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Evaluation of trace element contents and human health risk assessment via consumption of *Liza aurata* from the southern coasts of the Caspian Sea, Iran

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ABSTRACT

Knowledge of the effects of trace element accumulations in fish tissues on consumer health is of great importance. Concentration of trace elements (Hg, Pb, Cr, Cd, As, Fe, Zn, Mn, Co, Cu, Ni, Al, Sn, Ti, V) were determined in muscle of *Liza aurata*, wild fish caught from the southern coasts of the Caspian Sea in 2014 and 2015 in order to understand the accumulation pattern of trace elements in this fish and to assess the potential health risk posed by fish consumption. Following the standard instructions, the preparation and chemical digestion of the samples were performed using an atomic absorption spectrophotometer (AAS). The highest and lowest accumulations in the muscle belonged to Fe and V (13.988 ± 3.4 and 0.0009 ± 0.00079 µg g^{-1} wet weight) respectively. The accumulations of these elements were lower than the permissible range proposed by the WHO for human consumption. Results showed that element accumulations were not affected by sex. Negative correlation coefficients were found between Pb, Cd, As, Zn, Al, Cu, Mn and V levels in the tissues and the fish weight and total length. Moreover, in this study, the value of the hazard index (HI) was calculated to be 0.065. Estimated daily intakes (EDIs) of the elements were in the range of 0.0045 to 7.5934 for adults, and 0.021 to 36.675 for children, while the target hazard quotients (THQ) was below 1.0 for each element. These results exhibit that the consumption of the investigated *L. aurata* from the southern coasts of the Caspian Sea does not cause significant adverse health effects. However, some considerations should be observed regarding the consumption of fish by infants and pregnant women.

Keywords: *Liza aurata*, THQ, Estimated daily intake, Caspian Sea.

INTRODUCTION

In the last three decades, there have been reported cases of the heavy metals intoxication in human beings caused by consuming contaminated fish and aquatic animals (Anim *et al.* 2011). Fish, which are situated at the top of the aquatic animals' food chain in aquatic environments, may have great amounts of accumulated heavy metals in their body. These metals in combination with enzymes and proteins, influence the way of cells' functions (Ahmadi Kordestani *et al.* 2013) and can be replaced with the other salts and minerals in the body. The Caspian Sea is the world's largest lake and one of its most significant aquatic ecosystem which its ecological conditions have been negatively influenced by contaminants resulted from industrial/agricultural activities, urban/rural wastewaters, oil/gas production in the coast and the depths, as well as transportation activities related to ports (Pazooki *et al.* 2009). *Liza aurata* is an omnivorous benthic fish which has potential for accumulation of a substantial amount of contaminants, hence is considered as a suitable index for determining the accumulations of metals in aquatic ecosystems (Pazooki *et al.* 2009). There are several studies on the risk assessment of aquatic animals regarding heavy metals in the Caspian Sea (Johari *et al.* 2015; Alizadeh & Mirarab-Razi 2016; Yabanli, 2016; Nejat *et al.* 2018; Janbakhsh *et al.* 2018; Sattari *et al.* 2019a,b; Sattari *et al.* 2020a,b,c; Forouhar Vajargah *et al.* 2020a,b; Forouhar Vajargah *et al.* 2021a,b) and other parts of the world (Bat *et al.* 2018; Genc &Yilmaz 2018). Results of

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these studies showed that the hazard index (HI) was lower than 1 for all the species except the one conducted by Zhang *et al.* (2017). So, it is important to monitor the accumulation and potential human health risk associated with consumed fish species (Zhang *et al.* 2017). Furthermore, the risk involved in consuming aquatic animals in vulnerable groups such as children and pregnant women leads us to carefully assess this kind of contaminations. In this study we determined the accumulation of 15 different elements (lead, cadmium, mercury, arsenic, aluminum, vanadium, tin, and thallium, chromium, copper, manganese, zinc, nickel, iron, and cobalt) on edible (muscles) and non-edible (liver and gill) tissues of *L. aurata* in the southern part of the Caspian Sea. In addition, we investigated their relationships with weight, total length, and sex indices on edible and non-edible tissues of *L. aurata* in this part. Moreover, the main objective was to measure the amount of daily/weekly element accumulation in children and adults, and also determining the permitted limits for them along with the risk of this fish to cause non-cancerous diseases and comparing it with the standard sets by the WHO.

MATERIALS AND METHODS

Sampling and the chemical digestion preparation method

Regarding objectives of this study, dispersion, consumption level, and the hunting season of this species from the southern coasts of the Caspian, fish samples were collected from 10 sites (Fig. 1). Totally, 100 mature *L. aurata* (55 males and 45 females, with average weight and length of 879.766 ± 250.423 and 49.09 ± 4.43 respectively) were caught in the time period between autumn 2014 and spring 2015.

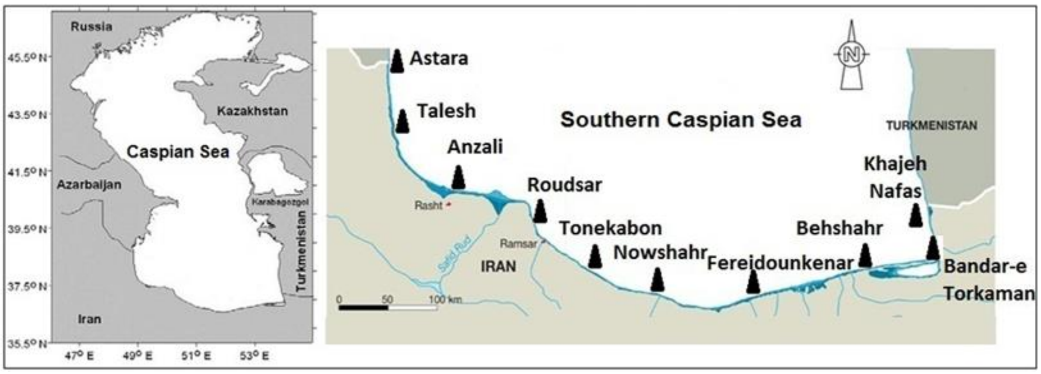

Fig. 1. Map sampling stations of fishes in the south coasts of the Caspian Sea.

After rinsing the samples with distilled water, their weight and length were recorded. Based on reproductive organs (ovaries and testes) sex determination was performed. To perform chemical digestion, 10 g of each tissue (muscle, liver, and gills) of the fish were placed in a flask containing 5 mL hydrogen peroxide and 65% nitric acid with a 1:3 ratio. High quality solutions were used for diluting the solutions and digesting the samples (Merck, Germany). The element standard solutions from Merck were used for the calibrations. Then, the samples were placed in the heater digest machine for 5 h under a maximum 140 ℃. In the next step, the mass of the filtered solution by Whatman paper filter (size 42) was increased to 5 mL with distilled water (Lakshmanan *et al*. 2009; Moopam 2010). The accuracy of data for trace elements was EPA method standard (EPA method 3051A, 2007). An atomic absorption instrument (Germany AAS4 Zeiss) equipped with graphite furnace system working in µg g^{-1}, was used to measure the accumulation of the heavy metals (Moopam 2010).

