The concentration and probabilistic risk assessment of potentially toxic elements in fillets of silver pomfret (Pampus argenteus): A global systematic review and meta-analysis

Mohammadreza Alipour1, Mansour Sarafraz1, Hossein Chavoshi2, Abotaleb Bay3, Amene Nematollahi4, Mohsen Sadani5,*, Yadolah Fakhri6,*, Yasser Vasheghian7, Amin Mousavi Khaneghah8

1Student Research Committee, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, 1417653911, Iran
2Department of Anatomy, Shahid Beheshti University of Medical Sciences, Tehran, 1417653911, Iran
3Environmental Health Research Center, Golestan University of Medical Sciences, Golestan, 4934174515, Iran
4Department of Food Safety and Hygiene, School of Health, Fasa University of Medical Sciences, Fasa, 8668874616, Iran
5Department of Environmental Health Engineering, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, 1417653911, Iran
6Food Health Research Center, Hormozgan University of Medical Sciences, Bandar Abbas, 7916839319, Iran
7Institute of Research and Development, Duy Tan University, Da Nang 550000, Vietnam
8Department of Food Science Faculty of Food Engineering, University of Campinas (Unicamp), Rua Monteiro Lobato 80 Caixa 6121 Campinas, São Paulo, 13083-862, Brazil

ABSTRACT

The contamination of fish type products such as silver pomfret fish fillets by potentially toxic elements (PTEs) has raised global health concerns. Related studies regarding the concentration of PTEs in fillets of silver pomfret fish were retrieved among some international databases such as Scopus, PubMed and Embase between 1 January 1983 and 10 March 2020. The pooled (mean) concentration of PTEs in fillets of silver pomfret fish was meta-analyzed with the aid of a random-effect model (REM). Also, the non-carcinogenic risk was estimated via calculating the 95th percentile of the total target hazard quotient (TTHQ). The meta-analysis of 21 articles (containing 25 studies or data reports) indicated that the ranking of PTEs in fillets of silver pomfret fish was Fe (11,414.81 μg/kg wet weight, ww) > Zn (6055.72 μg/kg ww) > Cr (1825.79 μg/kg ww) > Pb (1486.44 μg/kg ww) > Se (1053.47 μg/kg ww) > Cd (992.50 μg/kg ww) > Ni (745.23 μg/kg ww) > Cu (669.71 μg/kg ww) > total As (408.24 μg/kg ww) > Co (87.03 μg/kg ww) > methyl Hg (46.58 μg/kg ww). The rank order of health risk assessment by country based on the TTHQ for adult consumers was Malaysia.
Introduction

Elements can be divided into two main groups: those commonly known as trace elements (which at low concentrations are essential for human health) such as Iron (Fe), potassium (K), phosphorus (P), Calcium (Ca), Sodium (Na), selenium (Se) and Magnesium (Mg); and heavy metals or toxic metals (which even at low concentrations can cause some health issues) such as mercury (Hg), Nickel (Ni), Lead (Pb), Tin (Sn), Arsenic (As), Cadmium (Cd), Cobalt (Co) and Chromium (Cr) (Atamaleki et al., 2020; Borzoei et al., 2018; Moradi et al., 2020b; Mostafaii et al., 2020). All elements (trace elements and/or heavy metals), without considering their concentration, can be defined as potentially toxic elements (PTEs) (Abedi et al., 2020; Mousavi Khaneghah et al., 2020).

PTEs can be released into the environment from different sources, such as domestic and industrial waste discharge, agricultural activities, geological weathering, industrial and mining activities, atmospheric deposition, and improper solid waste disposal (Atamaleki et al., 2019; Borzoei et al., 2019; Fakhri et al., 2019a; Henry et al., 2006; Mwakalapa et al., 2019; Rezaei et al., 2019b; Su, 2014; Zhang et al., 2010). Exposure to PTEs may lead to some adverse effects on the nervous system, liver, lung, heart, kidney and bones of humans as well as animals (Djahed et al., 2018; Fakhri et al., 2019a; Ghaniean et al., 2017; Keramati et al., 2018; Moradi et al., 2020b), besides some teratogenic, carcinogenic, and mutagenic effects (Fakhri et al., 2017b; Fathabad et al., 2018; Khan et al., 2015).

