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Toxic metals in the muscle and liver of five main commercially-important fishes from the Persian Gulf, Southern Iran

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ABSTRACT

The purpose of this study was to determine and compare the concentrations of six toxic metals (Cd, Pb, Fe, Cu, Zn, Mn) in the muscle and hepatic tissues of five commercially important fish species including narrow-barred Spanish mackerel, *Scomberomorus commerson,* Black pomfret, *Parastromateus niger*, Silver pomfret, *Pampus argenteus*, blackspot snapper, *Lutjanus fulviflammus* and Tigertooth croaker, *Otolithes ruber,* since they are very common in the household fish consumption. The fish samples were collected from three main landing areas along Bushehr and Hormozgan provinces during spring 2017. Our results indicated that lead concentration was higher than those of other measured heavy metals in all examined fish species, while it was an inverse situation for cadmium. We found that the concentration of the measured metals totally were higher in the liver than in muscle of all the examined fish. There was no significant intra-specific variation in metal concentration among the fish from the same species. Since it is very important to the consumer to choose between the species, we also detected the mean values of the metal concentration in the muscle of the relatively same aged species, sampled from same stations.

Key words: Biomagnification, Commercial fishes, Heavy metals, Iran, Persian Gulf.

INTRODUCTION

Fish as a valuable source of protein, constitute essential minerals, vitamins, and different kind of fatty acids (Medeiros *et al*. 2012). Many health care institutes advise pregnant females to consume fish at least twice per week to get omega-3 fatty acids (Kris-Etherton *et al*. 2002). While the consumption of the fish is very important, there is global concerns regarding the effect of the marine pollution on the food safety (Yilmaz *et al*. 2007; Zhao *et al*. 2012). Accumulation of such toxic metals in fish biomass is related to different species-specific characteristics (such as age, body length, sex, feeding habits, ecological requirements) and water biochemical characteristics (such as salinity, pH, temperature, hardness) (Demirak *et al*. 2006, Al-Busaidi *et al*. 2011; Rahman *et al*. 2012). Concentration of such toxic heavy metals in edible parts of fish and their potential side effects have been extensively investigated (Yilmaz *et al*. 2007, Elnabris *et al*. 2013). It is acknowledged that such accumulated heavy metals have many adverse health effects (Abou-Elnage *et al*. 2005; Farkas *et al*. 2002; Yilmaz *et al*. 2007). For instance, high level of lead content causes health problems in the nervous system, kidneys, anemia and sexual disability (Kim *et al.* 2015). Marine pollution and accumulation of heavy metals along the food chain brings about serious impacts such as growth demolition, behavior, and genetic abnormalities in fishes (Amini Ranjabar & Sotodehnia 2005, Naghipour *et al.* 2016). We selected five of the most common fish species in the household-food basket to determine which species are more safe to be consumed based on the amount of nominated heavy metals accumulated in their edible parts. Regarding the selected species, there is some previously-published literature. Sadeghi *et al.* (2011) reported that the concentration of Pb, Cd, and Ni in the edible parts of *P. niger* is lower than EPA, UK, and WHO food safety standards. The same results were also obtained by Abarshi *et al.* (2017) for *T. croaker*. Khazaei *et al.* (2013) found that Pb, Ni, and Cd contents were higher than the WHO safety standards for *O. rubber* and *P. argenteus*. Some investigations showed that these metals can be deposited and magnified in the sediment and aquatic biomass (Linnik & Zubenko 2000) and reach a harmful level in the upper trophic levels (Abarshi *et al.* 2017). Comparing the amount of heavy metals accumulated in muscle tissue of different fish species showed that the accumulation of heavy metals in pelagic species was lower than that in carnivorous benthic species (Romeo *et al.* 1999, Shahab Moghadam *et al.* 2010). In this study, the heavy metal contents of the edible tissue parts and important accumulating organs including hepatic tissue were investigated in five commercial fish from landing areas of Bandar-e-Abbas harbor, the Persian Gulf, and compared against the globally recommended maximum permissible limit.

MATERIAL AND METHODS

We obtained a total of 30 specimens from each species (totally 150 specimens) purchased from a fisherman who caught the specimens from landing ports along Bushehr and Hormozgan provinces (the Persian Gulf) (Fig. 1). All specimens were weighted and transferred in a cool box to the laboratory and then frozen at (-20 C°) for dissection (Turkmen *et al.* 2012). Before defrosting, the morphometric characteristics such as total length and caudal fin lengths were recorded to the nearest 0.1 mm. The hepatic and muscle tissues were frozen after dissecting at −18°C. After defrosting in the laboratory, each sample was weighed to the nearest 0.001 g, put onto petri dishes, and placed in the dryer at 80°C. After obtaining the stable weight, the samples were digested in 2 mL of 65% nitric acid and the entire solution was diluted to 10 mL with deionized water.

