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Original Article

Bioaccumulation of heavy metals in eight fish species of the Khur-e Khuran International Wetland in the Persian Gulf, Iran

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Abstract: Heavy metals are among the most toxic pollutants in aquatic ecosystems. This study was conducted to evaluate the concentration of heavy metals viz. lead, cadmium, chromium, zinc, cobalt, and copper in eight commercial fishes of Khur-e Khuran international wetland (KIW), Iran. The results showed that the highest concentration of heavy metals attributed to Zn as 176.5 µg g^{-1} dry weight in *Platycephalus indicus* and the lowest to Pb as 0.12 µg g^{-1} dry weight in *Sillago sihama*. Average concentrations of heavy metals in eight examined fish species were 29.15, 49.73, 1.39, 0.45, 1.43 and 1.56 µg g^{-1} dry weight for Cu, Zn, Cd, Pb, Co and Cr, respectively. The results also show that measured values of most heavy metals in some examined fishes of KIW were higher than those maximum permissible limit (MPL) according to international standards. The high concentrations of some metals in some examined fishes of KIW may be due to industrial and residential activities in adjacent coast i.e. in mainland and Qeshm Island, and marine traffic

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Introduction

The importance of aquatic ecosystems is significant due to providing irreplaceable habitats for maintaining the biodiversity (MacFarlane and Burchettt, 2000). Therefore, knowledge on disturbances of these ecosystems is crucial for their protection (Storelli et al., 2005). In this regard, understanding the sources and concentrations of pollutants in aquatic environments and their effects requires their monitoring, and evaluation of contamination rate by analysis of water, sediment and organisms (Ochieng et al., 2007).

Heavy metals are persistent pollutants and due to the biological toxicity, are not biodegradable (de Mora et al., 2004). These elements enter into the aquatic environment from different sources such as municipal and industrial sewage, leaching and carrying toxic chemicals by water from lands, agricultural activities and atmospheric deposition (Sekhar et al., 2003). The amount of these pollutants is much higher in aquatic organisms than the surrounding environment due to accumulation and bio-magnification. Since, many marine species are consumed by human, therefor, knowing the normal levels of metals, or at least their regular concentrations in the marine environment is necessary to identify and evaluate heavy metals' pollution (Ruelas-Inzunza and Paez-Osuna, 2000; Castro-Gonzalez et al., 2008).

Aquatic organisms, especially fishes, are in the food basket of human as valuable protein source and it is estimated providing 15-20% of animal protein (FAO, 2010). However, aquatic organisms can be contained high levels of some heavy metals that may be risky for human consumption. Fish are relatively situated at the top of the aquatic food chain; therefore, they can accumulate heavy metals (Yilmaz et al., 2007; Vinodhini and Narayanan, 2008; Zhao et al., 2012); i.e. they generally have a large potential to accumulate biological environmental pollutants (Türkmen et al., 2009). Age, length, weight, sex, nutritional habits, ecological requirements, and

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seasonal changes in chemical properties of water such as salinity, hardness, temperature, concentration of heavy metals in water and sediment are among the effective factors in accumulation of heavy metals in different organs of fishes (Demirak et al., 2006). Therefore fishes are also used as a biological indicator to determine the effect of heavy metal pollution in aquatic ecosystems (Fernandes et al., 2008). In addition, fish species can be used to assess the health of aquatic ecosystems (Begüm et al., 2005).

Wetlands are ecologically important due to their hydrologic attributes and their role as an ecotone between terrestrial and aquatic ecosystems (Pascoe, 1993). There are three main sources of risk that are commonly considered in wetlands, including heavy metals and non-metal elements, such as Cd, Cr, Cu, Hg, Ni, Pb, Zn, As, Bo, and Se (Pollard et al., 2007; Nabulo et al., 2008; Bai et al., 2010); organic pollutants, such as oil compounds and pesticides (Ji et al., 2007; Rumbold et al., 2008; Gao et al., 2009), and natural parameters such as water availability and salinity (Speelmans et al., 2007; Sun et al., 2009; Xie et al., 2011).

