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Distribution of Metals in the Tissues of Benthic, *Euryglossa orientalis* and *Cynoglossus arel.*, and Bentho-Pelagic, *Johnius belangerii.*, Fish from Three Estuaries, Persian Gulf

Fazel Abdolahpur Monikh · Sadegh Peery · Omid Karami · Mehdi Hosseini · Afshin Abdi Bastami · Amir Faraz Ghasemi

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Abstract Concentrations of Cd, Co, Cu, Ni, Pb, Fe and Zn were determined in the muscle, liver and gills of three commercial benthic and pelagic fish species (*Johnius belangerii*, *Euryglossa orientalis* and *Cynoglossus arel*) from three estuaries in the northwest Persian Gulf. Metals levels varied significantly depending on the tissues, species and locations. Generally, the results showed that liver accumulate higher concentrations of the metals in comparison to muscle and gills, except in few cases. Among the species, *E. orientalis* showed the highest levels of Co, Cu, Ni and Fe, while the highest concentrations of Pb and Zn were observed in *C. arel*. *J. belangerii* accumulated the highest level of Pb element.

Keywords Persian Gulf · Musa estuary · Benthic · Benthopelagic · Pelagic

Increase in the amount of released contaminants in the marine environment during last decades result in vast studies in the field of marine pollution. One of the main subjects that attract the attention of many researchers is metals contamination and their effects on the environment (Henry et al. 2004; Yilmaz and Yilmaz 2007). Due to, metals are non-biodegradable, have a remarkable ability to transfer through food chains and are potentially toxic for organisms (Chen and Chen 1999). They are introduced to marine environment via different anthropogenic sources such as petrochemical wastewaters, mineral and agricultural runoff, oil transportation and urban effluents (Karadede et al. 2004).

Fish, which usually occupies the last levels of aquatic food chains, are considered as the main aquatic pathway for metals to be transferred into human body (Svensson et al. 1992). Biological and ecological factors such as size, sex (Al-Yousuf et al. 2000), ecological needs, habitat, feeding habits (Bustamante et al. 2003) and season (Navarro et al. 2006) have significant influences on metals bioaccumulation, bioavailability and therefore on their transference.

The northwest of the Persian Gulf receives pollution from three developing countries, including Iraq, Iran and Kuwait. Besides, Arvand river, the biggest river in the sea, empties enormous amount of contamination in this area. For instance, according to Al-Saad et al. (1998) this river carries about 48 tons of oil residues to the northwest Persian Gulf annually. On the other hand, ecological characteristics of this part of the Persian Gulf make it rich in chlorophyll and subsequently rich in production (Sheppard et al. 2010). These conditions provide an ideal area for many species of marine organisms such as fish, shrimp, mussel and crab. Therefore, the northwest of the Persian Gulf is considered as a vital area for fisheries in the sea. The main aim of this study is to determine the level of Cd, Co, Cu, Ni, Pb, Fe and Zn in muscle, liver and gills of three commercially valuable fish species in the northwest Persian Gulf. The other purpose of current study is to investigate the influences of habitat on metals accumulation.

F. Abdolahpur Monikh (✉) · S. Peery · A. F. Ghasemi
Department of Marine Biology, Faculty of Marine Science, Khoramshahr University of Marine Science and Technology, P.O. Box 64199-669, Khoramshahr, Iran
e-mail: Fazel_abdolahpur2@yahoo.com

O. Karami · A. A. Bastami
Department of Environment Science, Faculty of Science and Research, Islamic Azad University, Tehran, Iran

M. Hosseini
Department of Marine Biology, Faculty of Biological Science, Shahid Beheshti University, Tehran, Iran

Materials and Methods

During this study, three stations were chosen along the Iranian coast of the northwest Persian Gulf (Fig. 1). Ten fish of each species (*Euryglossa orientalis*, *Cynoglossus arel* and *Johnius belangerii*) from each station were caught by trawl and in some cases by gill net in the summer of 2010. The samples were immediately transferred to the laboratory in icebox and then frozen at −20°C until dissection.

For analysis, whole liver, gills and sufficient amount of muscle were dissected and oven-dried at 90°C until they reached a constant weight. A porcelain mortar was used to grind the dry tissues. About 2 g of dried muscle, 1 g of dried liver and gills were transferred into digestion flasks. Concentrated nitric acid (65 %, Merck) and perchloric acid in the ratio of 2:1 were added and then the flasks were kept on the hot plate until all the tissues were dissolved.