Calculating the accumulation of metals in terms of wet weight

The Eq. 1 can be used to obtain the correction factor for converting dry to wet weight. Thus, the dry weight of the fish sample was obtained by multiplying its wet weight to CF = 0.2 (UNEP/FAO/IAEA/IOC., 1984).

Eq. 1: CF = 1 - (the amount of moisture in the fish muscle/100)

Calculating the daily and weekly accumulation

Following the method proposed by the United States Environmental Protection Agency, the level of contaminant accumulation through food was calculated in terms of estimation daily intake (EDI) and estimation weekly intake (EWI), using Eqs. 2 and 3, respectively.

Eq. 2: $\mathrm{EDI} = \frac{C \times \mathrm{MS_D}}{BW}$ Eq. 3: $\mathrm{EWI} = \frac{C \times \mathrm{MS_W}}{BW}$

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where EDI is the estimated daily intake (μg g^{-1} bw day^{-1}), EWI is the estimated weekly intake (μg g^{-1} bw $week^{-1}$), C is the mean concentration of heavy metals in foodstuffs (μg g^{-1}), MSD: the rate of the daily fish consumption (38 g in a day, according to fish consumption per capita in the southern coasts of the Caspian Sea), MSW: the rate of the weekly fish consumption (266 g in a week, according to fish consumption per capita in the southern coasts of the Caspian Sea).

Calculating the permissible limit and number of times of consuming fish

In the method (USEPA, 2000), the permissible amount of consuming fish and other aquatic animals in a certain period of time is calculated based on the amount of metals in the edible tissues of the fish, which uses the reference dose (RfD) provided in Eq. 4:

Eq. 4: $$\text{CRlim} = \frac{\text{RfD} \times \text{BW}}{C} \times 7$$

where Crlim: Permissible limit of consuming fish in terms of kg day^{-1}, BW: Body weight (adults 70 kg, children 14.5 kg), RfD: Reference dose (μg g^{-1} bw day^{-1}).

Moreover, Eq. 5 can be used to calculate the permissible number of times for fish consumption in a month:

Eq.5: $$\text{CRmm} = \frac{\text{CRlim} \times \text{Tap}}{\text{MS}}$$

where CRmm: The permissible rate of consuming fish (times in a month), MS: The amount of each meal (227 g in adults to 114 g in children), Tap: Average time period (4.3 weeks in a month)

Calculating the target hazard quotients (THQ)

To determine concentration of the element that does not cause any problem in the body, Eq. 6, proposed by the United States Environmental Protection Organization, is used to calculate the probability of people's risk of non-cancerous diseases (USEPA, 2000). To calculate this index, it is assumed that the amount of metal entered is equal to the amount accumulated by the body (EPA-503/8-89-002. 1989) and also cooking does not eliminate the contaminants (Cooper *et al.* 1991). According to this index, if the resulted number is higher than 1, it demonstrates that the probability of non-cancerous diseases is rather high, and if the resulted number is lower than 1, it shows that consuming the aquatic studied animals do not harm the consumers.

Eq.6: $$\text{THQ} = \frac{EF \times ED \times IR \times C}{BW \times RfD \times AT}$$

where THQ: Target Hazard Quotients, EF: Encounter frequency (frequency in the exposure) 365 days a year, ED: Total time of encounter (time of exposure) 70 years, IR: The daily rate of consuming fish; (38 g day^{-1} according to fish consumption per capita in the southern coasts of the Caspian Sea), AT: An average of the days being exposed (365 days × 70 years = 25550 days).

The total hazard index (Eq. 7) is the sum of the 15 metals' risk (Chien *et al.* 2002).

Eq.7: Hazard Index (HI) = ΣTHQ

Statistical analyses

SPSS 20 was used to analyze the data and Excel software was used to draw diagrams. Moreover, to test the differences among sites, one way ANOVA and the parametric independent t test was performed. Correlation between trace elements uptake with standard length and weight was investigated by Pearson correlation. Post hoc test (Tukey) was applied to determine statistically significant differences following ANOVA. The p-value of less than 0.05 were considered statistically significant ($P < 0.05$).

RESULTS

The results of the bioassay of the sampling sites showed that the mean weight and total length were 877.83 ± 276.24 g (range: 1844-384g) and 49.28 ± 4.85cm (range: 61-37.5cm) respectively. The results of the t-test in male and female showed that differences in weight and total length were not statistically significant ($P>0.05$). According to Table 1, the content of metals varied between sampling sites ($P < 0.05$) except for Cu. The mean accumulations of all metals in *L. aurata* were much lower than the regulatory limits for fish and fishery products

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permitted by the WHO for human consumption except for Mn and Co (WHO guideline are illustrated in Table 4). Differences in the element accumulation in muscles, liver, and gills of *L. aurata* were also studied (Table 2, Fig. 2). The order of element concentrations in the three aforementioned tissues was as follow: liver>gill>muscle (Fig. 3) exhibiting significant differences between these tissues (P<0.05). The order of elements concerning to the total accumulation was Fe>Cu>Zn>Co>Mn>Pb>Cr>Cd>Ni>Hg>As>Al>Sn>Ti>V.

Table 1. Mean (± SD), element concentrations (μg g^{-1} wet weight) in *Liza aurata* and ANOVA test results between different sites. Noting that accumulation of these elements was not significantly different between sexes in the southern coasts of the Caspian Sea (P > 0.05).

