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Metal concentrations in fillet and gill of parrotfish (*Scarus ghobban)* from the Persian Gulf and implications for human health

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ABSTRACT

Despite the benefits of seafood's consumption, the bioaccumulation of metals in fish can endanger consumers' health. This study analyzed lead (Pb), mercury (Hg), Arsenic (As), and Cadmium (Cd) concentrations in fillet and gill of parrotfish (*Scarus ghobban*) using flame atomic adsorption spectroscopy (FAAS). The potential non-carcinogenic and carcinogenic health risks due to consumption of *Scarus ghobban* fillet were assessed by estimating average target hazard quotient (THQ) and total target hazard quotient (TTHQ) and Incremental Lifetime Cancer Risk cancer risk (ILCR) of the analyzed metals. This study indicated that Cd, Pb, As and Hg concentrations were significantly ($p < 0.05$) lower than Food and Agriculture Organization (FAO) and national standard limits. The meal concentrations (μg/kg dry weight) in both fillet and gill were ranked as follows Pb > Cd > As > Hg. THQ and TTHQ were lower than 1 for adults and children, indicating that consumers were not at considerable non-carcinogenic risk. However, ILCR value for As was greater than 10^{-4}, indicating that consumers are at carcinogenic risk. Overall, this research highlighted that although the consumption of parrotfish from the Persian Gulf does not pose non-carcinogenic health risks, carcinogenic risks derived from toxic As can be detrimental for local consumers.

1. Introduction

Seafood is a great source of many important minerals, vitamins, essential fatty acids (e.g., polyunsaturated omega-3 fatty acids), and proteins that decrease risk of heart diseases (Adel et al., 2016a; Longo et al., 2013; Miri et al., 2017; Bourre and Paquotte, 2008; Sikorski, 2012; Wall et al., 2010). However, higher concentration of inorganic (toxic metals and metalloids) (Fakhri et al., 2018a; Dadar et al., 2017; Shahsavani et al., 2017; Saha et al., 2016a, 2016b) and organic contaminants (Tierney et al., 2013) in seafood has raised concern for human health through their consumption. Contamination of seafood from metals has become a serious issue due to their stable, non-biodegradable, and longtime persistence in food chain (Adel et al., 2016b; Dadar et al., 2017; Ouédraogo et al., 2015; Seixas et al., 2014; Shahsavani et al., 2017; Zafarzadeh et al., 2017). Bioaccumulation of metals in fish influenced by their nutritional habits, ecological requirements, concentration of metals in water and sediments, fish's life, seasonal changes, and physicochemical properties of water (Fakhri et al., 2018b; Conte et al., 2015; Dadar et al., 2016; Başyiğit and Tekin-Özan, 2013; Malik et al., 2010). Among heavy metals, cadmium (Cd),

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lead (Pb), mercury (Hg), arsenic (As), copper (Cu) have higher potential to be accumulated in fish to concentrations above the standard limits (Bosch et al., 2016a, 2016b; Vandermeersch et al., 2015). Chronic and acute exposures to heavy metals can endanger human health (Fakhri et al., 2018c; Fathabad et al., 2018; Ghasemidehkordi et al., 2018; Adel et al., 2016a; Dórea, 2008; Copat et al., 2012). For example chronic exposure to Pb can cause cerebral diseases and gastrointestinal colitis (Flora et al., 2012), Cd can results in bone pain and cardiovascular diseases (Fagerberg et al., 2017; Kobayashi, 1978), Hg can impair the senses of hearing, touch and sight (Duruibe et al., 2007; Lohren et al., 2015).

