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Mercury Concentrations in Commercial Fish from Freshwater and Saltwater

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Abstract Research was performed to investigate the concentration of mercury in muscle and liver of fish species from freshwater (*Barbus xanthopterus, Barbus grypus*, *Liza abu)* and saltwater (*Cynoglossus arel*, *Periophthalmus waltoni*, *Otolithes ruber)* in Khouzestan, Iran. In freshwater fish, muscle was polluted in comparison with liver except for *Barbus xanthopterus* which high levels of mercury were measured in liver. In saltwater fish liver was contaminated than muscle except for *Cynoglossus arel* which high level of mercury was found in muscle. Significant variations in metal values were evaluated using student's *t* test at $P < 0.05$. Mercury concentrations were well above the permissible limits suggested by WHO and FDA guidelines.

Keywords Mercury · Commercial fish · Freshwater · Saltwater

Khouzestan has various water resources such as freshwater and saltwater and it is located in southern part of Iran. These water resources supply the water demands of numerous cities, several villages, thousands hectares of agricultural lands and several hydropower plants. There are considerable Freshwater resources in Khouzestan including Karoon, Dez, Bahmanshir and Karkhe Rivers. Also, Mahshahr and Abadan Seaports are important saltwater resources in Khouzestan, Iran. They play an important role in water and fish supply which have great economic values. *Barbus xanthopterus, Barbus grypus*, *Liza abu*, *Cynoglossus arel*, *Periophthalmus waltoni* and *Otolithes ruber* have high market value and are the main fish products in water resources in Khouzestan.

Anthropogenic sources such as industrial wastes, agriculture and urban sewage, geochemical structure and mining of metals create a potential source of heavy metals pollution in the aquatic environment and its contamination has been identified as a concern in coastal environments. The contamination chain of heavy metals almost always follows the cyclic order: industry, atmosphere, soil, water, phytoplankton, zooplankton, fish and human. Heavy metals can be accumulated by aquatic organisms through a variety of pathways, including respiration, adsorption and ingestion and often reach the human body by ingestion (Mendil et al. 2010).

Mercury (Hg) is a persistent and hazardous environmental pollutant. Mercury species can undergo a variety of transformations in the environment, and ionic Hg can be transformed into one of the most toxic forms, methylmercury (MeHg), by both abiotic and biotic pathways (He et al. 2007). The levels of mercury (Hg) in fish tend to reflect the average characteristics of the local aquatic environment. This makes them good bio indicators of environmental variability, useful for investigating the influence of spatial variation in water chemistry and other environmental characteristics on fish Hg (Belger and Rider Forsberg 2006).

The main objective of this study was to determinate the contents of mercury in the muscle and liver of some commercial fish such as *Barbus xanthopterus, Barbus grypus*, *Liza abu*, *Cynoglossus arel, Periophthalmus waltoni* and *Otolithes ruber* in water resources of Khouzestan, Iran, in order to assess fish quality and to assess the health risk for humans. This could help us understand the enrichment behavior of mercury in freshwater and saltwater in Khouzestan and emphasize the need to discard the most polluted tissues of the fish.

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Materials and Methods

The concentrations of mercury were measured in the muscle and liver of *Barbus xanthopterus, Barbus grypus* and *Liza abu* from freshwater, *Cynoglossus arel, Periophthalmus waltoni* and *Otolithes ruber* from saltwater caught by gillnet in Khouzestan in summer 2010. The number of samples was 48 fish in each river and seaport. After capture, fish were placed in plastic bags and transported to the laboratory in freezer bags with ice and then fish were immediately frozen at −20°C.

