*Pollution, 6(4): 849-862, Autumn 2020*
DOI: 10.22059/poll.2020.302068.798
Print ISSN: 2383-451X Online ISSN: 2383-4501
Web Page: https://jpoll.ut.ac.ir, Email: jpoll@ut.ac.ir

# Evaluating the Accumulation and Consumption Hazard Risk of Heavy Metals in the Fish Muscles of Species Living in the Waters of the Persian Gulf, Iran

**Norouzi, M.*[*]***

Department of Biology, Faculty of Marine Biology, Tonekabon Branch, Islamic Azad University, P.O.Box 46817, Tonekabon, Iran

Received: 05.02.2020 Accepted: 01.07.2020

**ABSTRACT:** The aim of this study was to determine the levels of Cd, As, Hg, Pb, and Cr in the edible part of eleven most consumed fish species collected from the north-east coast of Persian Gulf, Iran, during 2017. An inductively coupled plasma atomic emission spectroscopy (ICP-AES) instrument was used to measure the concentration of heavy metals. The results were compared within acceptable limits for human consumption set by various health institutions. The order of heavy metals about total accumulation was Cr>As>Pb> Cd> Hg. The mean heavy metals concentrations of fish species muscle decreased in the order of Acanthopagrus latus> Planiliza subviridis> Lutjanus lemniscatus > Alectis indica> Epinephelus areolatus> Otolithes ruber> Epinephelus chlorostigma> Lethrinus crocineus> Euryglossa orientalis > Cynoglossus arel > Grammoplites suppositus. Probably the difference in the concentration of metals between samples depends on fish species, diet, and habitat. These species were declared to exhibit a low probability of causing non-cancerous diseases. The comparison of the accumulation and hazard risk of consuming the five heavy metals existing in the eleven species that were sampled from the coasts of Khuzestan, Maah-shar Harbour, with the WHO and USEPA guidelines showed that although consuming these fish species does not threaten the consumers' health, pregnant women and children should be cautious about consuming them. The HI was calculated for 70 kg body weight of adults and 14.5 kg body weight of children. The amount of optimal consumption is different for different weights of consumers.

**Keywords:** Fish consumption, risk assessment, toxic elements, Persian Gulf.

## INTRODUCTION

Aquatic animals are so important to human diet. However, aquatic animals can carry hazardous amounts of the metals that threaten the health of both aquatic species and the human consuming them. Fishes from the coasts of the Persian Gulf, where growing industrial and refinery activities and population growth in countries surrounded the waters have resulted a considerable increase of heavy metal content and various contaminants in its aquatic ecosystems (Keshavarzi et al., 2018).

Though contamination of the Persian Gulf by different environmental pollutants is concerned, few studies have investigated the risk of consuming these fishes with respect to heavy metals. Among various heavy metals and fish species, the hazard of some heavy metals on *Oreochromis niloticus* (Tayebi & Sobhanardakani, 2020), *Otolithes ruber* (Sadeghi et al., 2019; Mardoukhi et al., 2013), *Acanthopagrus latus* (Koshafar &

[*] Corresponding Author, Email: mnoroozi@toniau.ac.ir

Velayatzadeh 2016), *Carcharhinus dussumieri* (Adel et al., 2016) and some other species (Keshavarzi et al., 2018; Shahri et al.,2017; Askary sary & Karimi, 2017; Malakootian et al., 2016; Khoshnood & Khoshnood, 2013; Abdolahpur Monikh et al., 2013), and have reported in the other parts of the world and Iran (Liua et al., 2019; Varol & Sünbül**,** 2018; Jiang et al., 2018; Genc & Yilmaz, 2018; Alipour & Banagar, 2018; Łuczyńska et al., 2018; Gu et al., 2017; Moslen & Miebaka, 2017; Zhang et al., 2017; Kawser Ahmed et al., 2016; Çulha et al., 2016; Nasrabadi et al., 2015; Nasrabadi & Bidabadi, 2013). Some studies have shown that the hazard index (HI) of mercury is lower than 1 for all examined species in Persian Gulf except *Otolithes ruber* (Mardoukhi et al., 2013).

Khuzestan province coastal waters, Persian Gulf is an area where there are many petrochemical plants, Oil tanker traffic, agricultural runoff and household wastewater, one of Iran's most polluted coastal waters. Due to the presence of semi-closed estuary, the pollutant removal time is relatively long and this trend will subsequently increase amount of pollution in the region. On the other hand, the estuaries and their tributaries are important areas for the fishing industry in the region. Popular and commercial fish in these estuaries are consumed by locals. Since a potential contaminant source (a petrochemical complex) is located near a major fishery harbor in the study area, the present study was performed.

This research aims to quantify and measure the lead, cadmium, mercury, chromium and arsenic accumulation in the muscles of eleven fish species of Khuzestan province coastal waters. Besides, their economic value and popularity, these eleven species were chosen due to their diet and habitat roles. The selected species were members of the coastal carnivorous and omnivorous fish families. This study compares the heavy metal levels with the global standards announced by the United States Environmental Protection Agency (USEPA), and World Health Organization (WHO). Moreover, relationships between tissue metal contents and fish size, the daily and weekly intake amounts for children and adults as well as their permissible level of consumption are calculated. In addition, the risks of hazards of consuming these fish species are evaluated with respect to their potential of causing non-cancerous diseases and compared with the standards set by WHO.

## MATERIAL AND METHODS

These eleven species were different diet and habitat. The selected species were members of the coastal carnivorous (*Otolithes ruber*, *Lethrinus crocineus*, *Alectis indica*), coastal demersal carnivorous (*Euryglossa orientalis*), demersal carnivorous (*Cynoglossus arel*, *Grammoplites suppositus*, *Acanthopagrus latus*, *Epinephelus areolatus*, *Epinephelus chlorostigma*, *Lutjanus lemniscatus*), and coastal omnivorous (*Planiliza subviridis*) fish families (Sadeghi, 2001) (Table, 1).

Maah-shar Harbour is located in the south of the Khuzestan province, Iran (49°13' and 30°33'). Fish species were caught by trawlers from the coasts of Maah-shar Harbour. Due to the fact that the studied samples were chosen among edible fish species with weights that are mostly demanded by the market, the relationship between the length and weight indices and the amounts of metals aggregated in the species were taken into consideration. The samples were identified according to identification (Sadeghi, 2001). After that, the fish species were frozen at -20 °C. In total, 66 fish belonging to 11 species were caught, frozen and transferred to the Laboratory of Fishery Researches. One day prior to the experiments, the required samples were removed from the freezer and placed in a refrigerator to unfreeze them gradually. After unfreezing, the samples were completely rinsed with distilled water to remove their mucosal membranes that had absorbed the metals from the surface of their bodies. Then, the extra water was discharged and all samples were subjected to bioassay. In order to carry out the chemical digestion experiments, 10 g wet muscle tissue was separated from each fish and put in a flask containing 5 ml hydrogen peroxide and nitric acid (65%) with a 1 to 3 ratio. The flask was placed in a heater digesting machine for 5 h at the maximum temperature of 140 $^{oC}$. In the next step, the transparent solution that was resulted from the digestion process was filtered using a number one Whatman paper and the volume of the filtered solution was increased to 5 ml using distilled water. Then, the solution was transferred to a digestion tube (Lakshmanan et al., 2009; MOOPAM, 2010). Finally, an inductively coupled plasma atomic emission spectroscopy (ICP-AES) instrument was used to measure the concentration of the heavy metals. For fish samples, the limits of detection (LOD, mg/kg wet weight) were the following: Cr 0.005, As 0.003, Cd 0.001, Pb 0.005, and Hg 0.001.