Concentrations of the metals were determined by an atomic absorption spectrometer (SavantAA Sigma) of GBC Scientific Equipment Pty. Ltd. (Dandenong, VIC 3175, Australia) with hyper pulse deuterium background corrector in flame air-acetylene.

All reagents used were of analytical reagent grade (Merck, Germany). Blank samples and standard reference material DORM 2 (National Research Council of Canada: dogfish muscle) were employed in order to avoid possible contamination during analysis and to check the accuracy of analytical procedures respectively. The agreement was satisfactory with the recovery. The recovery rates of metals were between 94.6 % and 106 %.

Statistical analysis was performed using SPSS program. In order to assess significant differences between species and tissues, one-way ANOVA and Duncan multiple comparison test were applied. The significance level was set at $\alpha = 0.05$.

Results and Discussion

The results of statistic analysis for comparison of metals concentrations between stations and between tissues of *J. belangerii*, *E. orientalis* and *C. arel* (expressed as μg g^{-1} dry weight) are shown in Tables 1, 2 and 3 respectively. Even though each fish species obtained from the three estuaries are relatively of the same size and weight, however metals concentrations in their tissues were completely various. In general, among the three stations, Musa estuary fishes accumulated the highest concentrations of the studied elements in their tissues in comparison to the same species from the other stations. The high metals levels in the fish of Musa estuary can be explained by the located Emmam port, tremendous traffic of oil tankers, enormous discharges of petrochemical units, agricultural activities and urban developing in the area (Safahieh et al. 2011).

Fish collected from the mouth of Arvand river also demonstrated relatively high metals levels in their tissues in comparison to those from Selech estuary. Arvand river is used for many Iraqi and Iranian industrial, shipping and irrigation purposes. In addition, it passes a lot of cities, ports and harbors. For instance, it passes the Iraqi port of Al-Basrah and the Iranian ports of Abadan and Khoramshahr before emptying into the Persian Gulf. Therefore, these sources could result in huge amount of metals in this river and its organisms.

In General, the accumulation orders of metals in the tissues were found to be liver > gills > muscle for the studied species, except for Ni in *J. belangerii* that was gills > liver > muscle. For *J. belangerii,* the concentrations of Cd, Cu, Fe and Zn in the liver were significantly higher than those in the muscle and gills while the concentration of Ni in the gills was significantly higher than the liver and muscle. For *E. orientalis,* the levels of all the metals in the liver were significantly higher than the muscle and gills. Regarding *C.* arel, the concentrations of Cd, Cu, Pb, Fe and Zn in the liver tissue were significantly higher than those in the muscle and gills, except Fe element in *C. arel* of Arvand river.

Metals are taken up by fish from food and water, distributed throughout fish body by blood and eventually accumulated in target organs. Some tissues such as liver and kidney are considered as target organs for metals

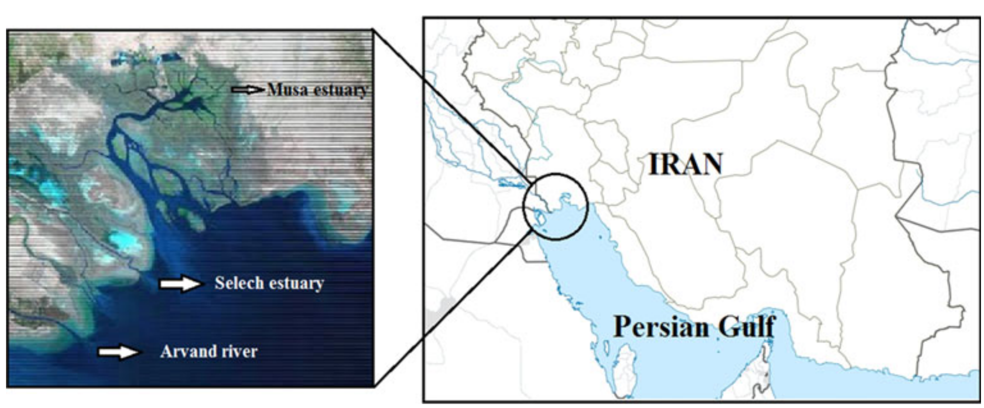

Fig. 1 A map showing of the Persian Gulf and the stations

Table 1 Metal concentration (mean and SD) based on μg g^{-1} w in *Johnius belangerii* tissues collected from three estuaries in the northwest Persian Gulf