All reagents were of analytical reagent grade unless otherwise stated. Double deionised water (Milli-Q Millipore 18.2 MΩ cm^{-1} resistivity) was used for all dilutions. HNO_3, H_2O_2 and HCl were of suprapur quality (E. Merck, Darmstadt, Germany). All the plastic and glassware were cleaned by soaking in dilute HNO_3 (1/9, v/v) and were rinsed with distilled water prior to use. The element standard solutions used for calibration were produced by diluting a stock solution of 1,000 mg/l of the given element supplied by Sigma Chem. Co. St. Louis, USA. Perkin Elmer Analyst 700 model AAS equipped with MHS 15 CVAAS system was used for mercury determination. A hallow cathode lamp operating at 6 mA was used and a spectral bandwidth of 0.7 nm was selected to isolate the 253.7 nm mercury line. $NaBH_4$ (1.5%) (w/v) in NaOH (0.5%) (w/v) was used as reducing agent. The analytical measurement was based on peak height. Reading time and argon flow rate was selected as 10 s and 50 ml min^{-1}. Milestone Ethos D microwave (Sorisole-Bg, Italy) closed system (maximum pressure 1,450 psi, maximum temperature 300°C) was used.

One gram of sample was digested with 6 ml of concentrated HNO_3 (65%) (Suprapure, Merck, Darmstadt, Germany) and 2 ml of concentrated H_2O_2 (30%) (Suprapure, Merck, Darmstadt, Germany) in microwave digestion system and diluted to 10 ml with double deionized water (Milli-Q Millipore 18.2 M cm^{-1} resistivity). A blank digest was carried out in the same way (digestion conditions for microwave system were applied as 2 min for 250 W, 2 min for 0 W, 6 min for 250 W, 5 min for 400 W, 8 min for 550 W, vent: 8 min, respectively; Tuzen 2009). The whole data were subjected to a statistical analysis and correlation matrices were produced to examine the inter-relationships between the investigated trace metal concentrations of the samples. Data statistics were performed using SPSS 17 software. Paired samples *T* Test were used to compare differences between samples. A *P*-value less of 0.05 was considered statistically significant.

Results and Discussion

The concentrations of mercury (mg kg^{-1} wet weight) in muscle and liver of *Barbus xanthopterus, Barbus grypus* and *Liza abu* from freshwater, *Cynoglossus arel, Periophthalmus waltoni* and *Otolithes ruber* from saltwater are summarized in Tables 1 and 2. Mercury levels in muscles of riverine fish were high in comparision with seaport fish except for *Periophthalmus waltoni*, but this species was less polluted in comparision with *Barbus xanthopterus*. Mercury levels in muscle of *Barbus xanthopterus* in Karoon and Dez Rivers were higher than other species in freshwater and saltwater. In muscles of *Barbus grypus* and

Table 1 Mercury levels (mg kg^{-1} wet weight) in muscle of freshwater and saltwater fish

Species	*n*	Location	Mean ± SD	Min	Max
Barbus xanthopterus (a)	48	Karoon River	1.22 ± 0.39^{a}	0.60	1.85
Barbus xanthopterus (b)	48	Dez River	$0.93 \pm 0.07^{b,a}$	0.74	1.12
Barbus grypus (a)	48	Karoon River	$0.83 \pm 0.02^{c,a,b}$	0.76	0.89
Barbus grypus (c)	48	Karkhe River	0.28 ± 0.03^{d}	0.19	0.36
Liza abu (d)	48	Bahmanshir River	$0.29 \pm 0.02^{e,d}$	0.23	0.36
Liza abu (a)	48	Karoon River	0.03 ± 0.01^{f}	0.01	0.05
Liza abu (b)	48	Dez River	$0.02 \pm 0.00^{g,f}$	0.01	0.04
Liza abu (c)	48	Karkhe River	$0.02 \pm 0.00^{h,f,g}$	0.01	0.04
Cynoglossus arel (e)	48	Mahshahr Seaport	0.73 ± 0.07^{i}	0.55	0.90
Periophthalmus waltoni (e)	48	Mahshahr Seaport	$0.90 \pm 0.04^{j,b}$	0.80	1.00
Otolithes ruber (e)	48	Mahshahr Seaport	0.05 ± 0.01^{k}	0.03	0.06
Otolithes ruber (f)	48	Abadan Seaport	0.07 ± 0.01^{l}	0.06	0.09
WHO			0.1		WHO (1985)
FDA			0.2		Burger and Gochfeld (2005)
Australian Food Standards Code			1.0		NSW Health Department (2001)

[a,b,c,d,e,f,g,h,i,j,k,l] $P < 0.05$, significantly different in muscle of fish in freshwater and saltwater of Khouzestan

n number of sample

Table 2 Mercury levels (mg kg^{-1} wet weight) in liver of freshwater and saltwater fish