Element	Astara (n = 10)	Talesh (n = 10)	Anzali (n = 10)	Rudsar (n = 10)	Tonekabon (n = 10)
Pb	0.284** ± 0.05	0.298** ± 0.04	0.236** ± 0.03	0.332** ± 0.06	0.329** ± 0.03
Cd	0.103** ± 0.04	0.135** ± 0.05	0.086** ± 0.05	0.130** ± 0.05	0.126** ± 0.04
Hg	0.050** ± 0.00	0.018** ± 0.00	0.037** ± 0.01	0.060** ± 0.01	0.041** ± 0.00
Cr	0.084** ± 0.01	0.111** ± 0.00	0.141** ± 0.00	0.119** ± 0.00	0.081** ± 0.02
As	0.023** ± 0.00	0.013** ± 0.00	0.006** ± 0.00	0.011** ± 0.00	0.022** ± 0.00
Cu	1.135 ns ± 0.15	1.303 ns ± 0.22	1.308 ns ± 0.41	1.161 ns ± 0.15	1.610 ns ± 0.13
Mn	2.500** ± 0.27	1.825** ± 0.29	2.051** ± 0.15	2.507** ± 0.26	3.485** ± 0.09
Zn	4.210** ± 0.14	4.293** ± 0.66	4.297** ± 0.45	3.406** ± 0.33	4.591** ± 0.14
Ni	0.120** ± 0.03	0.082** ± 0.01	0.075** ± 0.00	0.110** ± 0.01	0.091** ± 0.02
Fe	15.381** ± 1.22	15.203** ± 0.70	14.037** ± 1.11	13.693** ± 4.45	16.017** ± 0.23
Co	2.044** ± 0.30	2.999** ± 0.09	2.306** ± 0.30	2.304** ± 0.29	2.562** ± 0.09
Al	0.021** ± 0.00	0.017** ± 0.01	0.013** ± 0.00	0.033** ± 0.00	0.031** ± 0.01
V	0.018** ± 0.01	0.006** ± 0.00	0.008** ± 0.00	0.006** ± 0.00	0.019** ± 0.01
Sn	0.006** ± 0.00	0.021** ± 0.01	0.031** ± 0.00	0.027** ± 0.00	0.027** ± 0.00
Ti	0.0147** ± 0.00	0.009** ± 0.00	0.015** ± 0.00	0.005** ± 0.00	0.006** ± 0.00
	Nowshahr (n = 10)	**Fereydunkenar (n = 10)**	**Behshahr (n = 10)**	**Bandar-e Torkaman (n = 10)**	**Hojanepes (n = 10)**
Pb	0.277** ± 0.05	0.357** ± 0.00	0.365** ± 0.08	0.401** ± 0.07	0.424** ± 0.10
Cd	0.109** ± 0.04	0.117** ± 0.05	0.159** ± 0.07	0.175** ± 0.08	0.224** ± 0.05
Hg	0.044** ± 0.01	0.027** ± 0.00	0.046** ± 0.00	0.030** ± 0.00	0.050** ± 0.01
Cr	0.159** ± 0.01	0.147** ± 0.00	0.085** ± 0.01	0.098** ± 0.00	0.130** ± 0.01
As	0.027** ± 0.00	0.013** ± 0.00	0.028** ± 0.00	0.018** ± 0.00	0.031** ± 0.00
Cu	1.398** ± 0.79	1.471** ± 0.78	1.811** ± 0.53	1.770** ± 0.38	1.444** ± 0.69
Mn	1.959** ± 0.30	1.233** ± 0.31	1.546** ± 0.21	1.976** ± 0.24	2.700** ± 0.35
Zn	3.699** ± 0.14	3.574** ± 0.66	3.670** ± 0.34	2.923** ± 0.55	4.000** ± 0.09
Ni	0.099** ± 0.03	0.065** ± 0.00	0.057** ± 0.00	0.089** ± 0.01	0.070** ± 0.02
Fe	9.148** ± 6.06	15.930** ± 2.72	13.203** ± 1.34	12.325** ± 4.50	14.937** ± 0.24
Co	1.560** ± 0.18	2.225** ± 0.31	1.738** ± 0.17	1.844** ± 0.23	2.170** ± 0.17
Al	0.014** ± 0.00	0.011** ± 0.00	0.005** ± 0.00	0.024** ± 0.00	0.023** ± 0.01
V	0.011** ± 0.00	0.003** ± 0.00	0.004** ± 0.00	0.003** ± 0.00	0.011** ± 0.00
Sn	0.004** ± 0.00	0.017** ± 0.01	0.023** ± 0.00	0.020** ± 0.00	0.020** ± 0.00
Ti	0.009** ± 0.00	0.005** ± 0.00	0.011** ± 0.00	0.004** ± 0.00	0.003** ± 0.00

ns: not significant p > 0.05; **: Significant level is 0.01.

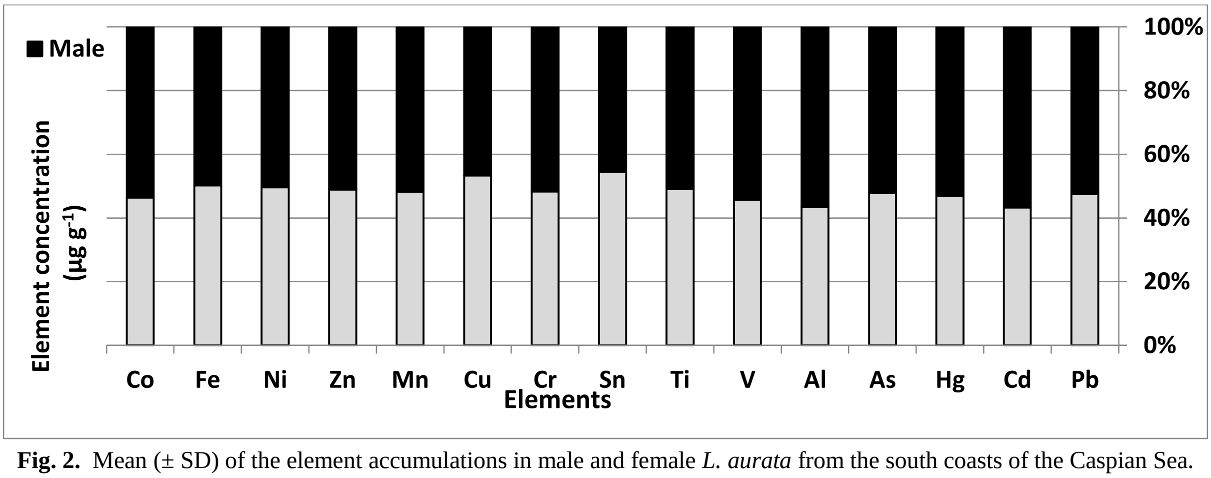

Fig. 2. Mean (± SD) of the element accumulations in male and female *L. aurata* from the south coasts of the Caspian Sea.

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Table 2. Mean (± SD) and the significant level of element concentrations (μg g^{-1} wet weight) in tissues of male and female *Liza aurata* in the southern coasts of the Caspian Sea.

element	muscle			Liver			Gills		
	Male	**Female**	**Sig.**	**Male**	**Female**	**Sig.**	**Male**	**Female**	**Sig.**
Pb	0.3481 ± 0.07	0.3147 ± 0.081	0.105	0.4863 ± 0.085	0.4473 ± 0.095	0.099	0.3417 ± 0.074	0.3202 ± 0.075	0.263
Cd	0.1561 ± 0.05	0.1191 ± 0.07	0.029	0.2780 ± 0.07	0.2137 ± 0.08	0.003	0.2149 ± 0.06	0.1902 ± 0.05	0.076
Hg	0.0432 ± 0.01	0.0382 ± 0.01	0.199	0.1372 ± 0.02	0.1169 ± 0.02	0.009	0.1051 ± 0.02	0.0861 ± 0.02	0.017
Cr	0.1198 ± 0.02	0.1118 ± 0.02	0.295	0.3052 ± 0.03	0.2717 ± 0.02	0.000	0.2087 ± 0.05	0.1862 ± 0.04	0.186
As	0.0203 ± 0.00	0.0186 ± 0.00	0.511	0.0506 ± 0.02	0.0495 ± 0.02	0.946	0.0332 ± 0.01	0.0317 ± 0.01	0.831
Cu	1.3428 ± 0.41	1.5337 ± 0.57	0.147	29.2984 ± 5.38	24.9083 ± 7.49	0.031	21.9918 ± 6.62	17.9690 ± 5.87	0.037
Mn	2.2601 ± 0.66	2.1022 ± 0.65	0.359	13.7971 ± 3.26	13.3131 ± 2.89	0.404	10.3894 ± 3.83	9.4296 ± 3.09	0.230
Zn	3.6534 ± 0.42	3.4988 ± 0.61	0.262	14.3028 ± 2.03	14.5373 ± 2.17	0.434	9.0115 ± 2.48	9.6943 ± 2.72	0.234
Ni	0.0768 ± 0.02	0.0756 ± 0.02	0.849	0.1461 ± 0.03	0.1498 ± 0.04	0.795	0.1085 ± 0.02	0.1109 ± 0.02	0.597
Fe	13.9251 ± 2.98	14.0465 ± 3.81	0.892	97.3733 ± 9.95	88.760 ± 6.56	0.000	76.3067 ± 10.77	70.0467 ± 9.91	0.024
Co	2.3397 ± 0.47	2.0220 ± 0.37	0.006	13.2462 ± 2.45	12.4009 ± 2.46	0.245	9.2217 ± 1.89	8.6261 ± 2.14	0.280
Al	0.0222 ± 0.01	0.0170 ± 0.01	0.290	0.0426 ± 0.01	0.0393 ± 0.01	0.659	0.0322 ± 0.01	0.0266 ± 0.01	0.143
V	0.0101 ± 0.00	0.0085 ± 0.00	0.454	0.0307 ± 0.01	0.0240 ± 0.01	0.020	0.0187 ± 0.01	0.0131 ± 0.00	0.031
Sn	0.0209 ± 0.00	0.0250 ± 0.05	0.198	0.0330 ± 0.00	0.0381 ± 0.08	0.057	0.0195 ± 0.00	0.0252 ± 0.00	0.044
Ti	0.0103 ± 0.01	0.0099 ± 0.01	0.774	0.0259 ± 0.01	0.0279 ± 0.00	0.328	0.0200 ± 0.01	0.0201 ± 0.01	0.942