Location	Tissues	Cd	Co	Cu	Ni	Pb	Fe	Zn
S1	M	3.15 ± 1.57^{a}	0.14 ± 0.03^{a}	1.97 ± 0.24^{a}	4.32 ± 1.23^{a}	0.73 ± 0.1^{a}	2.35 ± 0.42^{a}	7.22 ± 1.76^{a}
	L	38.31 ± 32.56^{c}	1.27 ± 0.31^{b}	12.27 ± 2.31^{c}	66.05 ± 10.52^{b}	2.91 ± 0.14^{c}	16.47 ± 5.18^{c}	43.69 ± 9.3^{c}
	G	29.22 ± 18.41^{b}	1.32 ± 0.3^{b}	8.02 ± 5.0^{b}	91.47 ± 4.3^{c}	1.85 ± 0.1^{bc}	10.61 ± 2.98^{b}	12.37 ± 2.27^{b}
S2	M	0.48 ± 0.02^{a}	0.18 ± 0.08^{a}	1.21 ± 0.27^{a}	1.17 ± 0.12^{a}	0.27 ± 0.01^{a}	1.18 ± 0.24^{a}	3.40 ± 0.52^{a}
	L	4.97 ± 1.7^{b}	0.94 ± 0.1^{b}	8.14 ± 2.14^{c}	19.34 ± 1.8^{b}	1.16 ± 0.04^{b}	12.44 ± 2.27^{c}	27.21 ± 4.42^{c}
	G	3.64 ± 2.87^{b}	1.02 ± 0.13^{b}	3.37 ± 0.6^{b}	36.12 ± 10.5^{c}	1.05 ± 0.28^{b}	6.26 ± 3.12^{b}	9.11 ± 0.63^{b}
S3	M	0.43 ± 0.2^{a}	0.21 ± 0.01^{a}	1.64 ± 0.64^{a}	1.92 ± 0.2^{a}	0.33 ± 0.07^{a}	0.98 ± 0.01^{a}	3.71 ± 0.21^{a}
	L	6.22 ± 1.1^{c}	1.14 ± 0.13^{b}	9.81 ± 4.36^{c}	14.28 ± 2.53^{b}	1.94 ± 0.4^{b}	9.33 ± 1.12^{c}	32.47 ± 10.53^{c}
	G	4.23 ± 1.26^{b}	1.08 ± 0.1^{b}	5.32 ± 2.75^{b}	31.36 ± 13.6^{c}	1.14 ± 0.16^{b}	6.13 ± 2.21^{b}	15.65 ± 1.76^{b}

S1 = Musa estuary, S2 = Selech estuary, S3 = the mouth of Arvand river

M muscle, *L* liver, *G* gills

a, b, c show significant differences among tissues

Table 2 Metal concentration (mean and SD) based on μg g^{-1} d.w in *Euryglossa orientalis* tissues collected from three estuaries in the northwest Persian Gulf

Location	Tissues	Cd	Co	Cu	Ni	Pb	Fe	Zn
S1	M	1.12 ± 0.26^{a}	0.27 ± 0.03^{a}	12.68 ± 2.21^{a}	6.27 ± 1.3^{a}	3.12 ± 0.26^{a}	7.43 ± 1.57^{a}	12.48 ± 9.1^{a}
	L	9.54 ± 3.46^{c}	3.41 ± 1.14^{c}	51.25 ± 5.6^{c}	105.97 ± 4.31^{c}	12.28 ± 2.36^{b}	83.36 ± 21.83^{c}	182.35 ± 12.64^{c}
	G	5.32 ± 2.35^{b}	2.33 ± 1.04^{bc}	21.83 ± 4.38^{b}	44.50 ± 11.3^{b}	4.88 ± 1.9^{a}	37 ± 4.37^{b}	39.17 ± 20.2^{b}
S2	M	0.18 ± 0.01^{a}	0.38 ± 0.03^{a}	3.42 ± 0.1^{a}	2.49 ± 0.2^{a}	0.80 ± 0.02^{a}	1.95 ± 0.2^{a}	8.32 ± 5.76^{a}
	L	2.97 ± 0.74^{c}	2.91 ± 0.73^{c}	16.06 ± 7.36^{c}	40.27 ± 8.34^{c}	2.03 ± 0.42^{b}	22.47 ± 7.83^{c}	61 ± 15.3^{c}
	G	0.91 ± 0.01^{b}	1.20 ± 0.2^{b}	8.52 ± 1.04^{b}	10.19 ± 4.62^{b}	0.97 ± 0.02^{a}	4.13 ± 0.52^{b}	16.20 ± 8.33^{b}
S3	M	0.89 ± 0.12^{a}	3.21 ± 1.37^{a}	4.83 ± 1.12^{a}	3.27 ± 0.82^{a}	3.92 ± 0.63^{a}	4.82 ± 0.04^{a}	4.08 ± 1.11^{a}
	L	4.37 ± 1.62^{c}	23.26 ± 8.93^{b}	23.21 ± 1.85^{b}	72.18 ± 7.6^{b}	21.37 ± 2.4^{c}	54 ± 15.73^{c}	64.29 ± 12.47^{c}
	G	1.92 ± 0.4^{b}	4.29 ± 1.48^{a}	6.52 ± 2.86^{a}	4.24 ± 0.68^{a}	6.52 ± 1.14^{b}	12.39 ± 2.68^{b}	11.46 ± 6.76^{b}