Species	*n*	Location	Mean ± SD	Min	Max
Barbus xanthopterus (a)	48	Karoon River	1.36 ± 0.35^{a}	0.81	1.92
Barbus xanthopterus (b)	48	Dez River	1.15 ± 0.14^{b}	0.80	1.49
Barbus grypus (a)	48	Karoon River	0.72 ± 0.01^{c}	0.44	1.00
Barbus grypus (c)	48	Karkhe River	0.23 ± 0.05^{d}	0.09	0.36
Liza abu (d)	48	Bahmanshir River	0.04 ± 0.00^{e}	0.01	0.06
Liza abu (a)	48	Karoon River	0.02 ± 0.00^{f,d}	0.01	0.03
Liza abu (b)	48	Dez River	0.02 ± 0.01^{g,d,e,f}	0.01	0.04
Liza abu (c)	48	Karkhe River	0.02 ± 0.01^{h,d,f,g}	0.01	0.04
Cynoglossus arel (e)	48	Mahshahr Seaport	0.65 ± 0.14^{i}	0.48	0.82
Periophthalmus waltoni (e)	48	Mahshahr Seaport	0.98 ± 0.11^{j}	0.73	1.01
Otolithes ruber (e)	48	Mahshahr Seaport	0.15 ± 0.05^{k}	0.07	0.19
Otolithes ruber (f)	48	Abadan Seaport	0.17 ± 0.07^{l}	0.08	0.22

^{a,b,c,d,e,f,g,h,i,j,k,l} $P < 0.05$, significantly different in liver of fish in freshwater and saltwater of Khouzestan

n number of sample

Liza abu in freshwater mercury levels were higher than saltwater species except for *Periophthalmus waltoni* from Mahshahr seaport in compare with *Barbus grypus* from Karoon River and *Cynoglossus arel*, *Periophthalmus waltoni* from Mahshahr seaport in comparision with *Barbus grypus* from Karkhe and *Liza abu* from Bahmanshir Rivers. Mercury levels in muscles of saltwater species were higher than *Liza abu* from Karoon, Dez and Karkhe Rivers.

Generally, in this research mercury levels have significant differences ($P < 0.05$) in muscles of fish between freshwater and saltwater except for *Barbus xanthopterus* in Dez River which did not have significant differences with *Periophthalmus waltoni* in Mahshahr seaport. Mercury levels in muscle of *Barbus xanthopterus* in Karoon and Dez Rivers were higher than other species in freshwater and *Barbus grypus* has high mercury levels in comparision with *Liza abu* except for *Barbus grypus* in Karkhe River which has lower mercury levels than *Liza abu* Bahmanshir River. The mercury levels in *Liza abu* in Dez and Karkhe Rivers were the same (0.02 mg kg^{-1}). In saltwater species, mercury level in muscle of *Periophthalmus waltoni* in Mahshahr Seaport was high in comparision with other saltwater species and mercury level in *Cynoglossus arel* in Mahshahr Seaport was higher than *Otolithes ruber* in Mahshahr and Abadan Seaports.

Mercury levels in liver of *Barbus xanthopterus* in Karoon and Dez Rivers were higher than other species in freshwater and *Barbus grypus* in Karoon and Karkhe Rivers has high mercury levels in comparision with *Liza abu* in Bahmanshir, Karoon, Dez and Karkhe Rivers. The mercury levels in *Liza abu* in Dez and Karkhe Rivers were the same (0.02 mg kg^{-1}). In saltwater species, mercury level in liver of *Periophthalmus waltoni* in Mahshahr Seaport was high in comparision with other saltwater species and mercury level in *Cynoglossus arel* in Mahshahr Seaport was higher than *Otolithes ruber* in Mahshahr and Abadan Seaports. In this research the results showed that the muscles of some commercial fish have higher levels of mercury than liver and in those muscle tissues were polluted in comparision with liver ($P < 0.05$). The levels of mercury in muscles of *Barbus grypus* in Karoon and Karkhe Rivers and in *Liza abu* in Bahmanshir and Karoon Rivers were higher than liver except for *Barbus xanthopterus* in Karoon and Dez Rivers that mercury levels in liver were higher than muscle and the mercury levels in *Liza abu* in Dez and Karkhe Rivers were the same (0.02 mg kg^{-1}) in muscle and liver. Mercury levels in liver of *Periophthalmus waltoni* in Mahshahr Seaport and *Otolithes ruber* in Mahshahr and Abadan Seaports were higher than muscle except for *Cynoglossus arel* in Mahshahr Seaport that mercury level in muscle was higher than liver.