Khur-e Khuran International Wetland (KIW) is a narrow strait separating the Qeshm Island from the Iranian mainland and it is one of the valuable coastal marine areas in the Persian Gulf. Many residents live on the coast of this wetland. The residents of the region are highly dependent on the marine environment and its resources, especially fishes. This wetland has high ecological importance as a unique aquatic ecosystems due to its shallow water and muddy bed that is suitable for spawning and rearing larva of many marine fishes. Therefore, this study aimed to evaluate the concentration of heavy metals in valuable commercial fishes of KIW.

Materials and Methods

Study area: KIW is located between 27-00 and 26-40 north latitude, 52-55 and 55-21 east longitude and between the Khamir Port and Qeshm Island in the southern coast of Iran (Fig. 1). The area now is protected as "Hara Protected Area" managed by the

Figure 1. Location of the Khur-e Khuran International Wetland.

Department of Environmental Protection of Hormozgan Province. A part of this coastal-marine region, the Hara protected area was registered in Ramsar Convention (1975) as Khur-e Khuran International Wetland including an area of 100000 hectares (HDE, 2001).

Sampling and Measurement: Three area in the Southern, Northern and Central parts of KIW was determined on 2010 TM satellite images as sampling stations. Then, samplings were performed by a motorized boats equipped to trawl, on January 2012. Among the 21 caught fish species, 8 species including *Lutjanus johni*, *Pomadasys furcatus*, *platycephalus indicus, Anodontostoma chacunda, Epinephelus coioides, Sillago sihama, Plectorhinchus pictus* and *Pampus argentus* were selected as valuable food fishes for further examinations.

In total 96 fishes, 12 specimens of each selected species, were collected and transferred to the laboratory, where the samples from their muscle were removed and dried in a freeze dryer (Alam et al., 2002). Then 8 ml nitric acid (65%) was added to1 gram of the dried muscle tissue of each sample and left in room temperature for initial digestion for 12 hours. For the final digestion, 3 ml of perchloric acid (70%) was added to each sample and put on a sand bath at 160°C based on Storelli and Marcotrigiano (2005). The obtained samples within each flask was then cooled in room temperature and diluted up to 25 ml with double distilled water. The diluted sample was filtered using 0.45 micrometers filter paper. The

Table 1. Average (±SD) concentrations of heavy metals in muscle of examined fish species (µg g^{-1} dry weight)

Species	Cr	Cu	Zn	Co	Cd	Pb
Pampus argentus	1.80±0.27	15.23±2.35	30.00±4.32	1.38±0.33	1.87±0.25	0.08±0.1
Sillago sihama	1.65±0.24	60.00±8.45	67.50±9.12	0.56±0.14	1.99±0.28	0.12±0.05
Pomadasys furcatus	1.15±0.19	4.88±0.98	24.42±5.17	1.01±0.19	0.75±0.16	0.45±0.09
Lutjanus johni	1.69±0.23	3.63±1.22	20.50±4.28	0.75±0.17	0.50±0.16	0.35±0.09
Epinephelus coioides	1.44±0.20	2.13±0.87	40.00±8.82	1.01±0.24	1.96±0.31	0.91±0.18
Plectorhinchus pictus	1.06±0.14	5.63±1.75	20.55±5.25	2.01±0.19	0.60±0.17	0.48±0.07
Anodontostoma chacunda	1.91±0.54	5.75±1.32)	18.35±4.93	1.05±0.20	0.58±0.13	0.76±0.12
platycephalus indicus	1.83±0.47	136.00±26.55	176.5±37.71	3.68±0.89	2.58±0.75	0.44±0.08

Table 2. The results of One-way ANOVA showing differences in heavy metals' concentrations between the examined species.

Metal	df	F	Sig.
Cr	7 48	462.784	0.000
Cu		62.288	0.000
Zn		124.312	0.000
Co		901.115	0.000
Cd		540.084	0.000
Pb		440.096	0.000

Table 3. Pearson correlation between the heavy metals values of the examined fishes.