More than 80 species of parrotfish are known in relatively shallow and subtropical oceans in the world. They show varying degrees of habitat preferences and utilize coral reef habitats. Some species spend majority of their life stages in coral reefs, while others use seagrass beds, algal beds and rocky reefs (Comeros-Raynal et al. 2012). Due to local and global anthropogenic pressures, parrotfish are losing their reef habits at an accelerated rate. Inshore coral reefs are more vulnerable to local environmental contamination due to their close proximity to the land and various contamination sources (Saha et al., 2016b). Since *Scarus ghobban* lives mostly near shallow shores they are more prone to bioaccumulation of contaminates such as heavy metals (Glynn et al., 2014). Although the consumption of various fish species, including *Scarus ghobban,* in Iran is gradually increasing, estimation of accumulated metal content in different fish organs and associated health risks through consumption of such fish are relatively underexamined. Therefore, it is highly essential to measure metal concentrations in fish to better inform the consumers regarding metal induced health risk (FAO, 2014). Hence, key objectives of this study were to assess the concentrations of four toxic metals (Cd, Pb, Hg, and As) in fillet and gill of *Scarus ghobban* from the Persian Gulf, and to estimate associated human health risks through their consumption.

2. Material and methods

2.1. Study area and sampling

This cross sectional study was performed in Hendijan beach of Khuzestan province, north of the Persian Gulf. The population of Hendijan (30°15′12.22″ N, 40°30′19.22″ E) is ∼50,000 and it has ∼90 km border with the Persian Gulf (Fig. 1). Sixty same-sized *Scarus ghobban* fish samples (harvested at 5 m depth of Hendijan beach) were purchased in 2013 (August to December). Approximately same size fish were selected for this study considering that fish length and weight has significant influence on metal accumulation (Eroğlu et al., 2017). Samples were collected in plastic bags containing ice powder and then transferred to the laboratory where they were kept at - 20 °C temperature until further processing and analysis.

2.2. Sample preparation and analysis

Fish samples were washed with distilled water and then 20 gm of gill tissue and 20 gm of fillet from each fish were removed. Gill and fillet tissues were dried in oven at 65 °C for 48 h. Average moisture content of fish tissue was 79%. One gm of dried gill and 1 gm of dried fillet for every fish sample were carefully weighed and digested with 4 ml of 30% H_2O_2 (Suprapur; Merck, Darmstadt, Germany), 5 ml of 68% HNO_3 (Suprapur; Romil Ltd., Cambridge, UK), and 1 ml of concentrated $HClO_4$ (Suprapur; Merck, Darmstadt, Germany). For measuring total Hg, solutions were additionally digested with 45 mg of V_2O_5 (Dadar et al., 2014). Then, the solutions were diluted with 50 ml of distilled water and 20 ml of 2% $K_2Cr_2O_7$. Digestion was carried out on a hotplate at 140 °C for ∼5 h until the solutions turned to white color. Digested Samples were filtered through 0.42 μm nitrocellulose membrane filter (Whatman's filter) and then diluted with distilled water to 1:5 ratio. Analyses of Cd, Pb and As were performed using flame atomic absorption spectrophotometry (Perkin-Elmer 4100 ZL) and total Hg with cold vapor generation method. The concentration of metals was reported on dry weight (d.w) basis. Overall recovery of Cd, Hg, Pb and As was 90%, 90%, 88%, and 93%, respectively. Limit of detection (LOD) for Cd, Hg, Pb and As were 0.006, 0.001, 0.005 and 0.003 mg/g, respectively. Wet weight was converted to dry weight using 79% moisture content (Saha et al., 2016a).

2.3. Non-carcinogenic risk assessment

Non-carcinogenic risk for the consumers of *Scarus ghobban* fish was estimated using Target Hazard Quotient (THQ) (equation (1))