Heavy metal concentrations varied significantly depending upon the type of fish tissues and locations. The comparison of mean concentrations of mercury in muscle and liver of freshwater and saltwater fish shows that the mercury levels of tissues are variable in fish (Canli and Atli 2003; Fernandes et al. 2007). The observed variability of heavy metal levels in different species depends on feeding habits (Romeoa et al. 1999), age, size and length of the fish and their habitats (Canli and Atli 2003). Concentrations of mercury detected in the muscle and liver samples showed different capacities for accumulating.

In general, the levels of mercury in the liver of *Barbus xanthopterus* in Karoon and Dez Rivers were higher than those found in the muscle. Havelkova et al. (2008) reported that the target organ for Hg accumulation in fish from heavily contaminated localities was the liver. The liver in fish is more often recommended as environmental indicator organ of water pollution than other fish organs (Karadede et al. 2004), it has the ability to accumulate large quantities of pollutants from the external environment and also plays an important role in storage, redistribution, detoxification and transformation of pollutants (Evans et al. 1993). The relatively high concentrations of heavy metals in liver were also found in different species of fish in Tigris River and Atatürk Dam Lake (Karadede and Ünlü 2000). Similarly to what we have said in relation to the liver, the mean mercury concentrations in the muscles of *Barbus grypus* and *Liza abu* were higher than those found in the liver. The high concentrations of mercury in muscles were also found in *Abramis brama* from the Western basin of Lake Balaton and in *Liza aurata* and *Solea vulgaris* from Southern Atlantic Coast of Spain (Farkas et al. 2003; Usero et al. 2003).

The metal concentration in muscle is important for the edible parts of the fish. Fish generally accumulate contaminants from aquatic environments, have been largely used in food safety studies. The maximum mercury level permitted in fish is 0.1 mg/kg for WHO (1985), 0.2 mg/kg for FDA (Burger and Gochfeld 2005) and 1.0 for Australian Food Standards Code (NSW Health 2001). Generally, mercury levels in analyzed fish samples were found to be higher than WHO and FDA legal limits (Table 1), except for *Liza abu* in Karoon, Dez and Karkhe Rivers and *Otolithes ruber* in Mahshahr and Abadan Seaports which mercury levels were lower than WHO and FDA legal limits. Mercury levels in commercial fish in Khouzestan were lower than Australian Food Standards Code except for *Barbus xanthopterus* in Karoon River which mercury level was higher than this legal limit. Contaminants in fish can pose a health risk to the fish themselves and to humans who consume them. Mercury toxicity cause growth deficits and affects fish organs. In humans, mercury is toxic to the developing fetus and considered a possible carcinogen (Ikem and Egilla 2008).

In the literature mercury levels in muscle and liver of fish samples have been reported as 0.10 and 0.09 mg kg^{-1} in *Abramis brama* from the Western basin of Lake Balaton, respectively (Farkas et al. 2003). Usero et al. (2003) found a mean mercury concentrations of 0.012 mg kg^{-1} in the liver and 0.013 and 0.014 mg kg^{-1} in the muscles of *Liza aurata* and *Solea vulgaris* from Southern Atlantic Coast of Spain. Also, the mean of mercury concentrations in muscle and liver of *Barbus grypus* and *Barbus xanthopterus* in Karoon and Dez Rivers in Khouzestan, Iran, were reported as: 0.73, 0.90; 0.79, 1.06 mg kg^{-1} and 1.28, 0.77; 1.42, 0.95 mg kg^{-1}respectively (Mohammadi et al. 2011).

The levels of mercury in Khouzestan fresh and saltwater resources in this study suggest that more extensive and intensive mercury monitoring of items consumed by humans combined with health directives are necessary to protect humans from mercury intoxication.

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