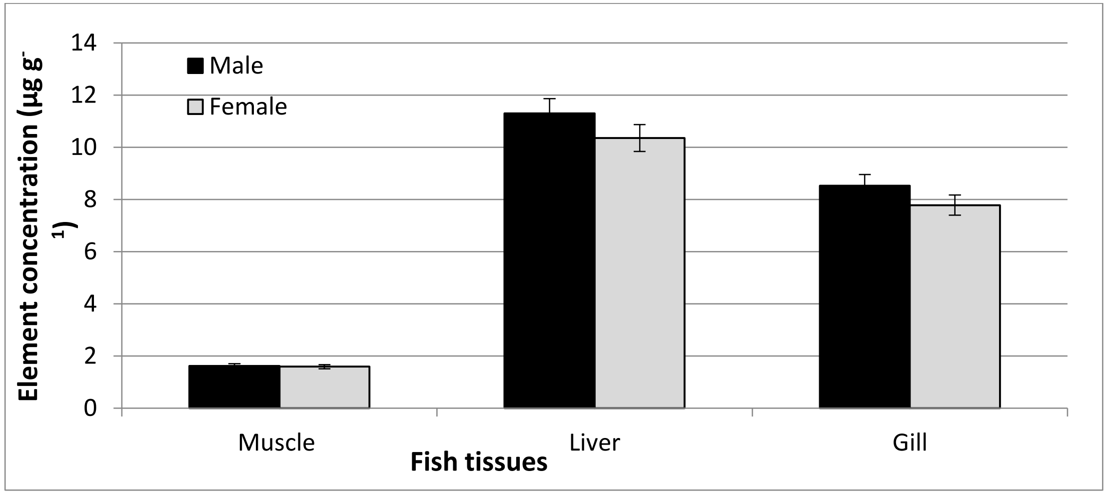

Fig. 3. Mean (± SD) of the element accumulations in some tissues of *L. aurata* from the south coasts of the Caspian Sea.

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Furthermore, the Pearson correlations revealed that there is no significant correlation between Hg, Cr, Ni, Fe, Co, Sn and Ti with the weight and total length. However, a strong, significant negative correlation was found between Pb, Cd, As, Zn, Al, Cu, Mn, V and these two items ($P < 0.05$). The element accumulations in this fish muscle were different exhibiting the highest Fe (13.988 ± 3.4), while the lowest V (0.0009 ± 0.00079) levels per µg g^{-1} wet weight (Table 3). In addition, Table 4, depicts the selected RFD values of 15 trace elements and the calculated results of the THQ for fish consumption. According to Table 5, the THQ values of each element, based on the average accumulations in fish muscle, were decreased in the following order: Hg>Mn>Cd>Co>Ti>Pb>Cu>Cr>Fe>Zn>As>Ni>Sn>Al, V. The hazard risk, the permissible limit of consumption, and the number of elements in a month is presented in Table 4. The HI for all the 15 elements was lower than 1, ranging from zero for Aluminum to 0.22 for Mercury.

DISCUSSION

The trace elements between sampling sites were significantly different. This may be due to differences in pollutant sources in sampling sites. The accumulation of trace elements increased from the southwest to the southeast coasts. The comparison of the data obtained from the fish muscle tissues with the WHO guideline exhibited that the concentrations of all the trace elements (Fe, Zn, Cu, Pb, Cd, Cr, Hg, Ni, As, Sn, Al, V, Ti) were lower than the global standard levels for these elements except for Mn and Co. Increased concentrations of cobalt and manganese may be mainly due to sewage disposal and evacuation to groundwater works by painting workshops, alloys and casting industries in the coasts of the Caspian Sea (Esmaili Sari 2002). In general, accumulation of some elements (Hg, Cd, Tl, Pb, Mn, Co, and Cu) in the *L. aurata* tissues can be due to the oil exploitation and transfer in the neighboring countries, discharging various kinds of urban, industrial, and agricultural wastewaters (because of the scattered cultivation of different agricultural products and the production of wastewater contaminated by chemical poisons and fertilizers) from the coast into the sea, unregulated traffic of oil tankers, merchant vessels, and yachts. *Liza aurata* are an omnivore fish, so it can be exposed to a high amount of these elements (Pazooki *et al*. 2009; Elsagh 2011). In the present study, the element accumulations in the fish muscles were not significantly different between sexes ($P > 0.05$). Some authors reported that the trace element concentrations in male and female fish are not significantly different including *Pagruss auratus*, *Platycephalus bassenssis* and *Neoplatycephalus richardsoni* (Fabris *et al.* 2006) and *Abramis brama* (Farkas *et al.* 2003). There is a significant inverse correlation between Pb, Cd, As, Zn, Al, Cu, Mn, V and the fish size (weight and total length). This inverse correlation may be due to the higher metabolic rate in young than in adult fish. There is a direct relationship between the metabolic rate and element accumulation levels in aquatic animals. Anan *et al*. (2005) reported that an increase in body size reduces element concentration in the bonyfish muscles of the Caspian Sea. Element accumulation in the fish gills is the first sign of water pollution, so gills can play an important role in revealing the total element levels in water (Canli & Atli 2003). In general, the different metal levels in the fish tissues depend on their physiological function. In addition, behavioral and dietary habits are another factors influencing the element accumulations in different organs of the fish body (Al-Yousuf *et al*, 2000; Carvalho *et al*. 2005). Moreover, the liver is considered as an environmental indicator for the assessment of water pollution because of the element tendency to accumulate in high levels compared to other tissues (Yilmaz 2009). As muscle in the most fish species throughout the world is the main part of the human diet, ensuring lowered accumulation of trace elements in this tissue compared to the liver and gill is very important. In this study, the highest trace element concentrations was found in the liver, followed by gills and the lowest in fish muscle. Target organs, such as liver and gills are metabolically active tissues, and metal accumulations have been reported in higher levels in these tissues compared to muscle in many mullet species as well as in the various fish species (Filazi *et al*. 2003; Abdolahpur Monikh *et al*. 2013; Yap *et al.* 2015; Çulha *et al*. 2016; Keshavarzi *et al.* 2018; Łuczyńska *et al*. 2018). Table 6 indicates a general overview in the order of trace element accumulations in the muscle of different marine and freshwater fish species. Based on the results, in most cases, Fe, Cu, Zn, and Co exhibited the highest concentration compared to the other examined elements. The reverse case can be observed for Sn, Ti and V. The obtained pattern of the elements accumulation in the present study is in general agreement with those reported by other authors worked on the other examined fish species (Table 6).