The prepared samples were then analyzed with the flame atomic absorption spectrometer. The final results were presented as concentrations in μg g^{-1} of the dry weight. The normal distribution of the data was checked with Kolmogorov-Smirnov test. T test was used to investigate mean difference of the heavy metals. Spearman rank correlation coefficient analysis was applied to test the significant relationships between heavy metal concentrations in different organs of each group. One-Way ANOVA was used to compare the significant differences in heavy metal concentrations among fish species and localities. Linear regression analysis was used to determine the intraspecific relationship between heavy metal contents and the specimens' weight.

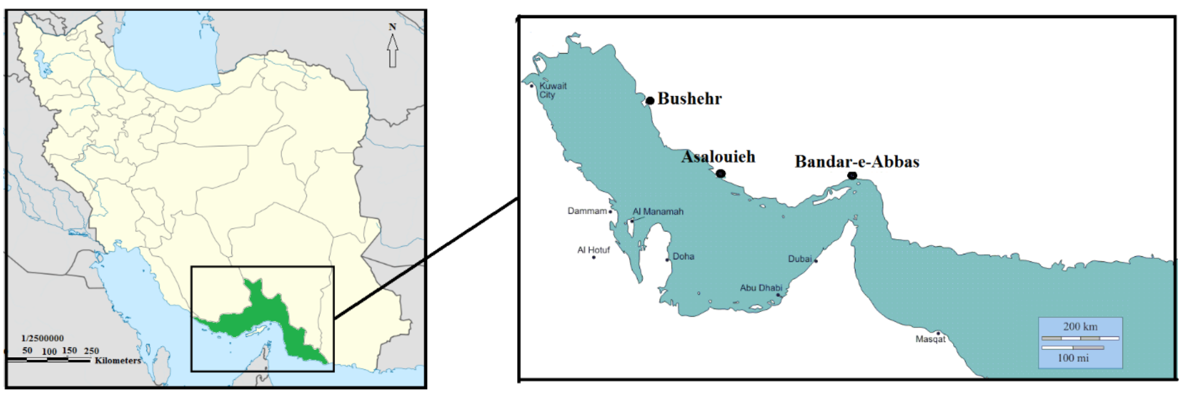

Fig.1. Specimens collection points along the Persian Gulf, Iran.

RESULTS

Our results indicated that the mean concentration of all heavy metals was significantly higher in Asalouieh landing area in comparison with the two other sites. The lowest amount of the heavy metals examined was recorded in muscle tissue, while all fish species showed the highest amount of heavy metals in the hepatic tissue as an accumulating organ. Regarding the inter-specific variation, there were no significant differences in heavy metal accumulation in all fish species, while ANOVA test showed some significant differences among the same species collected from different localities. The highest amount of lead was recorded in the hepatic tissue of *S. ommerson*, while *O. ruber* showed the lowest amount in its hepatic tissue. The concentration of Pb in its muscle ranged from 0.25 (± 0.07) ug g^{-1} dry weight, while the highest amount, i.e. 16.25 (± 3.50) ug g^{-1} dry weight was found in *L. fulviflammus.* Cadmium showed a relatively wide range from 0.73 (± 0.28) in *L. fulviflammus* liver to the highest concentration of 5.51(±1.90) ug g^{-1} in *P. niger* liver. The maximum concentration of Cd was detected in the liver of *P. niger* collected from Asalouieh (5.51 ± 1.90). Pb was concentrated in the Black pomfert liver, while the lowest amount was recorded in *S. commerson*. Examining muscle tissues also confirmed that the highest amount of Pb was detected in *S. commerson,* whereas the lowest value in tigertooth croaker (Table 1).

Table 1. Mean (±SD) concentrations of heavy metals in muscle and liver tissue of collected specimens from Bushehr.