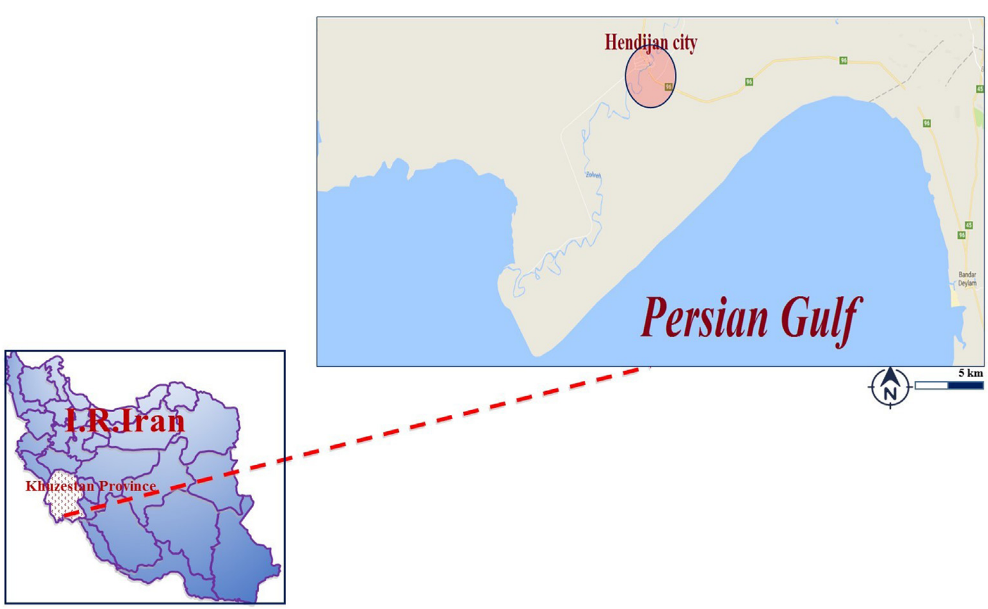

Fig. 1. Location of Hendijan city in the north of Persian Gulf.

Table 1
Statistics of metal concentrations (μg/kg. d.w) in fillet and gill of *Scarus ghobban* (n = 60).

	Fillet				Gill			
	As	Pb	Hg	Cd	As	Pb	Hg	Cd
Average	105.31	238.94	72.54	170.1	142.5	373.27	92.66	196.73
SD	30.21	101.26	20.16	50.33	60.24	108.36	52.37	80.63
Min	63.62	123.44	47.65	129.95	76.42	258.22	37.75	117.34
Max	139.32	341.33	98.11	211.21	211.64	492.33	134.56	271.43
Median	109.92	242.92	77.43	174.9	146.96	377.91	96.93	200.93

(Shahsavani et al., 2017; Heshmati et al., 2018):

$$THQ = (E_F \times E_D \times F_{IR} \times C_m \times 10^{-3}) / (RFD \times BW \times T_a) \quad (1)$$

E_F is the frequency of exposure (365 days in year), E_D is the exposure duration equivalent to an average life time of Iranian population (i.e.,70 years), F_{IR} is the per capita consumption of fish (g/person/day), C_m is the concentration of metal in the examined fish (mg/kg), RFD is the oral reference dose (mg/kg/day), BW is the body weight, T_a (= $E_F \times E_D$) is the exposure time for non-carcinogens. According USEPA, average body weights of adult and children are 60 and 15 kg, respectively (EPA, 1989). THQ less than 1 indicates that non-carcinogenic effects are very unlikely, while the value of THQ equal or greater than 1 indicates likelihood of non-carcinogenic risks (Abtahi et al., 2017; Adel et al., 2016a). RFD values for Cd, Pb, Hg and As (inorganic) were 0.001, 0.0005, 0.0003 and 0.0.003 (mg/kg-bw/day), respectively (EPA, 1993, 2000. According to Iranian fisheries organization, per capita fish consumption (F_{IR}) of Iranian adults (IFOSY, 2015) and children (Khoshnood et al., 2015) was estimated to 26.43 and 10.31 (assuming that children consumes 39% of adults) g/person/day, respectively.