S1 = Musa estuary, S2 = Selech estuary, S3 = the mouth of Arvand river

M muscle, *L* liver, *G* gills

a, b, c show significant differences among tissues

Table 3 Metal concentration (mean and SD) based on μg g^{-1} d.w in *Cynoglossus arel tissues* collected from three estuaries in the northwest Persian Gulf

Location	Tissues	Cd	Co	Cu	Ni	Pb	Fe	Zn
S1	M	2.43 ± 1.12^{a}	0.12 ± 0.1^{a}	7.29 ± 2.45^{a}	3.41 ± 0.75^{a}	5.63 ± 3.12^{a}	4.73 ± 0.58^{a}	10.21 ± 1.53^{a}
	L	12.31 ± 3.32^{b}	1.37 ± 0.73^{b}	48.42 ± 23.8^{c}	29.17 ± 11.4^{bc}	27.45 ± 8.11^{c}	47.18 ± 3.78^{c}	204.11 ± 36.62^{c}
	G	10.06 ± 4.3^{b}	1.94 ± 1.02^{b}	31.53 ± 21.6^{b}	31.24 ± 12.9^{c}	17.82 ± 14.2^{b}	20.14 ± 1.95^{b}	94.23 ± 8.35^{b}
S2	M	0.32 ± 0.03^{a}	0.10 ± 0.1^{a}	0.48 ± 0.22^{a}	1.78 ± 1.52^{a}	0.96 ± 021^{a}	2.05 ± 0.23^{a}	5.97 ± 0.78^{a}
	L	4.62 ± 3.12^{c}	1.43 ± 1.02^{b}	6.25 ± 2.04^{b}	22.76 ± 5.33^{b}	3.26 ± 0.67^{b}	16.91 ± 10.2^{c}	74.31 ± 34.37^{c}
	G	2.21 ± 0.2^{b}	1.52 ± 0.98^{b}	5.31 ± 2.34^{b}	24.13 ± 14.3^{bc}	2.97 ± 0.41^{b}	12.37 ± 4.75^{b}	54.48 ± 2.78^{b}
S3	M	1.03 ± 0.1^{a}	0.98 ± 0.52^{a}	0.84 ± 0.16^{a}	2.36 ± 1.44^{a}	5.84 ± 2.43^{a}	2.34 ± 0.15^{a}	6 ± 1.87^{a}
	L	10.53 ± 4.52^{c}	8.91 ± 3.21^{c}	6.30 ± 4.91^{c}	23.49 ± 9.83^{c}	43.27 ± 27.76^{c}	14.35 ± 9.64^{b}	114.92 ± 11.27^{c}
	G	4.64 ± 1.21^{b}	6.93 ± 2.04^{bc}	4.06 ± 2.92^{b}	20.11 ± 3.77^{b}	21.36 ± 4.47^{b}	20.93 ± 13.5^{c}	83.20 ± 7.93^{b}

S1 = Musa estuary, S2 = Selech estuary, S3 = the mouth of Arvand river

M muscle, *L* liver, *G* gills

a, b, c show significant differences among tissues accumulation (Yilmaz 2003). The very low concentrations of Cd, Co, Cu, Pb, Fe and Zn in the muscle of the fish species in comparison to their liver may be related to the content of metallothionein protein in liver tissue. Metallothionein protein that plays a significant role in the regulation and detoxification of metals is produced in high levels in liver tissue (Sen and Semiz 2007). This protein contains a high percentage of amino group, nitrogen and sulphur that sequester metals in stable complexes (Al-Yousuf et al. 2000).