	Cr	Cu	Zn	Co	Cd	Pb
Cr	1					
Cu	0.74	1				
Zn	0.47	-0.11	1			
Co	0.07	0.35	0.29	1		
Cd	0.73	0.47	0.38	0.82	1	
Pb	0.65	0.34	0.09	0.38	0.87	1

concentration of heavy metals, including Pb, Cd, Cr, Co, Cu and Zn were analyzed using graphite furnace atomic absorption spectrometer (ELMER PERKIN) model was used (MOOPAM, 1983). Standard reference material (DORM-2 National Research Council, Canada) was employed to control experiment quality and data validation, and measurements revealed 95% retrieval of all standard samples. Metal concentrations were expressed as µg g^{-1} of dry weight.

Statistical analysis: Data analysis was performed using SPSS 17. The mean of the heavy metals in fishes were compared using One-way ANOVA with significance level of 0.05. All data were tested for the homogeneity of variances and normality; the data which were not normally distributed or not homogeneous were transformed.

Results and Discussion

The concentration of heavy metals in examined species are presented in Table 1. The lowest and highest concentration of Cr were observed in *P. pictus* (1.06 µg g^{-1} dry weight) and *A. chacunda* (1.91 µg g^{-1} dry weight), respectively. The highest concentration of Cu was 136.00 µg g^{-1} dry weight in *P. indicus*, and the lowest as 2.13 µg g^{-1} dry weight in *E. coioides.* Maximum concentration of Zn was found in *P. indicus* (176.5 µg g^{-1} dry weight) and its minimum in *A. chacunda* (18.35 µg g^{-1} dry weight). The maximum and minimum concentration of Co was 3.68 and 0.56 µg g^{-1} dry weight in *P. indicus,* and *S. sihama*, respectively. The highest and lowest concentrations of Cd were found in *P. indicus* (2.58 µg g^{-1} dry weight) and *L. johni* (0.50 µg g^{-1} dry weight), respectively. In addition, Pb had the highest concentration in *E. coioides* (0.91 µg g^{-1} dry weight).

Accumulation patterns of all metals were significantly different ($P<0.05$) between the different species (Table 2). The correlation coefficients between heavy metals are shown in Table 3. A strong correlations were find between Cu/Cr, Cd/Cr, Cd/Co, pb/Cr and Pb/Cd. Order of the accumulated heavy metals in the muscle of studied fishes was as Pb < Cd < Cr < Co < Cu < Zn. The highest combined concentration of Zn, Cu, Cr, Co, Cd and Pb was recorded in *P. indicus* (176.50), *P. indicus* (136.00), *A. chacunda* (1.91), *P. indicus* (3.68), *P. indicus* (2.58) and *E. coioides* (0.91) µg g^{-1} dry weight, respectively. The combined average concentration of heavy metals in examined species

Table 4. Heavy metal concentrations in the muscle tissues from different regions of the world.

Reference	Cr	Cu	Zn	Co	Cd	Pb
	μg g-1 dry weight					
de Mora et al. (2004), Qatar coast	0.03	0.56	8.2	<0.005	0.013	0.113
de Mora et al. (2004),UAE coast	0.01	0.37	13.5	0.014	<0.001	0.025
de Mora et al. (2004), Bahrin coast	0.013	0.235	15.9	<0.01	0.001	0.028
de Mora et al. (2004), Oman coast	0.072	0.513	13.4	<0.05	<0.005	0.025
Oriyan et al. (2009) (*Pampus argentus*)	-	-	-	-	0.05	0.29
Askari Sari et al. (2011) (*Otolithes ruber*)	-	-	121.4	-	-	0.98
Askari Sari et al. (2011) (*Scomberomorus guttatus*)	-	-	33.7	-	-	0.41
Nabizadeh and Pourkhabbaz (2011) (*Sillago sihama*)	0.72	-	-	-	0.5	0.76
Nabizadeh and Pourkhabbaz (2011) (*platycephalus indicus*)	0.6	-	-	-	0.39	0.73
Gorur et al. (2012) (*Thunnus albacares*)	-	4.00	42.00	-	1.20	4.70
Khazaei et al. (2013) (*Pampus argentus*)	-	3.30	14.44	-	0.22	-
Elnabris et al. (2013) (8 commercially fishes)	-	2.62	2.90	-	2.73	2.78
El-Moselhy et al. (2014) (*Epinephelus* sp.)	-	0.29	2.42	-	0.12	0.88
El-Moselhy et al. (2014) (*Thunnus albacares*)	-	0.35	1.99	-	0.06	0.32
Khaled (2004) (*Siganus rivulatus*)	-	2.70	43.90	-	2.80	1.20
The present study	1.56	29.15	49.73	1.43	1.39	0.45