In order to estimate the non-carcinogenic risks induced by four analyzed metals together, total target hazard quotient (TTHQ) was estimated using equation (2) below (Fakhri et al., 2017a; Shahsavani et al., 2017; Storelli, 2008; Zafarzadeh et al., 2017):

$$TTHQ = THQ_{Cd} + THQ_{Pb} + THQ_{Hg} + THQ_{As} \quad (2)$$

2.4. Carcinogenic risk assessment

Estimated daily intake (EDI) for As and Pb was estimated using equation (3) (USEPA, 2000b):

$$EDI = (F_{IR} \times C_m) / BW \quad (3)$$

EDI is the estimated daily intake of metals (mg/kg/day), F_{IR} is the per capita fish consumption (g/person/day), C_m is the metal concentration in *Scarus ghobban* fish (mg/kg, dry weight basis) and BW is the body weight (Kg).

The carcinogenic risk of As in the *Scarus ghobban* fish was calculated using Incremental Lifetime Cancer Risk (ILCR) (Cao et al., 2014; Dadar et al., 2017; Fakhri et al., 2017b; Sultana et al., 2017):

$$ILCR = EDI \times CSF \quad (4)$$

EDI is the estimated daily intake (mg/kg/day) and CSF is the cancer slope factor. The values of CSF for As is 1.5 $(mg/kg/day)^{-1}$ (OEHHA, 2009). ILCR is the probability of lifetime human health risks from exposure to carcinogenic metals (Pepper et al., 2012). The acceptable ILCR value for regulatory purposes is between 10^{-6} and 10^{-4} (Li et al., 2013).

2.5. Statistical analysis

To determine normality of obtained data Kolmogorov–Smirnov test was used. Comparison of measured metal concentrations with standard limits was performed using one sample *t*-test. Metal concentrations between fillet and gill were compared using independent sample *t*-test. ANOVA (LSD) test was performed to statistically compare the metal concentrations among fish samples. Statistical significance was considered at $p < 0.05$. All statistical tests were performed using IBM SPSS Statistics 23.0 (IBM Corporation, Armonk, NY).

3. Results and discussion

3.1. Concentration of metals in fish organs

Determination of fish accumulated metals can be used as an indicator of environmental contaminants and health risks for consumers. Bioaccumulation of metals in fish depends on their lifetime, habitat, trophic levels, and chemical characteristic of contaminants (Lopez et al., 2013; Teffer et al., 2014; Jayapal et al., 2017). Average length and weight of the examined *Scarus ghobban* were 53 ± 5 cm and 1350 gr, respectively. The metals concentration measured in the edible fillet and gill tissue of *Scarus ghobban* are presented in Table 1. Concentrations of metals in the fillet tissue were significantly ($p < 0.05$) lower than the limits recommended by FAO (WHO, 2004) and national standard (ISIRI, 2009) (Fig. 2). The ranking order of metals based on their concentrations (μg/kg dry weight) in fillet were Pb (238.94 ± 101.26 μg/kg) > Cd (170.1 ± 50.33 μg/kg) > As (105.31 ± 30.21 μg/kg) > Hg (72.54 ± 20.16 μg/kg) and in gill were Pb (373.27 ± 108.36 μg/kg) > Cd (196.73 ± 80.63 μg/kg) > As (142.5 ± 60.24 μg/kg) > Hg (92.66 ± 52.37 μg/kg) (Table 1). The gill samples concentrated 1.35, 1.52, 1.27 and 1.15 times higher As, Pb, Hg and Cd, respectively, than the fillet samples. Similarly, Dobaradaran et al. (2010), Copat et al. (2013) and Elias et al. (2014) reported higher bioaccumulation of heavy metals in gill relative to other tissues. Our data showed that concentration of Pb in both gill and fillet was significantly higher than other examined metals, which may be due to the fact that Cd, Hg, and As can enter into fish through food ingestion (Dobaradaran et al., 2010) while the pathway for Pb involves both food ingestion and gill (Meng et al., 2014; Taweel et al., 2013). Additionally, the concentration of Pb in water and sediment in the Persian Gulf was higher than Cd, Hg and As (Pejman et al., 2017; Sharifinia et al., 2018; Zarezadeh et al., 2017). Therefore, relatively higher concentration of Pb is expected. Metal concentrations in fillet (except Hg and Cd) and gill were significantly ($p < 0.05$) different (Table 2). Pearson correlation statistics showed that metals in both fillet and gills were positively correlated, but the relationships were insignificant ($p > 0.05$) (Table 3). However, Cd–Pb relationship for fillet and gill was significantly ($p < 0.05$) negative (Table 3).