Consumption of seafood is mostly considered beneficial to human health due to offering some essential elements, such as calcium, phosphorus, and selenium (Iagodic et al., 2020), high-quality proteins, omega fatty acids, and vitamins (D and E) (Ozogul and Ozogul, 2019; Ralston et al., 2019; Rimm et al., 2018). In this regard, the Food and Agriculture Organization (FAO) declared that global fish production increased by 2.1% and reached 178.8 million tons in 2018 (FAO, 2020).

The entrance of PTEs into the aquatic environment can lead to bioaccumulation in fish (Takarina et al., 2018). Although seafood consumption can offer many nutritional benefits for human health, due to the bioaccumulation and biomagnification properties of PTEs into fish tissue, long-term consumption can endanger human health (El-Moselhy et al., 2014; Ghasemidehkordi et al., 2018; Hadiani et al., 2015; Tajdaroranj et al., 2018). In addition to the concentration of PTEs in aquatic environments, which may affect their concentration in fish tissue (Xie et al., 2020), the bio-accumulation of PTEs in fish tissues are strongly dependent on feeding habits, feeding life, location, size, and age (Liu et al., 2020; Sankar et al., 2006; Xie et al., 2020).

One of the most preferred marine fish species, due to its high nutritive value and edibility, is silver pomfret (Pampus argenteus), which live mainly in the coastal seas of South Asia, Southeast Asia, and the Middle East (Lan et al., 2018; Rodríguez and Suárez, 2001). Silver pomfret fillet is rich with microelements (Se and Mg) and unsaturated fatty acids that protect against coronary atherosclerosis, hyperlipidemia, and high cholesterol and other cardiovascular diseases (Inanli et al., 2020; Zhao et al., 2005). Studies indicated that the consumer demand for silver pomfret fish has increased in recent years (Hu et al., 2019; Lan et al., 2018).

However, although several studies have been carried out to measure the concentrations of PTEs in silver pomfret around the world (Agah et al., 2009, Agah et al., 2010; Ahmed and Levent, 2016; Huque et al., 2014; Jarapala et al., 2014; Jeevanaraj et al., 2019; Liu et al., 2013, 2018; Mohamad et al., 2015; Salam et al., 2019; Xia et al., 2013; Yasmeen et al., 2016), no systematic review or meta-analysis of the data has been conducted. Therefore, the current study was aimed to investigate the concentration of PTEs (Total As, Se, Pb, Zn, total Cd, Cu, Fe, Ni, Cr, Co, and methyl Hg) in silver pomfret via the aid of a meta-analysis. In addition, a related health risk assessment for the ingestion of PTEs via consumption of silver pomfret was conducted for adults and children.

1. Materials and methods

1.1. Search strategy and selection criteria

A systematic review was conducted according to the Cochrane protocol (Higgins and Green, 2011) and the following search was done according to the PRISMA protocol (Fig. 1) (Liberati et al., 2009). In this regard, several international databases, including Scopus, PubMed, and Embase, were searched for publications up to 10 March 2020 to retrieve the related studies. The following keywords were used for retrieve articles including “heavy metals” or “trace metals” or metals or metal(oid)s or element or “toxic metal” or “toxic elements” and fish or seafood or “marine food” or “silver pomfret” or “Pampus argenteus” or “white pomfret” or pomfret. To obtain additional articles, the reference lists of articles were reviewed. The inclusion criteria were articles meeting the conditions: (1) the concentration of PTEs in fillets of silver pomfret; (2) cross-sectional study; (3) reporting of
the concentration of PTEs (mean, range and/or median); (4) full text published in English language (in order to avoid further mistakes during translation from other languages). Review articles and books, letters to editors, correspondence and conferences were excluded due to lack of a peer review process. In addition, experimental studies such as studies on the fate of PTEs in fillets of silver pomfret were excluded.

1.2. Data extraction

After the screening of retrieved articles, the following characteristics were extracted: county, year of study, location of sampling, sample size, the mean concentration (total As, Pb, Ni, Cd, Zn, Cu, Fe, Se, Total Cr, Co, and methyl Hg), standard deviation concentration (SD) and range of concentrations of PTEs, method of detection, Limit of detection (LOD), and limit of quantification (LOQ).