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Table 4. Average and standard deviation of the element accumulation in muscle, the permissible limit of consuming elements, and the amount of daily and weekly accumulation of each elements by children and adult bodies.

	Element accumulation	Wet Metal accumulation	WHO Standard	RfD	Adults' EDI	Children's EDI	Adults' EWI	Children's EWI	PTWI	EWI/PTWI Adult's	EWI/PTWI Children's
Pb	1.65 ± 0.39	0.330 ± .079	0.4	0.0035	0.179 ± .043	0.8670 ± .20870	1.257 ± .302	6.069 ± 1.460	25	0.050	0.242
Cd	0.68 ± 0.32	0.137 ± .065	0.2	0.001	0.074 ± .035	0.3589 ± .17279	0.520 ± .250	2.512 ± 1.209	7	0.074	0.359
Hg	0.2 ± 0.07	0.040 ± .015	0.5	0.0001	0.0221 ± .0082	0.1065 ± .03968	0.154 ± .057	0.745 ± 0.277	5	0.039	0.186
Cr	0.57 ± 0.14	0.115 ± .029	1.3	0.005	0.062 ± .0159	0.303 ± .07678	0.439 ± .111	2.121 ± .537	23.3	0.019	0.091
As	0.09 ± 0.04	0.019 ± .009	0.2	0.003	0.0105 ± .005	0.0508 ± .02590	0.073 ± .037	0.355 ± .181	15	0.005	0.024
Cu	7.20 ± 2.53	1.441 ± .507	10	0.037	0.7825 ± .275	3.777 ± 1.32984	5.477 ± 1.928	26.442 ± 9.308	3500	0.002	0.008
Mn	0.745 ± 0.277	2.178 ± .660	1	0.014	1.1826 ± .358	5.709 ± 1.73140	8.278 ± 2.510	39.964 ± 12.119	9800	0.008	0.041
Zn	10.89 ± 3.30	3.866 ± .614	100	0.3	2.0990 ± .333	10.133 ± 1.60968	14.693 ± 2.334	70.933 ± 11.267	7000	0.010	0.047
Ni	0.43 ± 0.013	0.086 ± .027	60-80	0.02	0.0467 ± .014	0.225 ± .07079	0.327 ± .102	1.579 ± .495	35	0.009	0.045
Fe	69.93 ± 17	13.987 ± 3.400	100	0.7	7.5934 ± 1.846	36.657 ± 8.91206	53.153 ± 12.92	256.603 ± 62.38	5600	0.009	0.046
Co	10.87 ± 2.26	2.175 ± .452	0.04-0.26	0.02	1.1810 ± .245	5.701 ± 1.18508	8.267 ± 1.718	39.909 ± 8.295	700	0.012	0.057
Al	0.09 ± 0.05	0.019 ± .011	1	1	0.0106 ± .006	0.051 ± .03092	0.074 ± .044	0.358 ± .216	7000	0.037	0.179
V	0.04 ± 0.03	0.009 ± .007	0.5	0.009	0.0050 ± .004	0.024 ± .02081	0.035 ± .030	0.170 ± .145	-	-	-
Sn	0.1 ± 0.05	0.020 ± .011	250	0.0086	0.0109 ± .006	0.052 ± .02908	0.076 ± .042	0.366 ± .203	14000	0.000	0.000
Ti	0.04 ± 0.02	0.008 ± .004	1-60	0.00008	0.0045 ± .002	0.021 ± .01294	0.031 ± .018	0.152 ± .090	100	0.000	0.002

(-) No Existing Information

Units: metal accumulation and wet metal accumulation: µg g^{-1}; Reference dose (RfD): µg g^{-1} bw in the daytime; amount of daily absorption (EDI): µg g^{-1} day^{-1}; amount of weekly absorption (EWI): µg g^{-1} $week^{-1}$; the standard for the maximum permissible limit of weekly absorption (PTWI): µg g^{-1} 70 kg^{-1} bw $week^{-1}$.

Table 5. The average and standard deviation of the HI, the permissible amount of consumption, and the permissible times of consumption in a month.

	THQ	Cr_{lim} for Children	Cr_{lim} for Adults	CR_{mm} for Children	CR_{mm} for Adults
Pb	0.051 ± 0.012	0.162 ± 0.038	0.782 ± 0.186	0.006 ± 0.001	0.014 ± 0.003
Cd	0.074 ± 0.035	0.138 ± 0.078	0.666 ± 0.377	0.005 ± 0.002	0.012 ± 0.007
Hg	0.220 ± 0.082	0.041 ± 0.019	0.202 ± 0.092	0.001 ± 0.000	0.003 ± 0.001
Cr	0.012 ± 0.003	0.673 ± 0.196	3.252 ± 0.948	0.025 ± 0.007	0.061 ± 0.017
As	0.003 ± 0.001	3.277 ± 2.490	15.823 ± 12.02	0.123 ± 0.093	0.299 ± 0.227
Cu	0.021 ± 0.007	0.424 ± 0.163	2.047 ± 0.791	0.016 ± 0.006	0.038 ± 0.015
Mn	0.084 ± 0.025	0.102 ± 0.036	0.496 ± 0.174	0.003 ± 0.001	0.009 ± 0.003
Zn	0.007 ± 0.001	1.157 ± 0.212	5.587 ± 1.027	0.043 ± 0.008	0.105 ± 0.019
Ni	0.002 ± 0.000	3.685 ± 1.101	17.790 ± 5.317	0.139 ± 0.041	0.337 ± 0.100
Fe	0.010 ± 0.002	0.829 ± 0.487	4.003 ± 2.352	0.031 ± 0.018	0.075 ± 0.044
Co	0.059 ± 0.012	0.139 ± 0.0298	0.672 ± .144	0.005 ± 0.001	0.012 ± 0.002
Al	0.000 ± 0.000	1357.575 ± 1572.625	6553.812 ± 7591.984	51.206 ± 59.318	124.147 ± 143.812

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V	0.000 ± 0.000	27.452 ± 21.821	132.528 ± 105.345	1.035 ± 0.823	2.510 ± 1.995
Sn	0.001 ± 0.000	13.780 ± 17.829	66.528 ± 86.071	0.519 ± 0.672	1.260 ± 1.630
Ti	0.056 ± 0.033	0.195 ± 0.153	1.079 ± 0.844	0.007 ± 0.005	0.020 ± 0.016
HI	0.065				