**Table 1. The name, habitat, feeding mode and size of the analyzed fish species.**

| | Family, Fish species, Common name | Habitat; Favorable diet | Total length | Total weight |
|---|---|---|---|---|
| 1 | Carangidae, *Alectis indica,* Indian thread fish | coastal waters; fishes, squids, and crustaceans | 47.33 ±0.57 | 1203.33 ±32.14 |
| 2 | Serranidae, *Epinephelus chlorostigma,* Brownspotted grouper | Bottoms; fishes and crustaceans | 44.66±0.28 | 1041.66 ±36.85 |
| 3 | Lutjanidae, *Lutjanus lemniscatus,* Yellowstreaked snapper | offshore reefs and muddy habitats; Fishes, benthic invertebrates | 39.66 ±0.28 | 966.66±7.63 |
| 4 | Serranidae, *Epinephelus areolatus,* Areolate grouper | shallow waters; Zoobenthos, benthic invertebrates | 35.33 ±0.28 | 764±56.95 |
| 5 | Sparidae, *Acanthopagrus latus,* Yellowfin seabream | shallow c.w.; Zoobenthos, benthic invertebrates | 32.96 ±1.55 | 633.33 ±45.88 |
| 6 | Sciaenidae, *Otolithes ruber,* Tigertooth croaker | Amphidromous, Benthopelagic c.w.; fishes, invertebrates | 30 ±2.38 | 666.66±38.79 |
| 7 | Lethrinidae, *Lethrinus crocineus*, Yellowtail emperor | c.w.; fish, benthic invertebrates | 29.60±0.4 | 890.26±20.06* |
| 8 | Soleidae, *Euryglossa orientalis,* Oriental sole | shallow c.w.; bottom invertebrates | 29.5±3.14 | 550±164.27 |
| 9 | Cynoglossidae, *Cynoglossus arel,* Largescale tonguesole | Bottoms; bottom-living invertebrates | 24.4 ±1.45 | 672.54 ±156.84 |
| 10 | Platycephalidae, *Grammoplites suppositus,* Spotfin flathead | Bottoms; Zooplankton, zoobenthos Detritus | 37.63 ±4.11 | 616.66±54.01 |
| 11 | Mugilidae, *Planiliza subviridis*, Greenback mullet | shallow c.w.; algae, diatoms and benthic detrital material | 26.82 ±0.64 | 580.35±50.22 |

Note: coastal waters (c.w.).

The Eq. 1 was used to obtain the correction factor for converting dry weight to wet weight. Since about 80 wt.% of fish is water (FAO, 2009), the dry weight of the fish samples was calculated by multiplying their wet weight in CF = 0.2 (UNEP, 1984).

CF=1 - (the amount of moisture in the fish's muscle/100) (1)

Following the method proposed by the United States Environmental Protection Agency, Eqs. 2 and 3 were used to estimate the daily intake (EDI) and weekly intake (EWI) in adults and children regardless of sex of each heavy metal through consumption of each type of fish.

$$\mathrm{EDI} = \frac{C \times \mathrm{MS_D}}{BW} \tag{2}$$

$$\mathrm{EWI} = \frac{C \times \mathrm{MS_w}}{BW} \tag{3}$$

EDI: daily amount of metal intake through fish consumption (μg/g bw/day), EWI: weekly amount of metal intake through fish consumption (μg/g bw per week), C: metal concentration in the muscle tissue of the consumed fish (μg/g), $MS_D$ = Rate of daily fish consumption (32.57 g/day according to the EPA standard), $MS_W$= Rate of weekly fish consumption (228.00 g week[1] according to the EPA standard); Body weight (adults: 70 kg, children: 14.5 kg).

The method recommended by USEPA (USEPA, 2000) was adopted to determine the permissible limit of fish consumption. In this method, the metal levels of the edible fish tissues and the Reference Dosages (RfD) can be implemented in Eq. 4 to calculate the permissible amount of fish consumption in a certain period of time. The RfD values of the studied metals were considered as 0.0035 for lead, 0.001 for cadmium, 0.0001 for mercury, 0.005 for chromium (USEPA, 2000) and 0.003 for arsenic (USEPA, 2002). Eq. 5 was used to calculate the permissible frequency of fish consumption.

$$\mathrm{CR}_{\mathrm{lim}} = \frac{\mathrm{RfD} \times \mathrm{BW}}{C} \times 7 \qquad (4)$$

$Cr_{lim}$ - Permissible limit of fish consumption (kg/day), BW - Body weight (adults: 70 kg, children: 14.5 kg), RfD - Reference dose (μg/g bw/day).

$$\mathrm{CR}_{\mathrm{mm}} = \frac{\mathrm{CRlim} \times \mathrm{Tap}}{\mathrm{MS}} \qquad (5)$$

$CR_{mm}$ - Permissible frequency of fish consumption (times per month), MS - Amount of each meal (adults: 227 g, children: 114 g), $T_{ap}$ - Average time period (4.3 weeks per month)

It should be noted that calculation of Target Hazard Quotients (THQ) index requires considering the default amount of the metal assimilated by the body (EPA, 1989) and the fact that cooking does not affect the level of the contaminants (Cooper et al., 1991). According to this index, if the resultant ratio be lower than 1 indicating that consuming the studied aquatic animal has no harmful effect on its consumers. The total hazard index was calculated by summing up the risks related to the 15 metals, based on Eq. 7 (Chien, 2002).

$$\mathrm{THQ} = \frac{EF \times ED \times IR \times C}{BW \times RfD \times AT} \qquad (6)$$

THQ - Target Hazard Quotients, EF - Encounter (exposure) frequency during the 365 days of a year, ED - Total encounter (exposure) time in 70 years, IR - Daily rate of fish consumptioning fish; (32.5 g/day according to the EPA standard), AT - Average exposure time (365 days × 70 years = 25550 days).

$$\text{Hazard Index}\,(\mathrm{HI}) = \Sigma \mathrm{THQ} \qquad (7)$$

The Kolmogorov-Smirnov test was used to assess the normality of the data. Correlation between trace elements uptake with standard length and weight was investigated by Pearson correlation by the SPSS 20 software. Moreover, EXCEL 2007 was used to draw the graphs at a 95% confidence level.

## RESULTS AND DISCUSSION

According to the ANOVA results, the observed difference *heavy metals accumulation in fish species* is statistically significant ($p<0.05$) and the highest and lowest heavy metal levels refer to Pb in *P. subviridis* (0.021±0.001 μg/g) and *C. arel* (0.0027±0.0006 μg/g), Cd in *E. areolatus* (0.0114±0.0024 μg/g) and *G. suppositus* (0.0003±0.000 μg/g), Hg in *E. chlorostima* (0.0014±0.0001 μg/g) and *L. lemniscatus* (0.0003±0.000 μg/g), Cr in *A. latus* (0.19±0.009 μg/g) and *P. subviridis* (0.037±0.001 μg/g) and As in *P. subviridis* (0.143±0.006 μg/g) and *G. suppositus* (0.001±0.000 μg/g), respectively (Table 2). Generally speaking, the following order of heavy metal aggregation was detected in the muscle tissues of the studied fish samples: Cr>As> Pb>Cd>Hg.