El-Moselhy et al. (2014) measured concentration of Pb and Cd in fillet (166.1 ± 71 and 23.7 ± 7.9 μg/kg d.w. respectively) and gill (1216.6 ± 466.1 and 205.2 ± 63.2 μg/kg d.w., respectively) of Parrotfish (*Scarus gibbus*) from the Red Sea, Egypt. In accordance with our study, concentrations of Pb and Cd in the gill were higher than fillet. However, their reported concentrations in fillet were lower than this study, but in gill were relatively higher (El-Moselhy et al., 2014). El Shehawy et al. (2016) determined concentrations of Pb (940 ± 240 μg/kg d.w.) and Cd (540 ± 240 μg/kg d.w.) in fillet tissue of rusty parrotfish (*Scarus ferrugineus*) in Makkah central fish market,

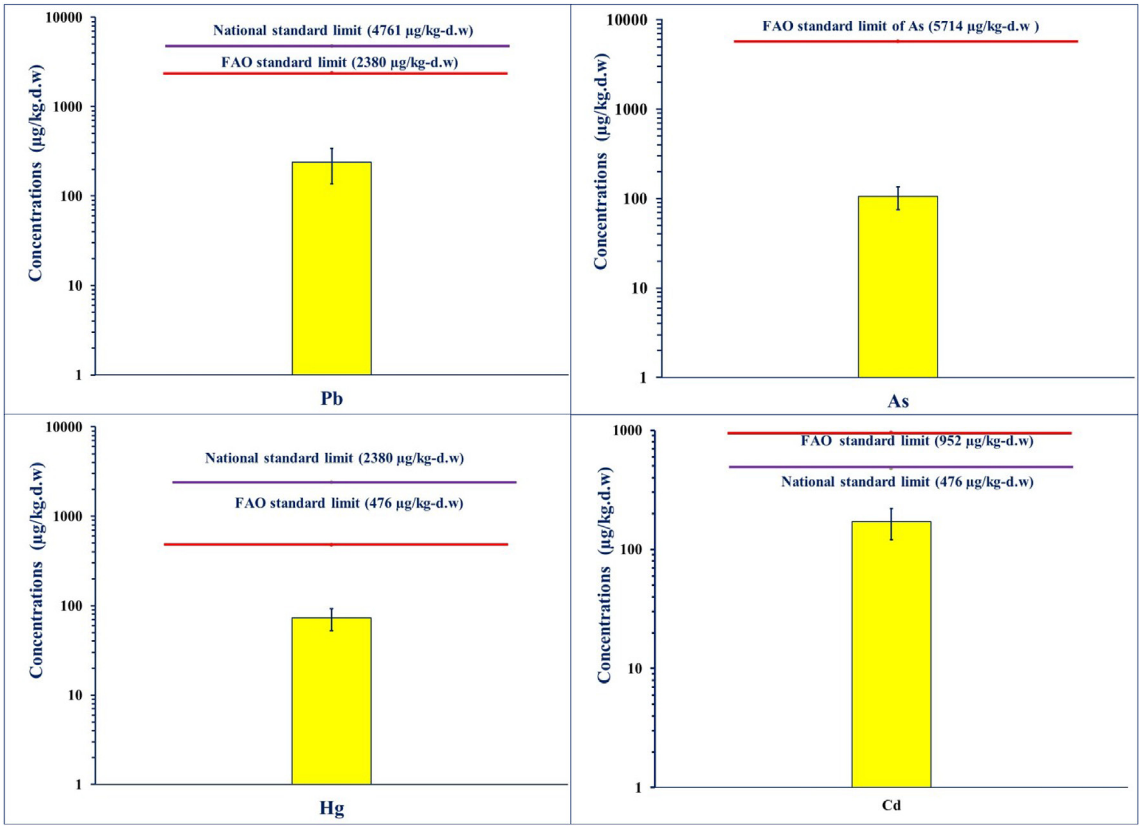

Fig. 2. Comparison of metal concentrations in fillet with FAO and national standard limits.