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
Acipenser persicus (n = ?)	Zn>V>Ni>Cd	<1		
Huso huso (n = 4)	Zn> Cd>V>Ni	<1	Southern Part of Caspian Sea, Iran	Mashroofeh *et al*. 2013
A. stellatus (n = 8)	Zn>V>Ni>Cd	<1		
Alosa caspia (n = 10)	Zn>Ni ≈ V	<1	southeast of the Caspian Sea, Iran	Sadeghi Bajgiran *et al.* 2016
Sander lucioperca (n = 10)	Zn>Ni ≈ V	<1		
Rutilus frisii kutum (n = 36)	Zn>Cu>Pb>Hg>Cd	<1	Southern Part of Caspian Sea, Iran	Monsefrad *et al.* 2012
Liza aurata (n = 48)	Cr>Cd	-	Bandar Anzali, Caspian Sea, Iran	Pazooki *et al.* 2009
fish species (n = 71)[1]	Zn>Fe>As>Cu>Hg>Mn>Cr>Ni>V>Pb	<1	Persian Gulf, Iran	Akhbarizadeh *et al.* 2018
fish species (n = 30)[2]	Ni > Hg > Cr > Pb	<1	Bandar Abbas, Persian Gulf, Iran	Malakootian *et al.* 2016
fish species (n = 50) [3]	Pb>Cd	<1	Persian Gulf, Iran	Khoshnood and Khoshnood, 2016
freshwater fish (n = 72)[4]	Zn>Cr>Cu>Pb>Cd>As	<1	Honghu Lake, China	Zhang *et al.* 2017
fish species (n = 255)[5]	Zn> Cr > Cu > Pb > Ni > Cd	<1	South China Sea	Gu *et al.* 2017
fish species (n = 22)[6]	Zn> Cr> Cu> As> Pb> Hg> Cd	<1	Lake Caizi, Southeast China	Jiang *et al.* 2016
fish species (n=16)[7]	Zn> Cu> Cr> As> Pb> Hg> Cd	<1		
fish species (n = 20)[8]	Zn>Cu>Hg	<1	Pluszne Lake, Poland	Łuczyńska *et al.* 2018
Scorpaena porcus (n =10)	Al > Cu > As > Pb > Ni > Cd = Hg > U	<1	Black Sea, Turkey	Çulha *et al.* 2016
fish species (n = 44)[9]	As>Pb>Zn>Fe>Ni>Mn>Cr>Co>Cd>Cu	<1	Turkey	Varol & Sünbül 2018
fish species (n = 20)[10]	Zn> Cu > Hg > Pb > Cd	-	Sarikum Lake, Turkey	Bat *et al.* 2019
Chelon auratus	Pb> Hg > Cd	<1	Southern Black Sea coasts, Turkey	Bat *et al.* 2018
fish species (n = ?)[11]	Pb>Cd	<1	Balik Lake, Turkey	Bat *et al.* 2015

1: *Alepes djedaba, Epinephelus coioides, Sphyraena jello, Platycephalus indicus*; 2: *Thunnus tonggol, Liza klunzingeri*; 3: *Lutjanus johnii, Lutjanus lemniscatus, Sillago sihama, Liza subviridis, Acanthopagrus latus, Pampus argentus;4: Hypophthalmichthys nobilis, Carassius auratus, Ctenopharyngodon idellus, Siniperca chuatsi, Ctenopharyngodon idellus, Pelteobagrus fulvidraco; 5: Thunnus obesus, Decapterus lajang, Cubiceps squamiceps and Priacanthus macracanthus;6: Aristichthys nobilis, Hypophthalmichthys molitrix, Ctenopharyngodon idellus, Cyprinus carpio, Culter alburnus;7: Megalobrama amblycephala, Carassius auratus, Silurus asotus;8: Perca fluviatilis, Rutilus rutilu; 9: Luciobarbus esocinus, Capoeta umbla,Cyprinus carpio, Luciobarbus mystaceus, Capoeta trutta; 10: Cyprinus carpio, Platichthys flesus,Liza aurata, Mugil cephalus; 11: Mugil cephalus, Cyprinus carpio , Perca fluviatilis, Stizostedion lucioperca.*

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Each EWI value of trace elements was significantly lower than the respective provisional tolerable weekly intakes (PTWI). In other words, there is no significant risk of consuming *L. aurata* captured from the southern coasts of the Caspian Sea, when only Pb, Cd, Hg, As, Al, V, Sn, Ti Cr, Cu, Mn, Zn, Ni, Fe, and Co are taken into consideration. EWI/PTWI values was selected to compare the potential health risks of different trace elements. EWI/ PTWI values of wild fish muscle were decreased in the following order: Cd>Pb>Hg>Al> Cr>Co>Zn>Fe≈Ni> Mn >As>Cu>Ti≈Sn, V. The above calculation results revealed that Cd, Pb, Hg, Al, and Cr were the major contributors of the non-carcinogenic risk of local inhabitants from fish consumption. Similar results have also been reported for Cr and Pb (Jiang *et al.* 2016; Zhang *et al*. 2017). The limitations of fish consumption based on EWI are listed in Table 4. Calculating the HI illustrates that consumption of the *L. aurata* muscles in which trace elements have a value lower than 1 (0.065), hence, its consumption in this region (i.e. the southern coasts of the Caspian Sea) does not impose a serious threat to the consumers. The amount of wet accumulation by the fish muscle, the permissible limit of consuming heavy metals (WHO 1996), and the daily and weekly accumulation of trace elements by adults and children are demonstrated in Table 4. Noteworthy, fish consumption is not the only way that trace elements can enter the human body. In this regard, consuming foods containing trace elements such as rice, wheat, and vegetables which constitute the largest part of the Iranian diet may enter more trace elements into the consumers' bodies. However, some considerations should be given regarding the consumption of the fish by infants and pregnant women. Because of the pattern of the heterogeneous fish consuming and its haphazard nature in Iran, it is possible that fishermen and even people who live nearby coasts, consume fish for an excessive number of times during a month. Thus, the concerned organizations (the Iranian Veterinary Organization, the Ministry of Health, etc.) are recommended to provide the consumers with a permissible amount of fish consumption information. It is noticeable that the highest levels of danger of non-cancerous diseases in trace elements are related to mercury, followed by cadmium, thallium, lead, and other elements such as arsenic, vanadium, tin, and aluminum, in the order of their appearance. Regarding the danger of non-cancerous diseases in trace elements, the highest danger is associated with manganese, cobalt, copper, and other elements such as chromium, zinc, nickel, iron, and aluminum (Zhang *et al.* 2017; 2018).

CONCLUSION

From the present study, it can be concluded that:

1. Analyses of the hazard risk of consuming *L. aurata* caught from the southern coasts of the Caspian Sea demonstrate that, according to the standards set by the WHO, the concentration of trace elements in this fish is permissible for human consumption, but the amount of its consumption by pregnant women and children should be subjected to some considerations.
2. 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 weight of consumers.
3. Regarding various sources of contamination heterogeneously are scattered on the southern coasts of the Caspian Sea, the accumulation levels related to *L. aurata* and other commercially important fish species are different. Therefore, the various regions of the Caspian Sea should be investigated regularly (every 3-5 years).
4. Due to the wide diversity in their diet, the sea fish have very large amounts of trace element accumulations in their tissues. Consequently, while we endeavor to increase the fish consumption per capita and including it in the people diet, we should also pay serious attention to the safety of aquatic foods.

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REFERENCES

Abdolahpur Monikh, F, Safahieh, A, Savari, A, Ronagh, MT & 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. *Bulletin of Environmental Contamination and Toxicology*, 906: 691-696.