		Pb	Cd	Fe	Cu	Mn	Zn
		Mean (±SD)	Mean (±SD)	Mean (±SD)	Mean (±SD)	Mean (±SD)	Mean (±SD)
O. ruber	Muscle	2.23 (±1.37)	0.15 (±0.02)	2.36 (±1.15)	0.55 (±0.05)	0.24 (±0.05)	3.46 (±1.55)
	Liver	5.24 (±2.46)	1.18 (±0.12)	25.15 (±5.65)	0.35 (±0.06)	0.98 (±0.15)	25.36 (±5.57)
S. commerson	Muscle	5.56 (±2.55)	1.55 (±0.55)	2.15 (±1.50)	0.45 (±0.13)	0.38 (±0.07)	4.25 (±2.12)
	Liver	15. 54 (±5.40)	2. 55 (±1.45)	37.29 (±10.35)	0.95 (±0.25)	1.40 (±0.68)	47.36 (±10.15)
P. niger	Muscle	3.45 (±1.25)	1.21(±0.24)	4.46 (±1.65)	0.25 (±0.03)	0.55 (±0.14)	3.14 (±1.25)
	Liver	9.35 (±4.30)	2.40 (±0.95)	14.25 (±4.65)	1.15 (±0.18)	0.85 (±0.15)	45.24 (±13.25)
P. argenteus	Muscle	1.55 (±0.25)	1.3 (±0.35)	1.35 (±0.58)	0.57 (±0.25)	0.28 (±0.06)	2.25 (±0.98)
	Liver	8.45 (±2.50)	1. 16 (±0.17)	35. 25 (±11.25)	0. 85 (±0.05)	0.94 (±0.08)	23.25 (±6.23)
L. fulviflammu	Muscle	2.15 (±0.95)	1.05 (±0.15)	2.46 (±1.27)	0.35 (±0.15)	1.65 (±0.55)	2.38 (±1.31)
	Liver	6.55(±1.15)	1.80 (±0.65)	15.25 (±7.35)	1.25 (±0.45)	0.59 (±0.15)	46.21 (±12.31)

Comparing the mean value of the measured heavy metals among different species indicated that the mean concentration of Cd and Mn were significantly higher in *L. fulviflammus* muscle than in other species ($P < 0.001$), while the concentration of Pb showed the reverse situation ($P < 0.001$) (Tables 2-3). The mean Fe concentration was higher in *P. argenteus* muscle compared to the other species. The highest Pb concentration was recorded in *P. niger* liver specimens. Linear regression analysis showed that there was a significant relation between Cd content and *P. niger* weight (t = 6.68, R^2 = 0.69). Lower regression coefficient for other species showed that there was no significant and considerable relation between other metal concentrations and species mean weight. Our results based on One-Way ANOVA test showed that there was a significant difference among fish species concerning to the heavy metal concentrations (F = 78.11, $P < 0.05$).

Table 2. Mean (± SD) concentrations of heavy metals in muscle and liver tissue of collected specimens from Asalouieh.

		Pb	Cd	Fe	Cu	Mn	Zn
		Mean (±SD)	Mean (±SD)	Mean (±SD)	Mean (±SD)	Mean (±SD)	Mean (±SD)
O. ruber	Muscle	4.10 (±1.47)	1.37 (±0.42)	3.50 (±1.25)	0.30 (±0.02)	0.20 (±0.02)	2.50 (±0.45)
	Liver	6.72 (±3.80)	2.95 (±0.93)	65.75 (±15.50)	1.20 (±0.15)	1.95 (±0.95)	40.40 (±4.55)
S. commerson	Muscle	72.22 (±6.50)	3.25 (±1.20)	4.25 (±0.50)	0.65 (±533)	0.47 (±0.13)	3.30 (±1.35)
	Liver	16.25 (±3.50)	5.51(±1.90)	45.18 (±10.55)	1.25 (±0.55)	1.20 (±0.55)	57.23 (±12.25)
P. niger	Muscle	6.47 (±2.15)	2.15(±0.348)	3.45 (±1.20)	0.15 (±0.04)	0.25 (±0.04)	2.45 (±1.02)
	Liver	13.55 (±3.25)	2.18 (±1.05)	75. 35 (±23.50)	2.05 (±1.08)	0.51 (±0.05)	37.27 (±10.95)
P. argenteus	Muscle	15.25 (±3.50)	2.25 (±1.05)	5.85(±2.40)	0.45 (±0.15)	0.45 (±0.05)	1.55 (±0.35)
	Liver	8. 50 (±2.80)	4. 50 (±1.95)	25. 51 (±5.50)	1. 15 (±0.55)	1.50 (±0.60)	37. 25 (±10.50)
L. fulviflammus	Muscle	7.46 (±2.10)	2.29 (±1.05)	4.15 (±1.25)	0.55 (±0.05)	0.65 (±0.15)	1.50 (±0.55)
	Liver	8.80 (±0.65)	2.80 (±0.65)	25.50 (±5.45)	1.45 (±0.55)	1.50 (±0.35)	43.37 (±13.55)

Table 3. Mean (±SD) concentrations of heavy metals in muscle and liver of collected specimens from Bandar-e-Abbas.

