals in fishes in the middle and lower reaches of the Yangtze River Basin.. Environ Pollut 2011; 159:2580-2585.
32. Maleki A, Azadi N, Mansouri B, Majnoni F, Rezaei Z, Gharibi F. Health risk assessment of trace elements in two fish species from the Sanandaj Gheshlagh Reservoir, Iran. Toxicol Environ Health Sci 2015;7:43-49.
33. Yu T, Zhang Y, Hu XN, Wei M. Distribution and bioaccumulation of heavy metals in aquatic organisms of different trophic levels and potential health risk assessment from Taihu lake, China. Ecotox Environ Safe 2012; 81:59-64.
34. Hajeb P, Jinap S, Ismail A, Fatimah AB, Jamilah B, Abdul Rahim M. Assessment of mercury level in commonly consumed marine fishes in Malaysia. Food Control 2009; 20: 77-84.