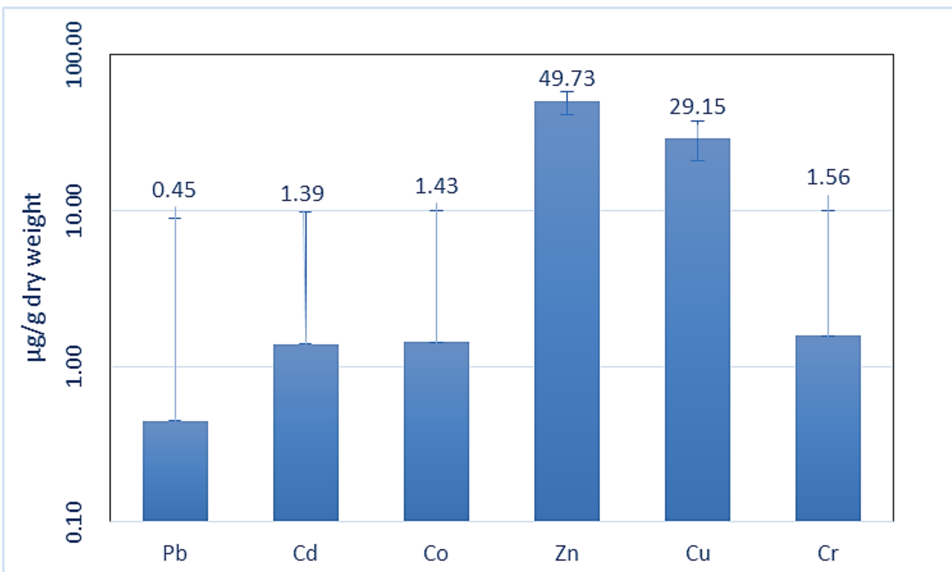

Figure 2. Average heavy metalS concentrations in 8 examined species fish Khur-e Khuran International Wetland.

are shown in Figure 2.

Table 4 shows heavy metal concentrations in the muscle tissues from different regions of the world. For example, Oriyan et al. (2011) reported the concentration of Pb in muscle tissues of *P. argentus* to be 0.3±0.29 ppm which is lower than the result of this study. Nabizadeh and Pourkhabbaz (2011) reported Cr concentration in *P. indicus* and *S. sihama* as 0.6 and 0.72 μg g^{-1}, whereas its concentration were 1.83 and 1.65 μg g^{-1} in the present study, respectively. Khazaei et al. (2013) reported the amount of Cu in muscles of *P. argentus* (3.30 ppm) that was more than that one in *E. coioides* (2.13 ppm) (Khazaei et al., 2013). In addition all reported values in de Mora et al. (2004) are lower than those obtained in the present study. Accumulation of heavy metals in living organisms is effected by absorption rate of metals and metabolism rate of the living organism. Difference in concentrations of heavy metals in fishes depends on a variety of factors such as feeding behavior (Obasohan and Oronsaye, 2004), distance to the pollution source (Barlas, 1999), age, length

Table 5. Maximum Permissible Limit (MPL) of heavy metals in fish muscles (mg g^{-1} wet weight) according to international standards.