Table 2
Results of ANOVA (LSD) test for metal concentration differences in fillet and gill of *Scarus ghobban*.

Tissue	Metals		*p* value
Fillet	As	Pb	0.0000
		Hg	0.0000
		Cd	0.0000
	Pb	Hg	0.0000
	Pb	Cd	0.0000
	Hg	Cd	0.6745
Gill	As	Pb	0.0000
		Hg	0.0001
		Cd	0.0006
	Pb	Hg	0.0000
	Pb	Cd	0.0000
	Hg	Cd	0.0000

Saudi Arabia and their reported concentrations were higher than this study.

3.2. Health risk assessment

3.2.1. Non-carcinogenic risk

Considering average concentrations of metals, estimated THQ of As, Pb, Hg, and Cd for adult consumers were 0.006, 0.077, 0.039 and 0.027, respectively and for children were 0.009, 0.12, 0.061 and 0.043, respectively (Fig. 3). Considering maximum metal concentrations, THQ of As, Pb, Hg, and Cd for adult were 0.007, 0.11, 0.053 and 0.034, respectively and for children were 0.012, 0.171, 0.082 and 0.053, respectively (Fig. 3). In each case, THQ values were < 1 for both adult and children, implying no non-carcinogenic health threats for the consumers. TTHQ for adults and children based on maximum metal concentrations were 0.204 and 0.318, and based on average metal concentrations were 0.149 and 0.233 (Fig. 4). Hence, no adverse non-carcinogenic health effect is expected for the consumers. THQ and TTHQ values for children were 1.55 times higher than adults.

Table 3
Pearson correlation coefficients among metals in the fillet and gill of *Scarus ghobban*.

Tissue		As	Pb	Hg	Cd
Fillet	As	1.00			
	Pb	0.02	1.00		
	Hg	0.03	0.09	1.00	
	Cd	0.13	−0.10	0.20	1.00
Gill	As	1.00			
	Pb	−0.01	1.00		
	Hg	0.19	0.00	1.00	
	Cd	0.12	−0.26	0.39	1.00

3.2.2. Carcinogenic risk

As, Pb and Cd are classified as carcinogens by International Agency for Research on Cancer (IARC) (IARC, 2002). As the CSF value for oral