**Table 2. Amount of the permissible heavy metal intake according to the international standards and the amount of intake for the 5 metals (µg/g wet weight) and average± standard deviation**

| fish species | Pb | Cd | Hg | Cr | As |
|---|---|---|---|---|---|
| *L. crocineus* | 0.003±0.0005 | 0.0005±0.0001 | 0.0008±0.0002 | 0.0796±0.01 | 0.007±0.0015 |
| *P. subviridis* | 0.021±0.001 | 0.0021±0.0024 | 0.0008±0.0001 | 0.0374±0.0014 | 0.143±0.006 |
| *E. orientalis* | 0.0028±0.001 | 0.0003±0.0001 | 0.0008±0.0001 | 0.0513±0.008 | 0.0036±0.006 |
| *C. arel* | 0.0027±0.0006 | 0.0004±0.0001 | 0.0009±0.0001 | 0.0467±0.008 | 0.006±0.0005 |
| *G. suppositus* | 0.003±0.0005 | 0.0003±0.000 | 0.001±0.0001 | 0.0498±0.004 | 0.001±0.0003 |
| *O. ruber* | 0.014±0.0025 | 0.0064±0.0017 | 0.0007±0.0001 | 0.146±0.0052 | 0.0067±0.0008 |
| *A. latus* | 0.016±0.001 | 0.0084±0.0015 | 0.0008±0.0001 | 0.19±0.0094 | 0.0072±0.0006 |
| *E. areolatus* | 0.0078±0.0098 | 0.0114±0.0024 | 0.0011±0.0001 | 0.156±0.015 | 0.0084±0.0005 |
| *E. chlorostima* | 0.0026±0.0002 | 0.0046±0.0011 | 0.0014±0.0001 | 0.12±0.02 | 0.0022±0.0003 |
| *A. indica* | 0.0032±0.0002 | 0.007±0.001 | 0.0003±0.0004 | 0.174±0.0183 | 0.0027±0.0003 |
| *L. lemniscatus* | 0.0035±0.0003 | 0.0095±0.0005 | 0.0003±0.000 | 0.18±0.017 | 0.0018±0.0004 |
| WHO | 0.4 | 0.2 | 0.5 | 1.3 | 0.2 |
| RfD | 0.0035a | 0.001a | 0.0001c | 0.005b | 0.003c |
| PTWI | 25 | 7 | 5 | 23.3 | 15 |

Note: RfD: reference dose, PTWI: the standard for the maximum permissible limit of weekly absorption: µg/g 70/kg bw/week
WHO, 1989; a)USEPA, 2011; b)USEPA, 2002; c)USEPA, 2000

*A. latus* and *P. subviridis* live in the sea, particularly in coastal waters often entering river mouths, estuaries, and fresh water to feed (Coad, 2017; Sourinejad et al., 2015). The coastal and estuarine zones are the source of marine sediment and the place where river's sediments sink. These areas are usually contaminated by various pollutants. Metals enter the aquatic environment by the disposal and discharge of agricultural, urban and industrial waste and deposited in sediments. Metals are deposited in sediment that is part of the aquatic ecosystem and remain in the sediment for a long time, then released into the environment (Keshavarzi et al., 2018). Jovanović et al., (2017) reported, sediments are the main route of direct transfer of heavy metals in many aquatic species. Metals accumulate in benthic feeders' tissues and they move upward by the food chain through bioaccumulation.

In *P. subviridis*, the amount of arsenic and lead were higher than other elements (Fig. 1). The sources of contamination of these elements are the entry of agricultural and industrial effluents into existing factories, refineries and petrochemicals in the region. Since these discharges are pollutant sources of coastal waters, studied areas are important from agricultural impacts on the living environment of aquatic animals. The high level of arsenic and lead in the *P. subviridis* tissues originate from its omnivorous diet. The economic activities in Maah-shar Harbor involve extraction of oil and gas and the relevant activities, shipping and agriculture. Bandar-e-Imam and Arvand Petrochemical companies are also located in the exclusive economic zone of Maah-shar. These have changed the coasts of the Khuzestan province into one of the most contaminated regions of Iran.

The mean heavy metals concentrations of fish species muscle decreased in the order of: *A. latus*> *P. subviridis*> *L. lemniscatus*> *A. indica*> *E. areolatus* > *O. ruber*> *E. chlorostima*> *L. crocineus*> *E. orientalis*> *C. arel*> *G. suppositus*. Toxic metals concentration distribution shows a significantly difference in fish muscle tissues. Fig. 1 shows the mean heavy metals concentration distribution in fish muscle of different kinds of fish. The mean concentrations of each metal in different fish species were as follows:

Pb: *P. subviridis*> *A. latus*> *O. ruber*> *E. areolatus*> *L. lemniscatus*> *A. indica*> *G. suppositus*≈ *L. crocineus*> *E. orientalis*> *C. arel*> *E. chlorostima*

Cd: *E. areolatus> L. lemniscatus> A. latus> A. indica>O. ruber> L. crocineus> E. chlorostima> P. subviridis > C. arel> E. orientalis> G. suppositus*

Hg: *E. chlorostima> E. areolatus> C. arel> L. crocineus> E. orientalis> P. subviridis> A. latus> O. ruber> A. indica> L. lemniscatus> G. suppositus*

Cr: *A. latus> L. lemniscatus> A. indica> E. areolatus> O. ruber> E. chlorostima> L. crocineus> E. orientalis> G. suppositus> C. arel> P. subviridis*

As: *P. subviridis> E. areolatus> A. latus> L. crocineus> O. ruber> C. arel> E. orientalis> A. indica> E. chlorostima> L. lemniscatus> G. suppositus*

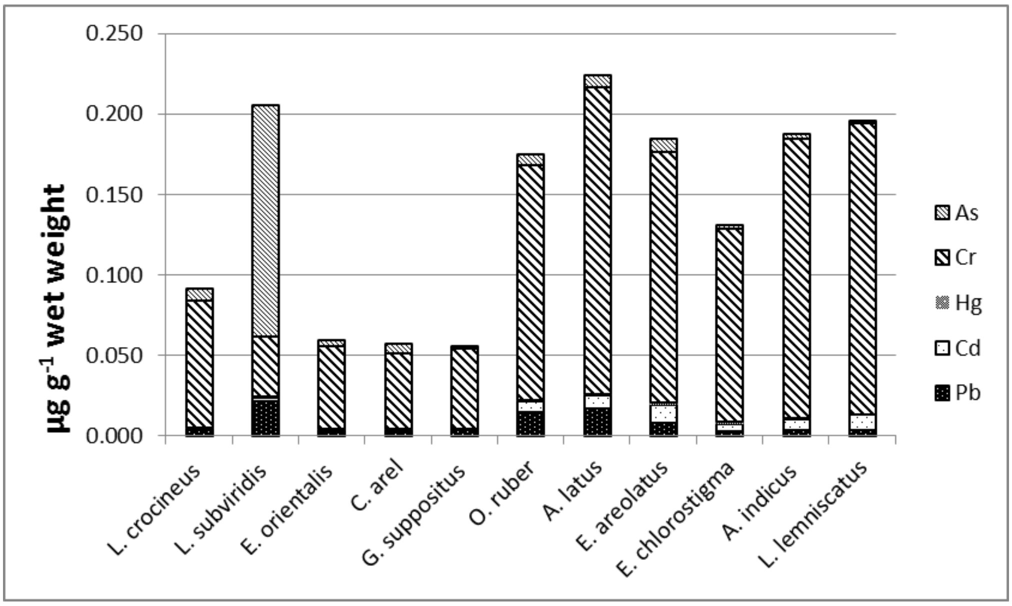


**Fig. 1. Heavy metals concentration (µg/g wet weight) in various species of fish muscle**

The studied fish species ranged from omnivorous to carnivorous (Table 1). However, small amounts of metals were detected in their muscles, which might be due to the low levels of heavy metal attachment to their proteins (Akoto et al., 2014). In general, the physiological state of a fish can affect bio-aggregation of heavy metals in its tissues (Kotze et al.,1999) and the amount of the aggregated metals depends on their physiological role (Lakshmanan et al., 2009).

Jiang et al., (2018) reported, that heavy metal concentrations were found significantly higher in demersal (inhabiting near the sediments) and piscivorous (possessing higher trophic level) fishes than in pelagic/benthopelagic (inhabiting the upper and lower water column) and herbivorous/planktivorous (possessing lower trophic level) fishes.

According to the results of this study, all examined heavy metals do not accumulated same amount in the muscle tissues of the studied fish species. Chromium and mercury’s concentration in the samples found as the highest and lowest, respectively (table 2). This study also exhibited that the species of fishes determine the level of accumulation of heavy metals in the muscle’s tissue (Keshavarzi et al., 2018; Abdolahpur Monikh et al., 2013 and 2012). These results originated from species diversified behavior such as habitat and different food consumption. Specifically, heavy metal accumulation can increase in a specific fish by consuming carnivorous diet, eating food and being placed at the end of the food chain (Roesijadi & Robinson, 1994; Heath, 1987).