Akhbarizadeh, R, Moore, F, & Keshavarzi, B 2018, Investigating a probable relationship between microplastics and potentially toxic elements in fish muscles from northeast of Persian Gulf. *Environmental Pollution*, 232: 154-163.

Received: March 25. 2021 Accepted: June. 22. 2021
DOI: 10.22124/CJES.2021.4925
Article type: Research

Alipour, H & Banagar, G 2018, Health risk assessment of selected heavy metals in some edible fishes from Gorgan Bay, Iran. *Iranian Journal of Fisheries Science*, 171: 21-34.

Alizadeh, S & Mirarab-Razi, J 2016, Growth and accumulation responses of *Populus nigra* L. exposed to hexavalent chromium excess', *Caspian Journal of Environmental Sciences*, 14: 253-261.

Al-Yousuf, MH, El-Shahawi, MS & Al-Ghais, SM 2000. Trace metals in liver, skin and muscle of *Lethrinus lentjan* fish species in relation to body length and sex. *Science of the Total Environment*, 256: 87-94.

Anan, Y, Kunito, T, Tanabe, S, Mitrofanov, I & Aubrey, DG 2005, Trace element accumulation in fishes collected from coastal waters of the Caspian Sea. *Marine Pollution Bulletin*, 518-12: 882-888 https://doiorg/101016/jmarpolbul200506038

Anim, AK, Ahialey, EK, Duodu, GO, Ackah, M & Bentil, NO 2011, Accumulation profile of heavy metals in fish smples from Nsawam, along the Densu River, Ghana. *Research Journal of Environmental and Earth Sciences*, 31: 56–60.

Bat, L, Arıcı, E, Sezgin, M & Şahin, F 2015, Heavy metal levels in the liver and muscle tissues of the four commercial fishes from Lake Balik, Kızılırmak Delta (Samsun, Turkey). *Journal of Coastal Life Medicine*, 3: 950-955. doi: 0.12980/jclm.3.2015j5-224

Bat, L, Şahin, F & Öztekin, A 2018, Toxic metal amounts in Chelon auratus (Risso, 1810): a potential risk for consumer's health. *Journal of Aquaculture & Marine Biology*, 7: 303-306. doi: 10.15406/jamb.2018.07.00225

Bat, L, Yardım, Ö, Öztekin, A & Sahin, F 2019, Bioaccumulation of metals in fish from Sarikum Lake. *Aquatic Science and Technology*, 7: 1-7.

Canli, M & Atli, G 2003. The relationships between heavy metal (Cd, Cr, Cu, Fe, Pb, Zn) levels and the size of six Mediterranean fish species. *Environmental Pollution*. 121: 129–136.

Carvalho, GP, Cavalcante, PRS, Castro ACL & Rosaj MOAI 2005. Preliminary assessment of heavy metal levels in *Mytella falcate* (Bivalvia, Mytilidae) from Bacanga River estuary, Sao Luis, State of Maranhao, Northeastern Brazil. *Revista Brasileira de Biologia*, 60: 1-7.

Chien, LC, Hung, TC, Choang, KY, Yeh, CY, Meng, PJ, Shieh, MJ & Han, BC 2002, Daily intake of TBT, Cu, Zn, Cd and As for fishermen in Taiwan. *Science of The Total Environment*, 2851–3: 177–185. https://doiorg/101016/S0048-9697(01)00916-0

Cooper, CB, Doyle, ME & Kipp, K 1991, Risks of consumption of contaminated seafood: the Quincy Bay case study. *Environmental Health Perspectives*, 90: 133–140. https://doiorg/101289/ehp90-1519503

Çulha, ST, Yabanl, M, Baki, B & Yozukmaz, A 2016, Heavy metals in tissues of scorpionfish (*Scorpaena porcus*) caught from Black Sea (Turkey) and potential risks to human health. *Environmental Science and Pollution Research*, 23: 20882–20892. https://doiorg/101007/s11356-016-7337-2

Elsagh, A 2011, Determination of some heavy metals in *Rutilus frisii kutum* and *Cyprinus carpio* fillet from south Caspian Sea. *Veterinary Researches and Biological Products*, 23: 33-44.

EPA 1989, Office of Marine and Estuarine Protection (WH-556f), Washington, DC. EPA-503/8-89-002

EPA method, Revision 1 2007, Microwave assisted acid digestion of sediments, sledges, soils and oils, EPA, USA. 3051A - 30

Esmaili Sari, A 2002. Pollution, health and environmental standards. University Press, Tarbiat Modares, 767 p.

Fabris, G, Turoczy, NJ & Stagnitti, F 2006, Trace metal concentrations in edible tissue of snapper, flathead, lobster, and abalone from coastal waters of Victoria, Australia. *Ecotoxicology and Environmental Safety*, 63: 286–292. https://doiorg/101016/jecoenv200411006

Farkas, A Salánki, J & Specziár, A 2003, Age- and size-specific patterns of heavy metals in the organs of freshwater fish Abramis brama L populating a low-contaminated site. *Water Research*, 37: 959–964. https://doiorg/101016/S0043-1354(02)00447-5

Filazi, A, Baskaya, R, Kum, C & Hismiogullari, SE 2003, Metal concentrations in tissues of the Black Sea fish *Mugil auratus* from Sinop-Icliman, Turkey. *Human & Experimental Toxicology*, 22: 85–87. https://doiorg/101191/0960327103ht323oa

Forouhar Vajargah, M., Sattari, M., Imanpur, J. and Bibak, M., 2020a. Length-weight relationship and some growth parameters of *Rutilus kutum* (Kaminski 1901) in the South Caspian Sea. E*xperimental animal Biology*, 9: 11-20.

Received: March 25. 2021 Accepted: June. 22. 2021
Article type: Research

Forouhar Vajargah, M., Sattari, M., Imanpour Namin, J. and Bibak, M., 2020b. Length-weight, length-length relationships and condition factor of *Rutilus kutum* (Actinopterygii: Cyprinidae) from the southern Caspian Sea, Iran. *Journal of Animal Diversity*, 2: 56-61.

Forouhar Vajargah, M., Sattari, M., Imanpour Namin, J., Bibak, M. 2021a. Evaluation of trace elements contaminations in skin tissue of Rutilus kutum Kamensky 1901 from the south of the Caspian Sea, *Journal of Advances in Environmental Health Research*, doi: 10.22102/jaehr.2021.259190.1201

Vajargah, M.F., Sattari, M., Namin, J.I. and Bibak, M., 2021b. Predicting the Trace Element Levels in Caspian Kutum (Rutilus kutum) from South of the Caspian Sea Based on Locality, Season and Fish Tissue. Biological Trace Element Research, pp.1-10.

Genc, TO & 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. Tarbiat Modares University*, 20: 71–82. Retrieved from http://jast-oldmodaresacir/article_17716html

Gu, YG, Lin, Q, Huang, HH, Wang, L, Ning, JJ & Du, FY 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 Pollution Bulletin*, 114: 1125–1129. https://doiorg/101016/JMARPOLBUL201610040

Janbakhsh, S, Hosseini Shekarabi, S & Shamsaie Mergan, M. 2018, Nutritional value and heavy metal content of fishmeal from the Southwest Caspian Sea. *Caspian Journal of Environmental Sciences,* 16: 307-317. doi: 10.22124/cjes.2018.3200

Jiang, H, Qin, D, Chen, Z, Tang, S, Bai, S & Mou, Z 2016, Heavy Metal Levels in Fish from Heilongjiang River and Potential Health Risk Assessment. *Bulletin of Environmental Contamination and Toxicology*, 97: 536–542. https://doiorg/101007/s00128-016-1894-4

Johari, S, Sourinejad, I, Asghari, S, Bärsch, N 2015, Toxicity comparison of silver nanoparticles synthesized by physical and chemical methods to tadpole (*Rana ridibunda*). *Caspian Journal of Environmental Sciences,* 13: 383-390.