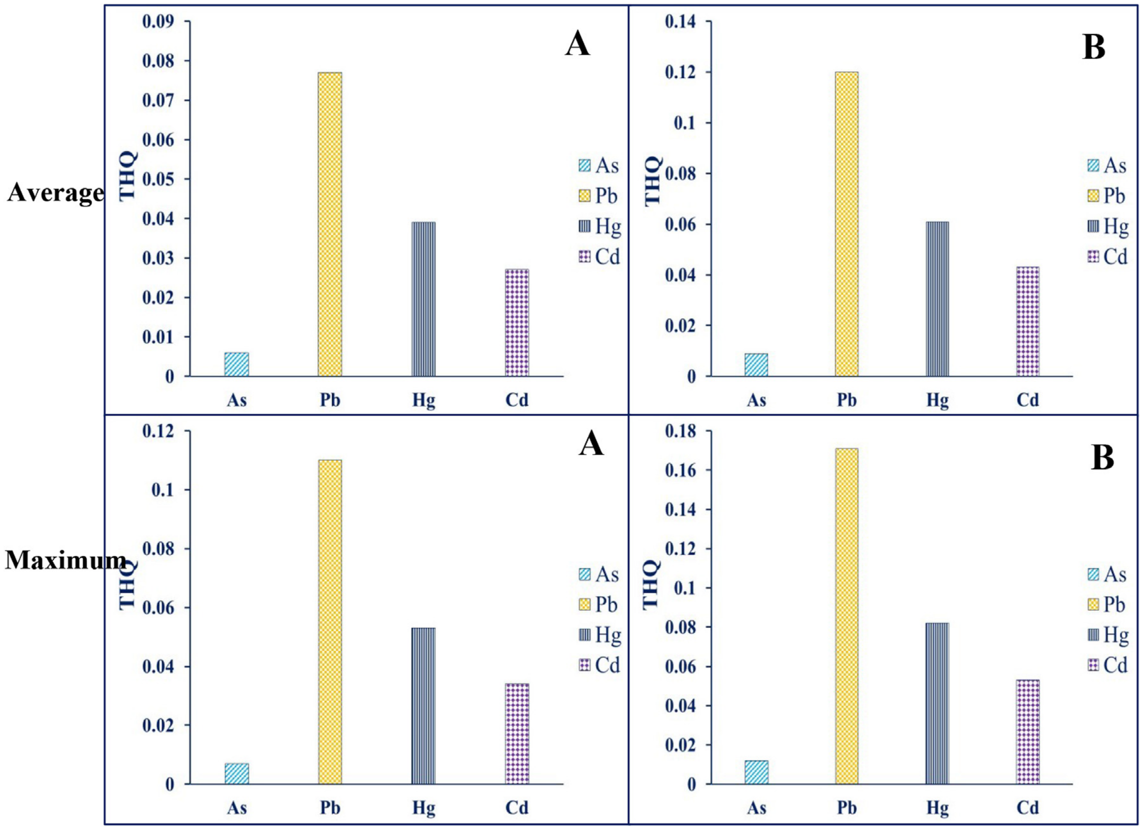

Fig. 3. THQ induced to average and maximum metals concentrations in the fillets of Scarus ghobban content in the adults and children.

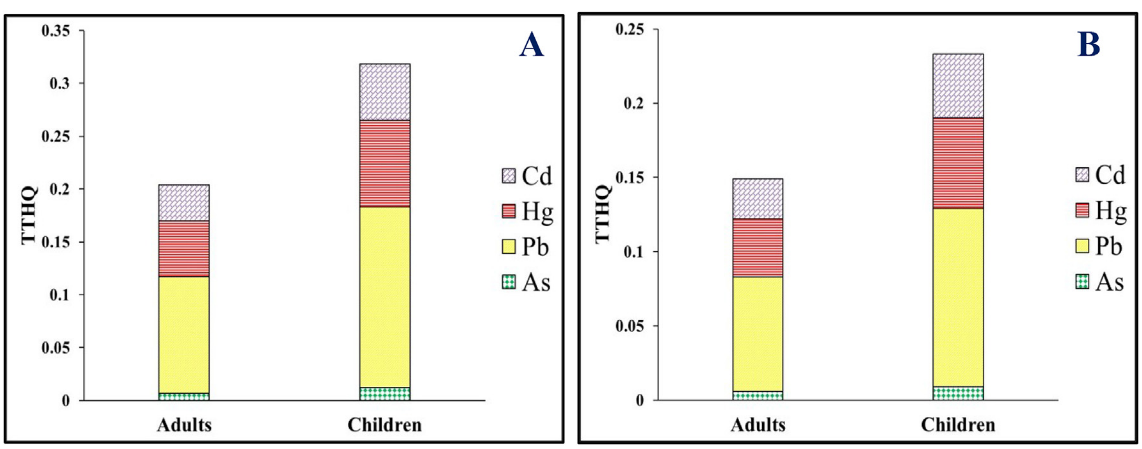

Fig. 4. TTHQ in adult and children consumers based on maximum (A) and average (B) concentration of metals in Scarus ghobban.