Reference	Cr	Cu	Zn	Co	Cd	Pb
IAEA-407 (Wyse et al., 2003)	0.73	3.28	-	-	0.18	0.12
UNEP (1985)	-	-	-	-	0.3	0.3
FAO/WHO (1989)	-	30	40	-	0.5	0.5
MAFF (20)00 (England)	-	20	30	-	0.2	0.5
WHO(Cheung et al. (2008)	0.15	-	-	-	1	1
TFC (20)02	-	20	-	-	0.05	0.2
FDA (Chen and Chen, 2001)	-	-	-	-	0.1	0.5

and weight (Benson et al., 2007) and type of habitat (Saei-Dehkordi and Fallah, 2011).

Based on the results, the average concentration of Pb in the examined fishes (0.45 µg g^{-1} dry weight) was lower than standards of WHO (Cheung et al., 2008) and FDA (2001) and higher than those of IAEA-407, UNEP (1985) and TFC (2002) and for Cd with an average of 1.39 µg g^{-1} dry weight was more than the standards given in Table 5. IAEA-407 and WHO standards for Cr are 0.73 and 0.15 µg g^{-1} dry weight, respectively and its values in the examined fishes were less than these standards. In addition, Cu values obtained in the current study (29.15 µg g^{-1} dry weight) were less than of FAO/WHO standards. Finally, that of Zn was more than maximum permissible limit based in FAO/WHO (1989) and MAFF (2000) standards.

The results show that measured values of heavy metals in this study are higher than those maximum permissible limit (MPL) according to international standards (Table 5). The high concentrations of some metals in examined fishes of KIW may be due to industrial and residential activities in adjacent coast i.e. in the mainland and Qeshm Island, and marine traffic that directly influence coastal waters by releasing pollutants. Furthermore, benthic species have higher rate of heavy metal concentrations due to absorbing pollutants from sediments in addition to water column and food as seen in *P. indicus* in the present study.

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چکیده فارسی

تجمع فلزات سنگین در برخی از ماهیان تالاب بین المللی خورخوران در خلیج فارس، ایران

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چکیده:
فلزات سنگین جزو مهم‌ترین آلاینده‌های سمی در اکوسیستم‌های آبی هستند. این مطالعه به منظور ارزیابی غلظت فلزات سنگین سرب، کادمیوم، کرم، روی، کبالت و مس در ۸ گونه از ماهیان تجاری تالاب بین المللی خور خوران ایران انجام شد. نتایج نشان داد که در بین فلزات سنگین بیشترین غلظت مربوط به فلز روی با ۱۷۶/۵ میکروگرم در گرم وزن خشک در گونه *Platycephalus indicus* و کمترین غلظت مربوط به فلز سرب با ۰/۱۲ میکروگرم در گرم وزن خشک در گونه *Sillago sihama* می‌باشد. میانگین غلظت فلزات سنگین در هشت گونه مورد مطالعه برای مس، روی، کادمیوم، سرب، کبالت و کرم به ترتیب ۲۹/۱۵، ۴۹/۷۳، ۱/۳۹، ۰/۴۵، ۱/۴۳ و ۱/۵۶ میکروگرم در گرم وزن خشک بود. نتایج همچنین نشان می‌دهد که مقادیر اندازه‌گیری شده در اغلب فلزات سنگین در برخی ماهی‌های مورد مطالعه در تالاب بین المللی خورخوران با توجه به استانداردهای بین‌المللی بالاتر از حداکثر حد مجاز (MPL) بود. غلظت بالای برخی از فلزات در ماهی‌ها ممکن است ناشی از فعالیت‌های صنعتی و مسکونی همچنین ترددهای دریایی در سواحل مجاور در سرزمین اصلی و جزیره قشم باشد.
کلمات کلیدی: تجمع زیستی، خلیج فارس، تالاب، فلزات سنگین، خورخوران.