1.3. Meta-analysis

The pooled concentration of PTEs in fillets of silver pomfret was estimated with consideration of standard error (SE), as presented in Appendix A Table S1. The Chi-square test and I² index were used to determine heterogeneity among studies. If the I² index > 50%, heterogeneity is significant (Higgins et al., 2008; Quan and Zhang, 2003), therefore pooled concentrations of PTEs were calculated by the aid of a random effect model (REM) (Khaneghah et al., 2018; Kuroki et al., 2017).

1.4. Health risk assessment

Health risk assessment can provide more interpretable results regarding human exposure to contaminated environments (food, water, and air) (Atamaleki et al., 2019). All equations used in health risk assessment are presented in Appendix A Table S1 and per capita consumption of fish in Appendix A Table S2, followed by the main characteristics of included studies presented in Appendix A Table S3.

2. Results and discussion

2.1. The PTE concentrations in silver pomfret fillet in different countries

The rank of pooled concentrations of PTEs in fillets of silver pomfret fish was Fe (11,414.81 μg/kg ww) > Zn (6055.72 μg/kg wet weight, ww) > Cr (1825.79 μg/kg ww) > Pb (1486.44 μg/kg ww) > Se (1053.47 μg/kg ww) > Cd (992.50 μg/kg ww) > Ni (745.23 μg/kg ww) > Cu (669.71 μg/kg ww) > total As (408.24 μg/kg ww) > Co (87.03 μg/kg ww) > methyl Hg (46.58 μg/kg ww) (Table 1).

There are numerous factors affecting PTE levels in silver pomfret fish, including environmental factors such as the chemical composition of water, foods, and sediments, in addition to physiological properties of the fish, such as species, sex, size, feeding strategies and metabolic activities (Jarapala et al., 2014). Furthermore, the physicochemical properties of water viz. metal content, pH, dissolved oxygen, salinity, ionic strength, conductivity, reodox potential, and temperature are affected by season of capture (Başyigit and Tekin-Özkan, 2013; Farejiya and Dikshit, 2016; Q. Liu et al., 2018; Mohammadmabizadeh et al., 2014; Salam et al., 2019).

As is clear from the results, there is a large diversity in the concentrations of different PTEs, while the highest and lowest average PTE concentrations were associated with Fe and Hg, at 11,414.81 and 46.58 μg/kg ww, respectively. When the fish are subjected to elevated PTE concentrations, they can take up the bioavailable elements directly from the water and feed (Jarapala et al., 2014) through the gills, digestive system, or skin (Salam et al., 2019). Agah et al. (2009) and Huque et al. (2014) indicated that fish muscle seemed to be a good bioindicator of PTEs in the marine ecosystem as well as coastal areas (Agah et al., 2009; Huque et al., 2014). Thus, the amount of PTEs in water, food, and sediments affects the bioaccumulation of these PTEs in body tissues (Mohammadmabizadeh et al., 2014; Sreenivasa Rao and Longvah, 2016; Xia et al., 2013). Additionally, Petkovšek et al. (2012) confirmed
that the levels of PTEs in fish tissues could reflect the PTE concentrations in the surrounding water and sediments (Petkovšek et al., 2012). For instance, while Fe is naturally the most abundant element in the Earth’s shell (Başyığıt and Tekin-Özan, 2013), a higher amount of Fe in fish muscle reflects the existence of higher concentrations of Fe in the environment surrounding the fish species (Liu et al., 2013). Moreover, Liu et al. (2013) showed that the presence of relatively low amounts of Hg in fish fillet represents the absence of Hg sources in the fish diet (Liu et al., 2013), while the Hg concentration in the coastal sediments is higher than in offshore waters due to anthropogenic activities (Liu et al., 2018; Xia et al., 2013).

Liu et al. (2018) demonstrated that the differences in the concentrations of PTEs in fish could be related to variations in the concentrations of PTEs in the surrounding environment (Liu et al., 2018). Hence, another possible reason for higher levels of PTEs like Fe and Zn can be associated with variation in the fish’s abilities to absorb different types of PTEs (Mohammadnabizadeh et al., 2013). Furthermore, fishes have less capacity to absorb toxic PTEs like Hg, which are not necessary for their growth and functions (Huque et al., 2014; Shokr et al., 2019). The bioconcentration factor in fish is influenced mainly by the physiological characteristics of the PTEs and the content of these elements in the surrounding environment (Liu et al., 2014). Previous studies have revealed that some PTEs like Zn and Fe are more accumulated compared with other PTEs like Hg and Cd (Imtiazuddin and Mumtaz, 2013; Liu et al., 2014; Sobhanardakani et al., 2011). It should be mentioned that Bosch et al. (2016) pointed out that the usage of Hg in several industries has diminished recently, due to growing awareness of Hg-related health problems, which could be another possible reason for the Hg level being the lowest among the PTEs (Bosch et al., 2016).