*A. latus* and *P. subviridis* have the highest levels of contamination and they are carnivorus and omnivorus, respectively. But their habitate are in shallow coastal waters. Coastal water is more polluted because of their proximity to pollutants. So, the area where fish is caught is of great importance.

The standard for the maximum permissible limit of weekly absorption (PTWI) in terms of kg fish per 70 kg body weight were calculated as 25 for lead, 7 for cadmium, 5 for mercury, 23.3 for chromium and 15 for arsenic. THQ values were as follows: Cr (0.1146)> Hg(0.0428)> As(0.0295)> Cd(0.0237)> Pb(0.0108) (Fig. 2). The average HI value was 0.221 being significantly lowers than 1. THQ of sample's muscle decreased in the following orders: *P. subviridis*> *A. latus*> *E. areolatus*> *L. lemniscatus*> *O. ruber*> *A. indica*> *E. chlorostima*> *L. crocineus*> *G. suppositus*> *C. arel*> *E. orientalis* (Fig. 3). As tables 3 and 4 exhibit, the permissible limits of heavy metal consumption are lower than the standard levels announced by WHO.

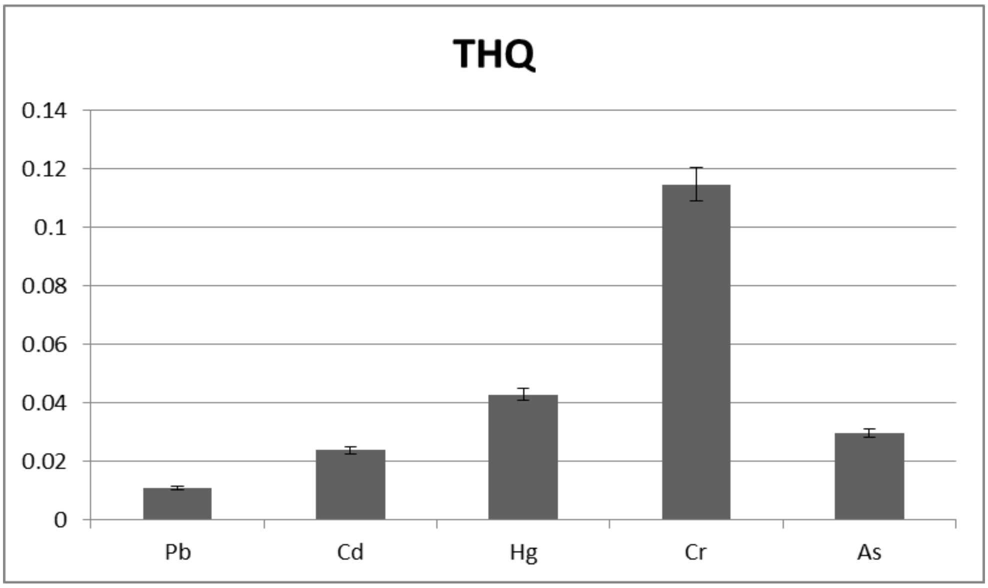


**Fig. 2. Comparison of total hazard quotient (THQ) in heavy metals**

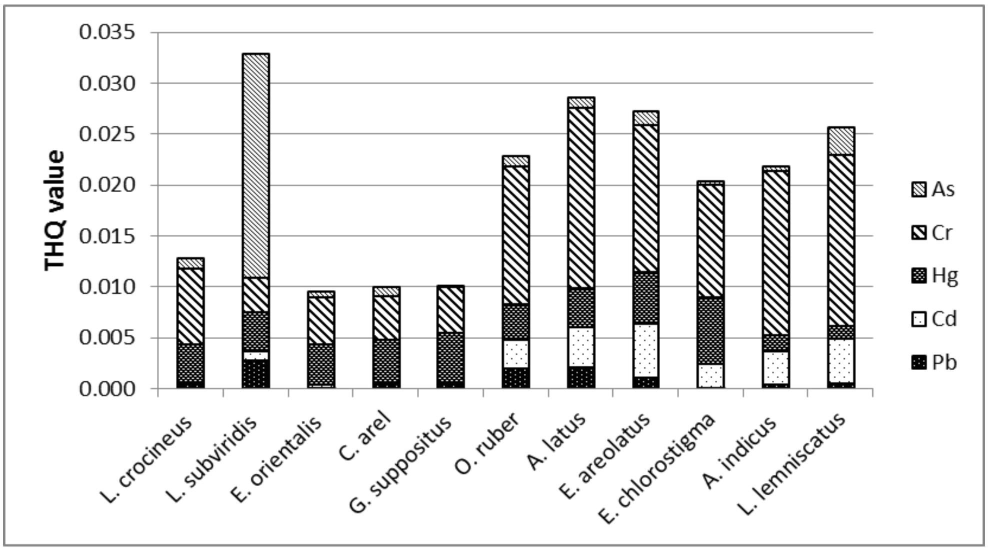


**Fig. 3. Comparison of total hazard quotient (THQ) in various species of fish muscle**

**Table 3. The amount of EDI and EWI of heavy metals in children and adult bodies by consuming fish collected from Maah-shar Harbor, Persian Gulf in Iran. (µg/kg bw/day)**

| fish species | | Pb | | Cd | | Hg | | Cr | | As | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | children | adults | children | adults | children | adults | children | adults | children | adults |
| *L. crocineus* | EDI | 0.007 | 0.001 | 0.001 | 0.0002 | 0.0017 | 0.0003 | 0.178 | 0.037 | 0.0161 | 0.0033 |
| | EWI | 0.051 | 0.01 | 0.0078 | 0.0016 | 0.0125 | 0.0026 | 1.251 | 0.259 | 0.1132 | 0.0234 |
| *P. subviridis* | EDI | 0.047 | 0.009 | 0.0047 | 0.0009 | 0.0018 | 0.00038 | 0.084 | 0.0174 | 0.322 | 0.0668 |
| | EWI | 0.332 | 0.068 | 0.0335 | 0.0069 | 0.0128 | 0.0026 | 0.588 | 0.121 | 2.259 | 0.467 |
| *E. orientalis* | EDI | 0.0064 | 0.0013 | 0.0006 | 0.0001 | 0.0019 | 0.00039 | 0.115 | 0.0238 | 0.008 | 0.0016 |
| | EWI | 0.045 | 0.009 | 0.0047 | 0.0009 | 0.0134 | 0.0027 | 0.807 | 0.167 | 0.0566 | 0.0117 |
| *C. arel* | EDI | 0.006 | 0.0012 | 0.0008 | 0.0001 | 0.002 | 0.00043 | 0.105 | 0.0217 | 0.0136 | 0.0028 |
| | EWI | 0.042 | 0.008 | 0.0062 | 0.0013 | 0.0146 | 0.003 | 0.735 | 0.152 | 0.095 | 0.0197 |
| *G. suppositus* | EDI | 0.006 | 0.0014 | 0.0007 | 0.0001 | 0.0023 | 0.00049 | 0.112 | 0.0232 | 0.0023 | 0.0004 |
| | EWI | 0.048 | 0.009 | 0.005 | 0.001 | 0.0167 | 0.0034 | 0.784 | 0.162 | 0.0167 | 0.0034 |
| *O. ruber* | EDI | 0.033 | 0.0069 | 0.0143 | 0.0029 | 0.00173 | 0.00036 | 0.327 | 0.0679 | 0.0151 | 0.0031 |
| | EWI | 0.233 | 0.048 | 0.1 | 0.0208 | 0.0121 | 0.0025 | 2.295 | 0.475 | 0.1058 | 0.0219 |
| *A. latus* | EDI | 0.0369 | 0.0076 | 0.0188 | 0.0039 | 0.0185 | 0.00038 | 0.428 | 0.0887 | 0.0161 | 0.0033 |
| | EWI | 0.258 | 0.053 | 0.132 | 0.0273 | 0.0129 | 0.0026 | 2.998 | 0.621 | 0.113 | 0.0234 |
| *E. areolatus* | EDI | 0.017 | 0.0035 | 0.0257 | 0.0053 | 0.0024 | 0.00051 | 0.350 | 0.0725 | 0.0188 | 0.0039 |
| | EWI | 0.12 | 0.024 | 0.180 | 0.0373 | 0.0172 | 0.0035 | 2.452 | 0.508 | 0.132 | 0.0273 |
| *E. chlorostima* | EDI | 0.006 | 0.0012 | 0.0104 | 0.0021 | 0.0031 | 0.00065 | 0.269 | 0.0558 | 0.005 | 0.001 |
| | EWI | 0.042 | 0.008 | 0.0733 | 0.0152 | 0.022 | 0.0045 | 1.886 | 0.390 | 0.0356 | 0.0073 |
| *A. indica* | EDI | 0.007 | 0.0015 | 0.0157 | 0.0032 | 0.0157 | 0.00016 | 0.390 | 0.08 | 0.006 | 0.0012 |
| | EWI | 0.051 | 0.0106 | 0.11 | 0.022 | 0.0054 | 0.0011 | 2.736 | 0.566 | 0.0429 | 0.0089 |
| *L. lemniscatus* | EDI | 0.008 | 0.0016 | 0.0214 | 0.0044 | 0.0006 | 0.00014 | 0.405 | 0.084 | 0.004 | 0.0008 |
| | EWI | 0.056 | 0.0116 | 0.149 | 0.0310 | 0.0047 | 0.0009 | 2.840 | 0.588 | 0.0283 | 0.0058 |