		Pb	Cd	Fe	Cu	Mn	Zn
		Mean (±SD)	Mean (±SD)	Mean (±SD)	Mean (±SD)	Mean (±SD)	Mean (±SD)
O. ruber	Muscle	0.25 (±0.07)	0.56 (±0.08)	1.46 (±0.90)	0.12 (±0.04)	0.21 (±0.01)	1.32 (±0.21)
	Liver	7.25 (±2.35)	1.02 (±0.07)	12.37 (±4.25)	0.45 (±0.12)	0.85 (±0.15)	12.25 (±3.45)
S. commerson	Muscle	1.25 (±0.45)	2.21 (±0.95)	1.45 (±0.24)	0.14 (±0.05)	0.34 (±0.14)	1.35 (±0.52)
	Liver	3.21 (±1.45)	1.21 (±0.79)	14.25 (±3.46)	0.35 (±0.15)	0.42 (±0.06)	28.24 (±9.24)
P. niger	Muscle	2.34 (±1.24)	0.48 (±0.01)	2.21 (±1.08)	0.13 (±0.02)	0.35 (±0.07)	1.46 (±0.45)
	Liver	4.21 (±2.36)	0.24 (±0.04)	42. 21 (±8.24)	0.54 (±0.24)	0.24 (±0.25)	16.86 (±7.48)
P. argenteus	Muscle	1.47 (±2.25)	0.49 (±0.75)	1.40 (±0.46)	0.24 (±0.18)	0.25 (±0.15)	1.14 (±0.48)
	Liver	4. 13 (±1.45)	0.89 (±0.09)	10. 12 (±3.42)	1. 02 (±0.84)	0.28 (±0.52)	19.14 (±8.42)
L. fulviflammus	Muscle	1.78 (±0.21)	1.18 (±0.24)	2.14 (±1.05)	0.25 (±0.12)	0.78 (±0.28)	2.25 (±1.04)
	Liver	4.15 (±1.48)	0.73 (±0.28)	9.23 (±1.27)	1.08 (±0.63)	1.05 (±0.42)	21.28 (±9.89)

One-Way analysis of variance also showed that there was a significant difference in Cd concentration among the fish species examined ($F = 12.52$, $P < 0.05$). *L. fulviflammus* from Asalouieh area showed the highest Cd concentration in its muscle. The mean metal concentrations in muscle of the fish species were found to be as the following order for each locality (Table 4).

Comparing our results with globally-accepted standards showed that the amount of Pb was higher than that in Asalouieh. It was also true for Cd in *P. niger, P. argenteus,* and *L. fulviflammus.*

Table 4. Heavy metals ranking sequences in different collection points.

Locality	Muscle	Liver
Asalouieh	Pb>Fe>Zn>Cd>Mn, Cu	Fe>Zn>Pb>Cd>Cu>Mn>
Bandar-e-Abbas	Zn>Pb>Fe>Cd>Mn>Cu	Fe>Zn>Pb>Cd>Cu>Mn
Bushehr	Pb>Fe>Zn>Mn>Cd>Cu	Zn>Fe>Pb>Cd>Mn>Cu

DISCUSSION

We investigated heavy metal concentrations in edible parts (muscle) and liver tissues of five commercially important fish species in southern part of Iran along the Persian Gulf coast and compared some potentially polluted areas with other non-polluted parts. Although such edible parts of fishes can not be regarded as the target organ to accumulate such metals, but it is important to elucidate its effect on human health (Bahnasawy *et al.* 2009). Abel *et al*. (1989) clarified that heavy metals threatened not only fishes but also humans. The metal concentrations measured reflected a clear influence of anthropogenic activities, since the highest amount of all the heavy metals was measured in fishes collected from Asalouieh where it is located near oil refinery facilities. The concentration of the heavy metals measured was higher than the standard levels recommended for this area. Additionally, the effective exposure of organisms to different metals may be influenced by either changes in metal speciation or relative distribution of metals among particles of different sizes and densities (Turkmen *et al*. 2012).