Environmental variables, especially the season of fishing, affect the PTEs’ bioavailability and further mobilization capacities (Başyığıt and Tekin-Özan, 2013; Fallah et al., 2011). According to Başyığıt and Tekin-Özan (2013) the highest amounts of Cd, Cr, Fe, Mn, Ni, Se, and Zn were reported in the spring, while Cr and Mo were abundant in autumn. Furthermore, an increase in PTE concentrations due to run-off carrying more elements to the lake was reported in rainy seasons (Başyığıt and Tekin-Özan, 2013). Moreover, considering the findings of Ahmed et al. (2016), significant differences in Cu and Zn levels among various seasons were noted (Ahmed and Levent, 2016). Therefore, the season of capture could affect the physicochemical properties of water, which results in changes in the chemical forms, availability, and accumulation rate of different PTEs selectively.

The accumulation rate of different PTEs is strongly dependent on the species, sex, and specific tissue. In this context, Mortazavi and Sharifian (2012) reported that the mean concentration of PTEs in male fish was lower than that of female fish. Fish age is a crucial parameter considering PTE concentrations in the fish body, which is positively associated with the length and weight of fish (Agah et al., 2009, 2010). For instance, Bosch et al. (2016) reported that Hg accumulation increased with age/size of fish, while Liu et al. (2013) stated that Hg bioaccumulation is positively related to fish length in all tissues of silver pomfret species. Moreover, some PTEs like Al, As, Co and Cu, were less accumulated in the younger silver pomfret species (Agah et al., 2009). However, a negative correlation between age and PTE concentrations in silver pomfret was demonstrated by some investigations (Başıyıçıt and Teker-Özan, 2013; Liu et al., 2013, 2014; Mohammadnabizadeh et al., 2013, 2014; Mortazavi and Sharifian, 2012; Salam et al., 2019) which can be correlated with the fact that PTE accumulation is slower than growth (Liu et al., 2014). Higher metabolic levels and changes in feeding habits with increasing age are among other reasons for this observation (Agah et al., 2009).

A considerable variation was observed among different countries regarding all types of PTEs (Table 1), while the differences in the number of studies conducted in each country play an important role affecting the PTE levels in different studies. In this context, some investigations regarding the concentrations of PTEs in silver pomfret fishes were performed in Iran, Pakistan, and China. A wide range of variations between these countries can be correlated with differences in geographical locations, agricultural practices, industries near the aquatic environment, analytical methods and established regulations. Disposal of industrial wastes by many factories into the water is considered the main source of bioaccumulation of PTEs in aquatic organisms. Furthermore, agricultural practices like application of sewage sludge, fertilizers, and pesticides are other important sources of PTE pollution (Hamada et al., 2018).