Note: EDI - daily intake and EWI - weekly intake (µg/g bw/day), bw - body weight, kg

**Table 4. The amount of CRmm and Crlim (kg/day) of heavy metals by children and adult bodies by consuming fish collected from Maah-shar Harbor, Persian Gulf in Iran**

| fish species | | Pb | | Cd | | Hg | | Cr | | As | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Crlim | CRmm | Crlim | CRmm | Crlim | CRmm | Crlim | CRmm | Crlim | CRmm |
| *L. crocineus* | children | 15.619 | 589 | 29.805 | 1124 | 1.893 | 71 | 0.920 | 34 | 6.224 | 34 |
| | adults | 75.405 | 1428 | 143.888 | 2725 | 9.138 | 173 | 4.443 | 84 | 30.050 | 84 |
| *P. subviridis* | children | 2.405 | 90 | 15.063 | 568 | 1.827 | 68 | 1.940 | 73 | 0.3031 | 73 |
| | adults | 11.611 | 219 | 72.722 | 1377 | 8.824 | 167 | 9.367 | 177 | 1.463 | 177 |
| *E. orientalis* | children | 19.193 | 723 | 52.361 | 1975 | 1.723 | 65 | 1.435 | 54 | 12.313 | 54 |
| | adults | 92.66 | 1750 | 252.77 | 4788 | 8.320 | 157 | 6.929 | 131 | 59.444 | 131 |
| *C. arel* | children | 19.431 | 732 | 37.861 | 1428 | 1.570 | 59 | 1.581 | 59 | 7.202 | 59 |
| | adults | 93.897 | 1776 | 182.77 | 3462 | 7.583 | 143 | 7.633 | 144 | 34.772 | 144 |
| *G. suppositus* | children | 16.844 | 635 | 46.092 | 1738 | 1.369 | 51 | 1.460 | 55 | 42.982 | 55 |
| | adults | 81.31 | 1540 | 22.514 | 4215 | 6.611 | 125 | 7.048 | 133 | 207.50 | 133 |
| *O. ruber* | children | 3.489 | 131 | 2.387 | 90 | 1.911 | 72 | 0.497 | 18 | 6.521 | 18 |
| | adults | 16.844 | 319 | 11.524 | 218 | 9.229 | 174 | 2.399 | 45 | 31.483 | 45 |
| *A. latus* | children | 0.283 | 116 | 1.763 | 66 | 1.783 | 67 | 0.38 | 14 | 6.069 | 14 |
| | adults | 14.961 | 283 | 8.512 | 161 | 8.609 | 163 | 1.838 | 34 | 29.302 | 34 |
| *E. areolatus* | children | 17.807 | 671 | 1.302 | 49 | 1.325 | 49 | 2.258 | 17 | 5.191 | 17 |
| | adults | 85.96 | 1628 | 6.286 | 119 | 6.398 | 121 | 0.467 | 42 | 25.064 | 42 |
| *E. chlorostima* | children | 18.99 | 716 | 3.228 | 121 | 1.097 | 41 | 0.615 | 23 | 19.417 | 23 |
| | adults | 91.679 | 1736 | 15.584 | 295 | 5.296 | 100 | 2.972 | 56 | 93.741 | 56 |
| *A. indica* | children | 15.619 | 589 | 2.100 | 79 | 4.241 | 159 | 0.419 | 15 | 16.053 | 15 |
| | adults | 75.403 | 1428 | 10.138 | 192 | 20.473 | 387 | 2.027 | 38 | 77.50 | 38 |
| *L. lemniscatus* | children | 14.33 | 540 | 1.523 | 57 | 5.012 | 189 | 0.403 | 15 | 25.003 | 15 |
| | adults | 69.213 | 1311 | 7.356 | 139 | 24.195 | 458 | 1.948 | 36 | 120.707 | 36 |

Note: Units; The permissible rate of consuming fish ($CR_{mm}$): a meal in a month and the permissible limit of fish consumption ($Cr_{lim}$): kg/day

The acceptable guideline for THQ is 1 (USEPA, 2011). A THQ below 1 indicated that the level of exposure is smaller than the reference dose. A daily exposure at this level is believed to be unlikely to cause any adverse effects during a person's lifetime. Calculated THQ for the investigated metals for all species is safe for human consumption. According Fig. 3, The mean THQ values of heavy metals at all fish species followed the descending order of Cr>Hg>As>Cd>Pb. Tables 3 and 4 show, the permissible limits of heavy metal consumption are lower than the standard levels announced by WHO (WHO, 1989) and Also, the hazard indices of all metals are have values lower than 1, which means that consuming the studied fish species is not harmful for the consumers.

For local residents, *C. arel* and *G. suppositus* was recommended as the daily consuming fish species, which had relatively lower toxic metals accumulation abilities, and followed by *E. orientalis* and *L. crocineus*. Consuming less than the amounts provided in Tables 3 and 4 by wild fish muscle tissues for an individual could basically assure local inhabitants' health. *P. subviridis*, *A. latus*, *E. areolatus and E. chlorostima* which had relatively higher bioaccumulation ability in Pb, As, Cr, Cd and Hg, was recommended as a sensitive bio-indicator in water quality monitoring.

Hazard index represents the ratio of the estimated dose of heavy metal exposure to the metal's reference dose (RfD). In this study, the hazard index of the five studied metals was lower than 1, which indicates that consuming the examined fish species has no harmful effect on the consumer's health. Therefore, consuming the fish species sampled from the coasts of Maah-shar does not pose any serious threat to the consumers. However, the low rate of aquatic animal consumption in Iran should not be neglected and it should be considered that the calculated hazard index values would increase with the rate of fish consumption. Also, the obtained value of the total hazard index (HI) is lower than 1(i.e. 0.221) in agreement with the results reported about the hazard of mercury in *Acanthopagrus latus* (Koshafar & Velayatzadeh 2016) and *Otolithes ruber* (Mardoukhi et al., 2013) in Persian Gulf.

The Pearson correlation test used to determine the correlation between total length, Weight and heavy metal accumulation in muscle tissue (Table 5). As the length and weight of the fish increase, the amount of lead and arsenic accumulation decreases, but the accumulation of chromium and cadmium increases. A significant correlation found between the accumulation of heavy metals of between As and Pb and Cr (+); Cr and Cd (+); Cr and Hg (-) in fish tissues.