cancer risk of Cd is not available, it was excluded from cancer risk assessment. Considering maximum concentrations of As, ILCR for adults were 9.18E-05 and 1.28E-06, and for children were 3.67E-04 and 5.11E-06, respectively (Fig. 5 A). Considering average concentrations of As, ILCR for adults and children were 6.96E-05 and 2.78E-04, respectively (Fig. 5 B). Since Body weight of children were lower than adult, ILCR for children was higher than adults (EPA, 2017; USEPA, 2000a, 2016). Values of ILCR $< 10^{-6}$, $> 10^{-4}$ and $> 10^{-3}$ represent safe limit, threshold risk and considerable cancer risk for the consumers, respectively (EPA, 2017; USEPA, 2000a, 2016). Our results showed that ILCR values of As did exceed threshold limit for both adults and children (Fig. 5A and B).

4. Conclusions

This study determined concentration of four metals, including As, Cd, Hg and Pb, in fillet and gill of parrotfish (*Scarus ghobban)* from the Persian Gulf, Iran. Concentrations of Pb were higher in both fillet and gill, whereas concentrations of Hg were the least. Analyzed metal concentrations were significantly ($p < 0.05$) lower than the FAO recommended and national standard limits. More metals accumulation were recorded in gill compared to fillet. No significant correlation among metals was observed in the both fillet and gill ($p > 0.05$). THQ and TTHQ values for fillet of *Scarus ghobban* were lower than 1 for both adults and children, indicating no considerable non-carcinogenic risk.

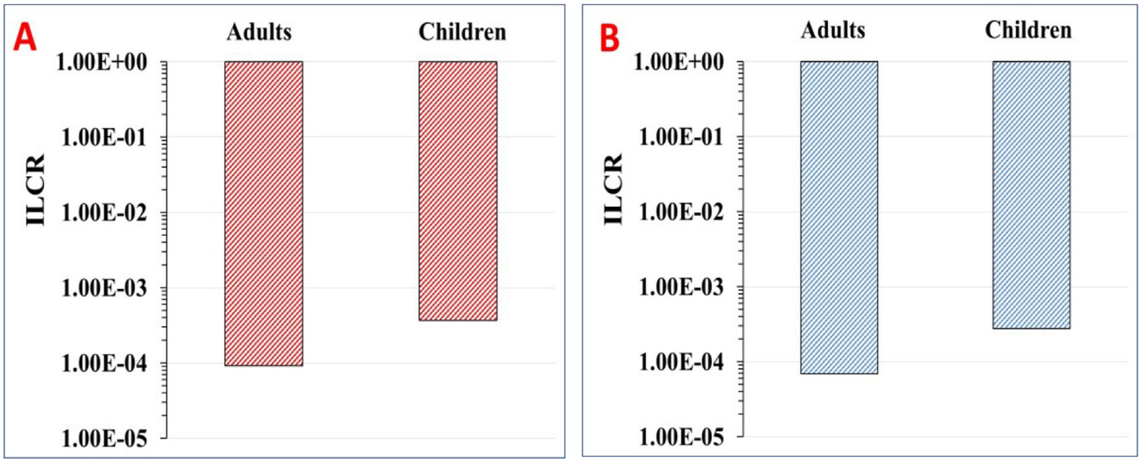

Fig. 5. ILCR in adult and children consumers based on maximum (A) and average (B) concentration of metals in Scarus ghobban.

On the contrary, ILCR values for adults and children indicated that they were at threshold carcinogenic risk (i.e.,10^{-4}). This study also highlighted that children are at higher non-carcinogenic and carcinogenic risks than adults in Hendijan, Iran. Hence, to protect the consumers from health risks through seafood consumption, the release of deadly toxic metals to water environment should be controlled and consistently monitored.

Declaration of interest

There is no conflict of interest.

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Transparency document

Transparency document related to this article can be found online at http://dx.doi.org/10.1016/j.fct.2018.05.041.

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