Gills usually reflect the concentrations of metals in surrounding water (Bustamante et al. 2003). This organ is directly in contact with water and suspended materials, thus could absorb different substances from the surrounding environment. They also serve a variety of physiological functions such as osmoregulation and gas exchange. Due to these functions, gills have remarkable influences on the exchange of toxic metals between a fish and its environment (Farkas et al. 2003). However, the muscle tended to accumulate less metal in comparison to the liver and gills. This finding may reflect the low concentration of metallothioneins in the muscle tissue (Allen-Gil and Martynov 1995).

The Zn, Fe and Cu values found in the fish tissues may be associated to their roles in the metabolic function (Yilmaz et al. 2007). These elements are essential and vital micronutrient for some enzymes activities and subsequently for biological systems (Bowen 1979). Therefore, some target organs such as liver and gills have the ability to regular and redistribute them in fish body (Tuzen 2009).

The comparison of the species according to metals accumulation was illustrated in Fig. 2. The results showed that there were significant differences between the species. The accumulation order of Co, Cu and Fe in the species was *E. orientalis* > *C. arel* > *J. belangerii*, while the accumulation of Pb and Zn displayed a different pattern in the species: *C. arel* > *E. orientalis* > *J. belangerii*. For Ni and Cd elements the sequences were *E. orientalis* > *J. belangerii* > *C. arel* and *J. belangerii* > *C. arel* > *E. orientalis* respectively.

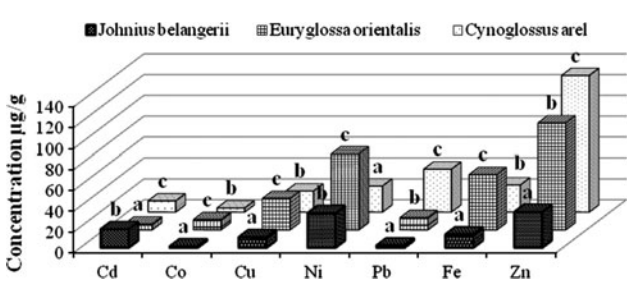

Fig. 2 Comparison of metals concentration between species

Despite of being benthic and non-migratory species, *E. orientalis* and *C. arel* indicated different metals accumulation in their tissues. These differences may be resulted from the variation in their diet and accumulation strategies. Generally, among the three species, the benthic species accumulated higher concentrations of the metals, due to the greater exposure to metals enriched sediment and interactions with benthic organisms (Huang 2003; Yi et al. 2008). Therefore, this finding could confirms that metals concentration is heavily controlled by habitat, feeding habits, capacity of metals accumulation and kind of species (Bustamante et al. 2003; Agah et al. 2009).

The concentration of Cd element in the bentho-pelagic fish, *J. belangerii*, was higher than *E. orientalis* and *C. arel*. Enrichment of Cd in the liver of *J. belangerii* with respect to the other species may be related to crustaceans-eating habits of the fish. The diet of *J. belangerii* consists of crustaceans plankton, mollusca and shrimp. Crustaceans have been reported as a vector of the transfer of Cd element to top marine predators of the food chains (Bustamante et al. 2003).

Table 4 summarized the mean values of metals concentration in the edible part of different fish species from different parts of the Persian Gulf, as well as permissible limits provided by different countries and organizations. Pourang et al. (2005) studied the metals concentrations in *Epinephelus coioides*, *Solea elongata* and *Psettodes erumei* from the north Persian Gulf. Compared to the results of Pourang et al. (2005), generally, our results were higher than their findings, except for Pb in *J. belangerii*. Similarly, De Mora et al. (2004) studied the concentrations of metals in some fish species from the south Persian Gulf. Present findings generally were higher for Cd, Co, Cu and Ni than those. The concentration of Fe in fish collected from the north Persian Gulf (Agah et al. 2009) was agreed well with the current result. On the other hand, the concentration of Co and Ni was higher, but Cu and Zn concentration was lower than our results. These comparisons indicated that metals concentrations in fish depend strongly on the habitat of the fish.