**Table 5. Pearson correlation test and relationship between length, weight and metal content in muscle tissue**

| | Pb | Cd | Hg | Cr | As |
|---|---|---|---|---|---|
| Cd | 0.163 NS | | | | |
| Hg | -.061 NS | -0.229 NS | | | |
| Cr | 0.108 NS | 0.845** | -0.369* | | |
| As | 0.648** | -0.183 NS | -0.007 NS | -0.396* | |
| Weight | - 0.425* | 0.298 NS | -0.266 NS | 0.470** | -0.312 NS |
| Total length | -0.359* | 0.419* | -0.082 NS | 0.547** | -0.366* |

NS) Not significant, *) Significant is 0.05 level, **) Significant is 0.01 level

Non-existence of relationship between the metals' accumulation and weight and body length have reported by Pourang et al.,(2005). They discuss that the capacity of the body and biochemical factors could have non-influence or variability.

On the other hand, comparison of biometric measurements between the eleven studied fish species *P. subviridis* samples, exhibited the highest Pb and As concentrations, while had not higher weight and length than other species. Thus, may be the species of fish, habitat (benthic, mezopelagic and pelagic), and feeding behavior are factors in observed differences in metals concentrations between different fish species.

Although there were several significant ($p<0.05$) differences between the species regarding the bioaccumulation of the selected metals, no definite trend could be established. Differences could be attributed to the different feeding habits of the species and intake of metals by the food (Coetzee et al., 2002).

In similar studies, Keshavarzi et al. (2018) reported that the species of fish, habitat and biometric features are the most important factors in observed differences in metal concentrations between different fish species. This may be related to the differences in ecological needs, swimming behaviors and the metabolic activities among different fish species.

A highly significant correlation between the heavy metals in the tissues was observed statistically in fishes. Specially, the correlation between As and Pb, Cr and Cd, were higher than that among other metals. Probably, the high levels of correlation coefficient between the metal represents the common source of these heavy metals is the same and the intensity of the pollution is high. Darvish Bastami et al. (2015) suggested that the positive linear relationship between heavy metals had common sources, mutual dependence and identical behavior during the transport. The negative correlations between Cr with Hg and As does not share the above specific metal traits with the other heavy metals. Pourang et al. (2005) reported that these inter- heavy metals relationships may be attributable to similar physicochemical properties of the metals involved. Also it has been regarded as indicative of similar biochemical pathways or, at its simplest, as demonstrating the binding of certain metals in animals indicates the occurrence of particular ligands. In addition, the concentration of elements in fishes can be explained by the enrichment of these metals in the sediment of region (Abdolahpur Monikh et al., 2012).

The results of this study demonstrated that the heavy metal concentrations of the studied species are significantly lower than the maximum permissible amount determined by the WHO standards (table 2). Therefore, with respect to the standard contamination thresholds, the observed densities are not hazardous. However recommended, children and pregnant women should be cautious about consuming these fish species due to the potential hazards of these heavy metals.

Table 6 indicates a general view on the order of heavy metals accumulation in the muscle of different marine and freshwater fish species. Based on the results, in most cases Cr and As show the highest concentration compared to the other studied heavy metals. The reverse case can be observed for Pb and Cd. The obtained pattern of the heavy metals accumulation in this study showed that the results are same as the other studies of fishes have been reported by other researchers. It should be noted that, the order of accumulation is determined by determined by the need, prevalence in the earth's crust. In the second place - geochemical features and pollution of region.

## CONCLUSION

Fish is not the only way of heavy metal entrance to the human body. Consuming any other heavy metals containing foods, such as rice, wheat, and vegetables that constitute the largest part of the Iranian diet, may introduce more heavy metals to the consumers' bodies. However, the consumed foods are not the same in different societies or even cities due to the differences in the tastes of people. Therefore, the intake of various contaminants through foods depends on the individuals' diets. Because of a diversity of cultures and diets of Iranian people, it is obvious that providing a specific pattern for the standard amounts of food consumption is not possible and sufficiently creditable. From the present study, it can be concluded that:

Although consuming these fish does not have harmful effects on the consumers' health, the amount of its consumption by pregnant women and children must be considered because embryos, infants, and children under 10 years are more vulnerable.

The HI was calculated for 70 kg body weight of adults and 14.5 kg bodyweight of children. The amount of optimal consumption is different for different weights of consumers.

Regarding various sources of contamination heterogeneously are scattered on the Persian Gulf, the accumulation levels related to this species and other economic species are different. Therefore, the various regions of the Persian Gulf should be refined regularly (every 3-5 years).

Due to the wide diversity in their diet, the sea fish have very large amounts of metals accumulation in their tissues. Consequently, while we endeavor to increase the fish consumption per capita and including it in the people's diet, we should also pay serious attention to the safety of aquatic foods.

**Table 6. THQ and Patterns of trace elements occurrence in the muscle of different species from various parts of the world. The orders are not based on statistical analyses**

| Species | Order | THQ | Sampling region | Reference |
|---|---|---|---|---|
| **This study** | **Cr>As>Pb> Cd> Hg** | **<1** | **Persian Gulf, Iran** | **This study** |
| *Euryglossa orientalis,* | Pb>Cd | | | |
| *Liza abu,* | Pb>Cd | | Musa estuary, Persian Gulf | Abdolahpur Monikh et al., 2013 |
| *Johnius belangerii* | Pb>Cd | | | |
| *Carcharhinus dussumieri* | Pb>Cd>Hg | <1 | Persian Gulf, Iran | Adel et al., 2016 |
| *Otolithes ruber* | Cd>Cr>Pb>As | Pb<1 | Oman Sea, Iran | Sadeghi et al., 2019 |
| *Anodontostoma chacunda* | Cd>Pb> Hg>As | As, Hg>1 | | |
| *Belangerii* | Cd>Pb> Hg>As | As, Hg>1 | Persian Gulf, Iran | Keshavarzi et al., 2018 |
| *Cynoglossurs arel* | Cd>Pb> Hg>As | As, Hg>1 | | |
| *Thunnus tonggol* | Hg > Cr > Pb | <1 | Persian Gulf, Iran | Malakootian et al., 2016 |
| *Liza klunzingeri* | Hg > Cr > Pb | <1 | | |
| *Lutjanus johnii* | Pb>Cd | <1 | Persian Gulf, Iran | Khoshnood & Khoshnood, 2013 |
| *Lutjanus lemniscatus* | Pb>Cd | <1 | | |
| *Acanthopagrus latus* | Pb>Cd | <1 | | |
| *Pampus argentus* | Pb>Cd | <1 | | |
| *Liza subviridis* | Pb>Cd | <1 | | |
| *Sillago sihama* | Pb>Cd | <1 | | |
| *Rutilus frisii kutum* | Pb>Hg>Cd | <1 | Caspian Sea, Iran | Monsefrad et al., 2012 |
| *Sardina pilchardus* | As>Hg>Cd>Pb | >1 | Eastern Mediterranean Sea | Sofoulaki et al., 2019 |
| *Engraulis encrasicolus* | As>Hg>Cd>Pb | >1 | | |
| *Acanthogobius hasta* | Cr> Cd >Pb | <1 | Laizhou Bay, China | Liua et al., 2019 |
| *Acanthopagrus schlegelii* | Cr> Cd >Pb | <1 | | |
| *Chelon haematocheilus* | Cr> Cd >Pb | <1 | | |
| *Lateolabrax japonicas* | Cr> Cd >Pb | <1 | | |
| *Mugil cephalus* | Cr> Cd >Pb | <1 | | |
| *Platycephalus indicus* | Cr> Cd >Pb | <1 | | |
| *Pleuronectiformes heterosomata* | Cr> Cd >Pb | <1 | | |
| *Luciobarbus esocinus* | As>Pb> Cr> Cd | <1 | Turkey | Varol & Sünbül, 2018 |
| *Capoeta umbla* | As>Pb> Cr> Cd | <1 | | |
| *Cyprinus carpio* | As>Pb> Cr> Cd | <1 | | |
| *Luciobarbus mystaceus* | As>Pb> Cr> Cd | <1 | | |
| *Capoeta trutta* | As>Pb> Cr> Cd | <1 | | |
| *Hypophthalmichthys nobilis* | Cr> Pb>Cd>As | <1 | Honghu Lake, China | Zhang et al., 2017 |
| *Carassius auratus* | Cr> Pb>Cd>As | <1 | | |
| *Ctenopharyngodon idellus* | Cr> Pb>Cd>As | <1 | | |
| *Siniperca chuatsi* | Cr> Pb>Cd>As | <1 | | |
| *Ctenopharyngodon idellus* | Cr> Pb>Cd>As | <1 | | |
| *Pelteobagrus fulvidraco* | Cr> Pb>Cd>As | <1 | | |
| *Thunnus obesus,* | Cr>Cu>Pb >Cd | <1 | South China Sea | Gu et al., 2017 |
| *Decapterus lajang* | Cr>Cu>Pb >Cd | <1 | | |
| *Cubiceps squamiceps* | Cr>Cu>Pb >Cd | <1 | | |
| *Priacanthus macracanthus* | Cr>Cu>Pb >Cd | <1 | | |
| *Scorpaena porcus* (n=10) | As > Pb > Cd = Hg | <1 | Black Sea, Turkey | Çulha et al., 2016 |