Keshavarzi, B, Hassanaghaei, M, Moore, F, Rastegari Mehr, M, Soltanian, S, Lahijanzadeh, AR & Sorooshian, A 2018, Heavy metal contamination and health risk assessment in three commercial fish species in the Persian Gulf. *Marine Pollution Bulletin*, 129(1), 245–252. https://doiorg/101016/JMARPOLBUL201802032

Lakshmanan, R, Kesavan, K, Vijayanand, P, Rajaram, V & Rajagopal, S 2009, Heavy Metals Accumulation in Five Commercially Important Fishes of Parangipettai, Southeast Coast of India Advance. *Journal of Food Science and Technology*, 1: 63–65.

Łuczyńska, J, Paszczyk, B & Łuczyński, M J 2018, Fish as a bioindicator of heavy metals pollution in aquatic ecosystem of Pluszne Lake, Poland, and risk assessment for consumer’s health. *Ecotoxicology and Environmental Safety*, 153: 60–67. https://doiorg/101016/jecoenv201801057

Malakootian, M, Mortazavi, MS & Ahmadi, A 2016, Heavy metals bioaccumulation in fish of southern Iran and risk assessment of fish consumption. *Environmental Health Engineering And Management Journal*, 3: 61–68. https://doiorg/1015171/EHEMJ201602

Monsefrad, F, Imanpour Namin, J & Heidary, S 2012, Concentration of heavy and toxic metals Cu, Zn, Cd, Pb and Hg in liver and muscles of Rutilus frisii kutum during spawning season with respect to growth parameters. *Iranian Journal of Fisheries Sciences*, 11: 825–839. Retrieved from http://jifroir/article-1-741-enhtml

MOOPAM (Manual of oceanographic observations and pollutant analyses methods) 2010, MOOPAM 2010: Regional Organization for the Protection of the Marine Environment, Kuwait. 54 p.

Nejat, S, Hermidas Bavand, D & Farshchi, P 2018, Environmental challenges in the Caspian Sea and international responsibility of its littoral states, *Caspian Journal of Environmental Sciences*, 16: 97-110. doi: 10.22124/cjes.2018.2953

Pazooki, J, Abtahi, B & Rezaei, F 2009, Determination of Heavy Metals (Cd, Cr) in the Muscle and Skin of *Liza aurata* from the Caspian Sea (Bandar Anzali). *Environmental Science*, 7: 21–32.

Sadeghi Bajgiran, S, Pourkhabbaz, A, Hasanpour, M & Sinka Karimi, M 2016, A study on Zinc, Nickel, and Vanadium in fish muscle of Alosa caspia and Sander lucioperca and food risk assessment of its consumption in the southeast of the Caspian Sea. *Iranian Journal of Health and Environment*, 8: 423–432. Retrieved from http://ijhetumsacir/article-1-5440-enhtml

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Sattari, M, Namin, JI, Bibak, M, Vajargah, MF, Faggio, C & Haddad, MS 2019a. Trace and macro elements bioaccumulation in the muscle and liver tissues of *Alburnus chalcoides* from the south Caspian Sea and potential human health risk assessment. *Journal of Energy, Environmental & Chemical Engineering*, 1: 13-20.

Sattari, M., Imanpour, J., Bibak, M., Forouhar Vajargah, M. and Khosravi, A, 2019b. Investigation of metal element concentrations in tissue of *Rutilus frisii* in the Southwest Caspian Sea. *Iranian Scientific Fisheries Journal*, 28: 149-161

Sattari, M., Namin, J.I., Bibak, M., Vajargah, M.F., Hedayati, A., Khosravi, A. and Mazareiy, M.H., 2019c. Morphological comparison of western and eastern populations of Caspian kutum, *Rutilus kutum* (Kamensky, 1901; Cyprinidae) in the southern Caspian Sea. *International Journal of Aquatic Biology*, 6: 242-247.

Sattari, M, Bibak, M, Bakhshalizadeh, Sh & Forouhar Vajargah, M 2020a. Element accumulations in liver and kidney tissues of some bony fish species in the Southwest Caspian Sea. *Journal of Cell and Molecular Research*, 12: 33-40.

Sattari, M., Imanpour Namin, J., Bibak, M., Forouhar Vajargah, M. and Mazareiy, M.H., 2020b. Trace elements contamination in Alosa braschnikowi of the southern basins of Caspian Sea-Guilan Province. *Journal of Animal Environment*, 12: 115-122.

Sattari, M, Bibak, M, Bakhshalizadeh, S & Forouhar Vajargah, M 2020c, Element accumulations in liver and kidney tissues of some bony fish species in the Southwest Caspian Sea. *Journal of Cell and Molecular Research*, 12: 33-40.

UNEP/FAO/IAEA/IOC 1984, Sampling of Selected Marine Organisms and Sample Preparation for Trace Metal Analysis 1984: Reference Method for Marine Pollution Studies, Nairobi. 34 p.

US-EPA (United States Environmental Protection Agency) 2000, Risk-based concentration table, Philadelphia. 89 p.

USEPA (United States Environmental Protection Agency) 2000, Guidance for assessing chemical contamination data for use in fish advisories 2000: Risk Assessment and Fish Consumption Limits, EPA/823–B94-004, Washington DC. 383 p.

Varol, M & Sünbül, MR 2018, Multiple approaches to assess human health risks from carcinogenic and non-carcinogenic metals via consumption of five fish species from a large reservoir in Turkey. *Science of The Total Environment*, 633: 684–694. https://doiorg/101016/JSCITOTENV201803218

WHO (World Health Organization) 1996, Guidelines for drinking-water quality 1996: Health criteria and other supporting information, Geneva. 973 p.

Yabanli, M, Alparslan, Y, Hasanhocaoglu Yapici, H, Yapici, S, Yozukmaz, A 2016, Determination of heavy metal content in commercial marine fish hunted From Southeast Aegean Sea (Turkey) and their potential risk for public health. *Caspian Journal of Environmental Sciences*, 14: 1-13.

Yap, CK, Jusoh, A, Leong, WJ, Karami, A & Ong, GH 2015, Potential human health risk assessment of heavy metals via the consumption of tilapia Oreochromis mossambicus collected from contaminated and uncontaminated ponds. *Environmental Monitoring and Assessment*, 187: 584. https://doiorg/101007/s10661-015-4812-z

Yilmaz, F 2009. The comparison of heavy metal concentrations (Cd, Cu, Mn, Pb, and Zn) in tissues of three economically important fish (*Anguilla anguilla, Mugil cephalus* and *Oreochromis niloticus*) inhabiting Köycegiz Lake-Mugla (Turkey). *Turkish Journal of Science and Technology*, 4: 7-15.

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