To assess the safety of the muscle tissue, which is used as a major source of protein, the obtained results for this tissue in present study was compared with the maximum permissible limits (MPL) provided by FAO (1983), WHO (1996), Ministry of Agriculture Fisheries and Food (United Kingdom) (MAFF), National Health Research Council (Australia) (NHMRC), European Communities and Saudi Arabia (Table 4). The values converted into $\mu g\ g^{-1}$ w w with a w w d^{-1}. w ratio of 0.2 for *J. belangerii*, 0.22 for *E. orientalis* and 0.25 for *C. arel*. Cadmium level in *J. belangerii* was found to be within MPL of FAO, while the concentration of the same element in *E. orientalis* and *C. arel* was lower than MPL of FAO. Copper level in the

Table 4 Comparison of average concentration of the metals (μg g^{-1} w w) in the muscle of the fish species collected from the northwest Persian Gulf with fishes from different parts of the Persian Gulf and some available standards

Locations/standards	Species	Cd	Co	Cu	Ni	Pb	Fe	Zn
Persian Gulf[a]	*Johnius belangerii*	0.27	0.03	0.32	0.49	0.08	0.3	0.95
	Euryglossa orientalis	0.16	0.28	1.53	0.88	0.57	1.04	1.82
	Cynoglossus arel	0.31	0.1	0.71	0.62	1.03	0.76	1.84
Persian Gulf, Northern part[b]	*Epinephelus coioides*	0.11			1.56	2.32		
Persian Gulf, Northern part[b]	*Solea elongata*	0.07			6.69	2.43		
Persian Gulf, Northern part[b]	*Psettodes erumei*	0.10			1.09	2.09		
Persian Gulf, Qatar[c]	*Epinephelus coioides*	0.01	<0.005	0.56	0.03	0.11	21.7	8.2
Persian Gulf, UAE[c]	*Epinephelus coioides*	<0.001	0.01	0.37	<0.01	0.02	25.1	13.5
Persian Gulf, Bahrain[c]	*Epinephelus coioides*	0.002	<0.01	0.23	<0.01	0.02	3.10	15.9
Persian Gulf, Oman[c]	*Epinephelus coioides*	<0.005	<0.05	0.51	<0.05	0.02	8.46	13.4
Persian Gulf, Northern part[d]	*Epinephelus tauvina**		2–8	0.1–0.2	9–39	2–9	2–4	4–5
Persian Gulf, Northern part[d]	*Otolithes rubber**		2–4	0.1–0.2	8–63	1–9	2–4	3–5
Persian Gulf, Northern part[d]	*Pampus argenteus**		2–18	0.1–0.2	1–100	3–33	3	3–5
FAO (1983)		0.5 (mg kg^{-1})		30 (mg kg^{-1})		2 (mg kg^{-1})		
WHO (1996)				30 (mg kg^{-1})		0.5 (mg kg^{-1})		
MAFF*[f]				20				
NHMRC*[f]		2		30		5.5		
Saudi Arabia*[g]				0.5		2		
EC*[g]				0.05		0.5		

* Concentration is in μg g^{-1} dry weight, except the cases are denoted with asterisk, which are in μg g^{-1} wet weight. MAFF = Ministry of Agriculture Fisheries and Food (United Kingdom), NHMRC = National Health Research Council (Australia), EC = European Communities

[a] This study, [b] Pourang et al. (2005), [c] De Mora et al. (2004), [d] Agah et al. (2009), [f] Huang (2003), [g] Al-Saleh and Shinwari (2002)

muscle of the fish was found to be higher than legal limits of EC and in the muscle of *E. orientalis* and *C. arel* was higher than legal limits of Saudi Arabia. The concentration of Pb in the muscle of *E. orientalis* and *C. arel* was found to be higher than MPLs of WHO and EC.

Current study provides new information on the distribution of metals in the tissues of three commercial fish from the northwest Persian Gulf. In general, the metals showed a strong tendency to accumulate in the liver tissue and followed by gills. Metals concentrations in edible part of the fish are below the proposed limit values for human consumption except in some cases. In addition, the results of present study showed that different species have various capacities to accumulate the metals from the surrounding environment. Thus, people how consume fish from this area should eat a diversity of fish to avoid consuming harmful quantity of essential and non-essential metals.

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