## ACKNOWLEDGEMENT
This work was supported by the Islamic Azad University, Tonekabon Branch. I am thankful for the supports provided by Tonekabon Branch, especially the Fisheries Research Laboratory. My special thanks from Mr. Bagheri Tavani, faculty of young research and elite club Tonekabon branch for his great efforts.

## GRANT SUPPORT DETAILS
The present research did not receive any financial support.

## CONFLICT OF INTEREST
The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

## LIFE SCIENCE REPORTING
No life science threat was practiced in this research

## REFERENCES
Abdolahpur Monikh, F., Safahieh, A., Savari, A., Ronagh, M.T. and Doraghi, A. (2013). The Relationship between heavy metal (Cd, Co, Cu, Ni, and Pb) levels and the size of benthic, benthopelagic and pelagic fish species, Persian Gulf. Bull. Environ. Contam. Toxic., 90; 691-696. DOI 10.1007/s00128-013-0986-7

Abdolahpur Monikh, F., Safahieh, A.R., Savari, A. and Doraghi, A. (2012). Heavy metal concentration in sediment, Benthic, benthopelagic, and pelagic fish species from Musa estuary (Persian Gulf). Environ. Monitor. Assess., 185; 215–222.

Adel, M., Conti, G.O., Dadar, M., Mahjoub, M., Copat, C. and Ferrante, M. (2016). Heavy metal concentrations in edible muscle of White cheek shark, *Carcharhinus dussumieri* (elasmobranchii, chondrichthyes) from the Persian Gulf: A food safety issue. Food. Chemical. Toxic., 97; 135-140

Akoto, O., Bismark Eshun, F., Darko, G. and Adei, E. (2014). Concentrations and health risk assessments of heavy metals in fish from the Fosu lagoon. Inter. J. Environ. Res., 8(2); 403-410.

Alipour H. and Banagar Gh.R. (2018). Health risk assessment of selected heavy metals in some edible fishes from Gorgan Bay Iran. Iran. Sci. Fish. J., 171; 21-34. DOI: 10.22092/IJFS.2018.115582. [In Persian.]

Askary sary A. and Karimi V. (2017). Measurement and comparative of Iron levels and hazard quotient (HQ) on muscle of farmed and marine fishes from Khuzestan south west of Iran. Iran. Sci. Fish. J., 25(5); 1-11. [In Persian.]

Chien, L.C., Hung, T.C., Choang, K.Y., Yeh, C.Y., Meng, P.J., Shieh, M.J. and Han, B.C. (2002). Daily intake of TBT Cu Zn Cd and As for fishermen in Taiwan. Sci. Total. Environ., 285, 177-85.

Coad, B.W. (2016). Review of the Freshwater Mullets of Iran (Family Mugilidae). Iran. J. Ichthyol., 4(2); 75-130. DOI: 10.7508/iji.2016.0

Coetzee, L., Du Preez, H.H. and Vuren van, J.H.J. (2002). Metal concentrations in *Clarias gariepinus* and *Labeo umbratus* from the Olifant and Klein Olifants River, Mpumalanga, South Africa: Zinc, copper, manganese, lead, chromium, nickel, aluminum and iron. Water SA., 28(4); 433-448.

Cooper, C.B., Doyle, M.E. and Kipp, K. (1991). Risk of consumption of contaminated sea food, the Quincy Bay Case Study. Environ. Health. Pers., 90; 133-40.

Çulha, S. T., Yabanl, M., Baki, B. and Yozukmaz, A. (2016). Heavy metals in tissues of scorpionfish (*Scorpaena porcus*) caught from Black Sea (Turkey) and potential risks to human health. Envi. Sci. Pollut. Res., 23(20); 20882–20892. doi: 10.1007/s11356-016-7337-2.

Darvish Bastami, K., Afkhami, M., Mohammadizadeh, M., Ehsanpour, M., Chambari, Sh., Aghaei, S., Esmaeilzadeh, M., Neyestani, M.R., Lagzaee, F. and Baniamam, M. (2015). Bioaccumulation and ecological risk assessment of heavy metals in the sediments and mullet *Liza klunzingeri* in the northern part of the Persian Gulf. Marine Pollut. Bult., 94; 329-334. doi.org/10.1016/j.marpolbul.2015.01.019

EPA-503/8-89-002. (1989). US EPA Office of Marine and Estuarine Protection Washington DC, USA.

FAO (Food and Agriculture Organizations of the United Nations) (2009). The state of world fisheries and aquaculture. Rome. Italy., 196 P.

Genc, T.O. and Yilmaz, F. (2018). Heavy Metals Content in Water Sediment and Fish (*Mugil cephalus*) From Koycegiz Lagoon System in Turkey: Approaches for Assessing Environmental and Health Risk. J. Agr. Sci. Tech., 20; 71-82.

Gu, Y.G., Lin, Q., Huang, H.H., Wang, L., Ning, J.J. and Du, F.Y. (2017). Heavy metals in fish tissues/stomach contents in four marine wild commercially valuable fish species from the western continental shelf of South China Sea. Marine Pollut. Bult.,114(2); 1125–1129. doi.org/10.1016/J.MARPOLBUL.2016.10.040

Heath, A.G. (1987). Water Pollution and Fish Physiology. CRC Press, Boca Raton, FL., 245P.

Jiang, Z., Xu, N., Liu, B., Zhou, L., Wang, J., Wang, C., Dai, B. and Xiong, W. (2018). Metal concentrations and risk assessment in water, sediment and economic fish species with various habitat preferences and trophic guilds from Lake Caizi, Southeast China. Ecotoxicol. Environ. Saf., 157; 1-8. DOI: 101016/j.ecoenv.2018.03.078. Epub 2018 Mar 30.

Jovanović, D.A., Marković, R.V., Teodorović, V.B., Šefer, D.S., Krstić, M.P., Radulović, S.B., Ćirić, J.S.I., Janjić, J.M. and Baltić, M.Ž. (2017). Determination of heavy metals in muscle tissue of six fish species with different feeding habits from the Danube River, Belgrade—public health and environmental risk assessment. Environ. Sci. Pollut. Res., 24 (12); 11383-11391.