However, muscles cannot accumulate heavy metals (Elnabris *et al*. 2013), but in polluted areas the concentration of such metals in muscle tissues may exceed the accepted standard levels for human consumption. Comparing the recorded heavy metal concentration with the maximum permissible levels (Sahebi *et al.* 2011) for human consumption (MPL) established by different organizations (Table 6) showed that all fishes from Asalouieh area were unsafe for human consumption. Metals such as Cu, Zn, Fe, and Mn were clearly below all the permissible limits for human consumption. Such metals are essential for metabolism in human bodies. Other investigated metals such as Pb and Cd, which are the non-essentials, are higher than all the permissible limits especially for Asalouieh fishing harbor, but they are below the limits in Bandar-e-Abbas and Bushehr fishing harbors compared to all the standard levels. Our results indicated that the amount of the metals accumulated in liver was higher than that in the muscle for all the specimens examined. Chen & Chen (2001) found that the muscles of *Sardinella lemuru* recorded the highest concentrations of Zn, Fe, Cu, and Mn among nine fish species collected from the Ann-Ping coastal waters, Taiwan. It was reported that larger fish biomass accumulated more heavy metals like Cd in its liver (e.g. *Caranx* sp.) that can be related to the age of the fish, since Cd is difficult to be excreted from liver once it is accumulated (Khaled 2004). This large fish might have accumulated high Cd concentrations throughout its long life. Eisler (2010) also reported that the accumulation of cadmium in liver was positively linked to the age of the fish. In the present study, we found that *S. commerson* showed higher Cd accumulation in its hepatic tissue that is in accordance with the previous literature. Our results indicated that *S. commerson* accumulated more Cd and Pb than other species corresponding to its mean weight and size compared to the other fish species. Our results regarding the concentration of Cd and Pb are in agreement with this order, but there is no regular pattern concerning the essential metals including Mn, Zn and Fe.

Table 5. ANOVA analysis of mean differences between three groups (locality, species and organs).

	Source	df	F	p		Source	df	F	p
Pb	Locality	2	45.85	<0.01	Cu	Locality	2	28.56	<0.001
	Species	4	25.46	<0.05		Species	4	21.57	<0.05
	Organ	1	87.58	<0.001		Organ	1	87.50	<0.001
Cd	Locality	2	240.12	<0.001	Mn	Locality	2	45.58	<0.05
	Species	4	110.58	<0.05		Species	4	71.25	<0.01
	Organ	1	356.45	<0.05		Organ	1	410.52	<0.01
Fe	Locality	2	2.05	<0.001	Zn	Locality	2	17.56	<0.001
	Species	4	15.17	<0.001		Species	4	20.25	<0.001
	Organ	1	71.25	<0.001		Organ	1	450.35	<0.001

Table 6. Maximum permissible levels for human consumption from different organizations.

Source	Metals						References
	Cd	Cu	Mn	Pb	Zn	Fe	
European Community	0.05	–	–	0.2	–	-	EC (2005)
England	0.2	20	–	2.0	50	-	MAFF (2000)
FAO (1983)	–	30	–	0.5	30	-	FAO (1983)
Turkish guidelines	0.1	20	20	1	50	-	Dural et al. (2007)
FAO/WHO limits	0.5	30	–	0.5	40	15	FAO/WHO (1989)
EU limits	0.1	10	–	0.1	–	-	EU (2001)
Saudi Arabia	0.5	–	–	2.0	–	-	SASO (1997)
Range of metals in the present study	0.24-3.25	0.12–0.907	0.20–1.65	0.25-72.22	1.14–4.25	1.35-5.85	Present study

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فلزات سنگین بافت عضله و کبد در پنج ماهی تجاری مهم صید شده ازجنوب ایران (خلیج فارس)

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چکیده

هدف این مطالعه اندازه‌گیری و مقایسه غلضت شش فلز سنگین مشتمل بر کادمیوم، سرب، آهن، مس، روی و منگنز در بافت‌های عضله و کبد پنج گونه از ماهیان تجاری مهم از نظر صید تجاری شامل حلوا سیاه، حلوا سفید، شوریده، شیرماهی و سرخوی خال سیاه بود. ماهیان مورد بررسی از سه بندرگاه در امتداد استان‌های بوشهر و هرمزگان در طی زمستان ۱۳۹۵ جمع‌آوری گردید. نتایج به دست آمده در این پژوهش حاکی از آن بود که سرب اندازه‌گیری شده در هر پنج گونهی مورد بررسی بالاتر از حدود استاندارد می‌باشد درحالی که در مورد کادمیوم عکس این وضعیت ثبت گردید. نتایج نشان داد که غلضت فلزات مورد سنجش به طور کلی در بافت کبد بالاتر از بافت عضله می‌باشد. در بین افراد متعلق به یک گونه غلضت فلزات مورد سنجش تفاوت معنی‌داری نشان نداد. از آنجاییکه انتخاب گونهی ماهی برای مصرف کنندگان اهمیت بسیاری دارد مقادیر میانگین غلضت فلزات در بافت عضله در گونه‌های تقریبا هم سن که از ایستگاه‌هایی یکسان نمونه‌برداری شده بودند نیز تعیین گردید.

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