Kawser Ahmed, M., Baki, M.A., Kundu, G.K., Saiful Islam, M., Monirul Islam, M. and Muzammel Hossain, M. (2016). Human health risks from heavy metals in fish of Buriganga river, Bangladesh. SpringerPlus., 5; 1697. DOI: 10.1186/s40064-016-3357-0

Keshavarzi, B., Hassanaghaei, M., Moore, F., Rastegari Mehr, M., Soltanianc, S., Lahijanzadeh, A.R. and Sorooshian, A. (2018). Heavy metal contamination and health risk assessment in three commercial fish species in the Persian Gulf. Marine Pollut. Bult., 129; 245-252. doi.org/10.1016/j.marpolbul.2018.02.032

Khoshnood, Z. and Khoshnood, R. (2013). Health risk evolution of heavy metals in sea food, TRSER., 15(1); 137-144. "The Wetlands Diversity" DOI: 10.2478/trser-2013-0012.

Koshafar, A. and Velayatzadeh, M. (2016). Risk assessment to consumers from mercury in *Acanthopagrus latus*. Food Hygiene., 623; 21-34. [In Persian.]

Kotze, P.J., Du Preez, H.H. and Vuren van, J.H.J. (1999). Bioaccumulation of Copper and Zinc in *Oreochromis mossamicus* and *Clarias gariepinus* from the Olifants River Mpumalanga South Africa. Water SA., 251; 9-110.

Lakshmanan, R., Kesavan, K., Vijayanand, P., Rajaram, V. and Rajagopal, S. (2009). Heavy Metals Accumulation in Five Commercially Important Fishes of Parangipettai Southeast Coast of India. Adv. J. Food. Sci. Tech., 1; 63-65.

Liua, H., Liua,G., Yuanb, Z., Ge, M., Wang, Sh., Liu, Y. and Da, Ch. (2019). Occurrence, potential health risk of heavy metals in aquatic organisms from Laizhou Bay, China. Marine Pollut. Bult., 140; 388–394. doi.org/10.1016/j.marpolbul.2019.01.067

Łuczyńska, J., Paszczyka, B., Marek J. and Łuczyńskib, M. J. (2018). Fish as a bioindicator of heavy metals pollution in the aquatic ecosystem of Pluszne Lake, Poland, and risk assessment for consumer's health. Ecotoxic. Environ. Saf., 153; 60–67. doi.org/10.1016/j.ecoenv.2018.01.057

Malakootian, M., Seddiq Mortazavi, M. and Ahmadi, A. (2016). Heavy metals bioaccumulation in fish of southern Iran and risk assessment of fish consumption, Environ. Health Eng. Manag. J., 3(2); 61–68. DOI:10.15171/EHEM.2016.02

Mardoukhi, S., Hosseini, V. and Hosseini, M. (2013). Risk to consumers from mercury in croaker (*Otolithes ruber*) from the Mahshahr port. Fish. Sci. tech., 2 (3); 43-55. [In Persian.]

Monsefrad, F., Imanpour Namin, J. and Heidary, S. (2012). The concentration of heavy and toxic metals Cu, Zn, Cd, Pb and Hg in the liver and muscles of *Rutilus frisii* kutum during spawning season concerning growth parameters. Iran. J. Fish. Sci., 11(4); 825-839.

MOOPAM. (2010). Manual of Oceanographic Observation and Pollutant Analyses Method (Moopam) 3 Ed. ROPME Kuwait.

Moslen M. and Miebaka C.A. (2017). Concentration of Heavy Metals and Health Risk Assessment of Consumption of Fish (*Sarotherodon melanotheron*) from an Estuarine Creek in the Niger Delta Nigeria. J. Environ. Sci. Toxic. Food Tech., 11 (3); Ver. II 68-73.

Nasrabadi, T., Maedeh, P. A., Sirdari, Z. Z., Bidabadi, N. S., Solgi, S. and Tajik, M. (2015). Analyzing the quantitative risk and hazard of different waterborne arsenic exposures: case study of Haraz River, Iran. Environ. Earth Sci., 74(1); 521-532.

Nasrabadi, T. and Bidabadi, N.S. (2013). Evaluating the spatial distribution of quantitative risk and hazard level of arsenic exposure in groundwater, case study of Qorveh County, Kurdistan Iran. IRAN J. Environ. Health Sci., 10(1); 30.

Pourang, N., Nikouyan, A. and Dennis, J. H. (2005). Trace Element Concentrations in Fish, Surficial Sediments and Water from Northern Part of the Persian Gulf. Environ. Monit. Assess. 109; 293–316. DOI: 10.1007/s10661-005-6287-9

Roesijadi, G. and Robinson, W.E. (1994). Metal regulation in aquatic animals: Mechanism of uptake, accumulation and release. In: Aquatic Toxicology; Molecular, Biochemical and cellular Perspectives. (eds: Malins DC, Ostrander GK) Lewis Publishers, London, 539P.

Sadeghi S.N. (2001). Morphological and Biological characteristics of southern Iranian fishes (The Persian Gulf and Oman Sea). 1st ed. Tehran., Iran: Naghsh-e Mehr. (In Persian).

Sadeghi, P., Loghmani, M. and Afsa, E. (2019). Trace element concentrations, ecological and health risk assessment in sediment and marine fish *Otolithes ruber* in Oman Sea, Iran. Marine Pollut. Bult., 140; 248–254. doi.org/10.1016/j.marpolbul.2019.01.048

Shahri E., Khorasani N., Noori Gh., Kord Mostafa Pour F. and Velayatzadeh M. (2017). Risk assessment of some heavy metals in four species of fish from Oman Sea in spring. J. Research. Environ. Health., Mashhad University Medical Science., 31; 30-39. [In Persian.]

Sofoulaki, K., Kalantzi, I., Machias, A., Spiros, A., Pergantis, S.A. and Tsapakis, M. (2019). Metals in sardine and anchovy from Greek coastal areas: Public health risk and nutritional benefits assessment, Food. Chemical. Toxic., 123; 113-124. doi.org/10.1016/j.fct.2018.10.053.

Sourinejad, I., Nikkhah Khaje Ataei, S., Kamrani, E. and Ghodrati Shojaei, M. (2015). Feeding habits of yellowfin seabream, *Acanthopagrus latus* in the northern region of the Persian Gulf. Casp. J. Environ. Sci., 13(1); 31-39.

Tayebi, L. and Sobhanardakani, S. (2020). Analysis of Heavy Metal Contents and Non-carcinogenic Health Risk Assessment through Consumption of Tilapia Fish (*Oreochromis niloticus*). Pollution., 6(1): 59-67, DOI: 10.22059/poll.2019.284500.639

UNEP (Environmental Protection Agency) (1984). Sampling of selected marine organisms and sample preparation for trace metal analysis reference metal for marine Pollution Studies No.7, Rev.2.

USEPA (US Environmental Protection Agency) (2000). Guidance for assessing chemical contamination data for use in fish advisories II Risk assessment and fish consumption limits. EPA/823–B94-004. United States Environmental Protection Agency Washington.

USEPA (US Environmental Protection Agency) (2002). Supplemental guidance for developing soil screening levels for superfund sites OSWER 9355. Office of Emergency and Remedial Response Washington.

USEPA (US Environmental Protection Agency). (2011). Exposure actors handbook. National Center for Environmental Assessment, Washington, DC (EPA/600/R-09/052F).

Varol, M. and Sünbül, M.R. (2018). Multiple approaches to assess human health risks from carcinogenic and non-carcinogenic metals via the consumption of five fish species from a large reservoir in Turkey, Sci. Total Environ., 633; 684–694. doi.org/10.1016/j.scitotenv.2018.03.218

WHO (World Health Organization). (1989). Heavy Metals – Environmental Aspects of Environment and Health Criteria. No.85. WHO, Geneva, Switzerland.

Zhang, J., Zhu, L., Li, F., Liu, Ch., Yang, Z., Qiu, Z. and Xiao, M. (2017). Heavy metals and metalloid distribution in different organs and health risk assessment for edible tissues of fish captured from Honghu Lake. Oncotarget., 8(60); 101672-101685. DOI: 10.18632/oncotarget.21901.