### Table 1 – Concentration (μg/kg wet weight, ww) of PTEs in fillet of silver pomfret fish in different countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>As</th>
<th>Pb</th>
<th>Cd</th>
<th>Zn</th>
<th>Cu</th>
<th>Fe</th>
<th>Ni</th>
<th>Cr</th>
<th>Se</th>
<th>Co</th>
<th>Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>4320.00</td>
<td>15330.00</td>
<td>6220.00</td>
<td>22250.00</td>
<td>3330.00</td>
<td>98020.00</td>
<td>13510.00</td>
<td>313.00</td>
<td>313.00</td>
<td>208.79</td>
<td>20.00</td>
</tr>
<tr>
<td>Iran</td>
<td>378.43</td>
<td>542.88</td>
<td>101.21</td>
<td>3589.61</td>
<td>583.92</td>
<td>2216.00</td>
<td>1424.87</td>
<td>779.44</td>
<td>144.58</td>
<td>144.58</td>
<td>144.58</td>
</tr>
<tr>
<td>China</td>
<td>1420.00</td>
<td>20.46</td>
<td>20.00</td>
<td>6404.29</td>
<td>208.79</td>
<td>1630.00</td>
<td>20.00</td>
<td>83.70</td>
<td>550.00</td>
<td>10.00</td>
<td>13.34</td>
</tr>
<tr>
<td>India</td>
<td>66.95</td>
<td>87.00</td>
<td>12.95</td>
<td>6625.00</td>
<td>1955.7</td>
<td>680.00</td>
<td>840.45</td>
<td>1305.06</td>
<td>45.00</td>
<td>208.79</td>
<td>20.00</td>
</tr>
<tr>
<td>Malaysia</td>
<td>600.00</td>
<td>110.22</td>
<td>2400.00</td>
<td>4830.00</td>
<td>40.00</td>
<td>40.00</td>
<td>779.44</td>
<td>144.58</td>
<td>144.58</td>
<td>144.58</td>
<td>144.58</td>
</tr>
<tr>
<td>Pakistan</td>
<td>134.96</td>
<td>906.79</td>
<td>976.50</td>
<td>2619.18</td>
<td>544.72</td>
<td>2219.68</td>
<td>180.00</td>
<td>428.12</td>
<td>250.00</td>
<td>250.00</td>
<td>250.00</td>
</tr>
</tbody>
</table>

2.2. Total As

As is considered as a human carcinogenic compound even at exceedingly low levels of exposure (Saei-Dehkordi et al., 2010). Fortunately, the total arsenic in fish and shellfish is predominantly organic arsenic (90%, arsenobetaine) which is virtually nontoxic, and therefore is not a health risk for consumers (Fakhri et al., 2020; Habte et al., 2015; Heidarieh et al., 2015).
The ranking of total As concentrations in fillets of silver pomfret fish based on the countries studied was Bangladesh (4520 μg/kg ww) > China (1420 μg/kg ww) > Malaysia (600 μg/kg ww) > Iran (378.43 μg/kg ww) > Pakistan (134.96) > India (66.95 μg/kg ww) (Table 1). As is a broadly distributed PTE, occurring in the air, soil, and water, and it enters into the environment due to natural activities and anthropogenic contamination, including smelting procedures, glass production, utilization of As-containing pesticides, and wood additives (Ahmed et al., 2016; Bosch et al., 2016). The differences in anthropogenic activities near the sea ecosystems could be the main reason for differences in As concentrations among investigated countries. Huque et al. (2014) reported that in Bangladesh, as one of the developing countries, the coastal and marine areas might be contaminated by ships, crude oil carriage systems, factory handling loss, water-oil from different sea cargo, mechanized vessels, and dumping of ballast (Huque et al., 2014). Also, Ahmed et al. (2016) reported that about 900 factories dispose of unrefined industrial wastes into the water in this country (Ahmed et al., 2016).

2.3. Pb

Chronic exposure to a high level of Pb can result in several health issues; mainly, brain and kidney damage, mental retardation and increased blood pressure (Fallah et al., 2011; Huque et al., 2014; Salam et al., 2019).

The rank of Pb concentration in fillets of silver pomfret fish based by country was Bangladesh (15,330 μg/kg ww) > Pakistan (906.79 μg/kg ww) > Iran (542.88 μg/kg ww) > India (87 μg/kg ww) > China (20.46 μg/kg ww) (Table 1). The mean concentrations of Pb in all countries were higher than the maximum permissible limit for Pb in fish recommended by WHO (500 μg/kg ww), except in samples from India and China (Tabinda et al., 2010; Zolfaghari, 2018).

Natural activities, mainly soil erosion, and anthropogenic sources including fast industrialization, fertilizer and pesticide use, and agricultural disposal, have increased the amount of Pb entering water ecosystems (Hamada et al., 2018; Shokr et al., 2019; Sreenivasa Rao and Longvah, 2016). Huque et al. (2014) also confirmed that urban activities, discharged river waters flowing into the sea, and accidental leakage or emission of crude petroleum are the most important factors in pollution of aquatic organisms with PTEs like Pb. In addition, Imtiazuddin, and Muntaz (2013) observed that PTEs like Pb are expelled from textile factories into the marine ecosystem in Pakistan (Imtiazuddin and Muntaz, 2013). Agah et al. (2009) stated that growing industrial pressure around the Persian Gulf environment has resulted in increasing the concentration of Pb in fishes in Iran (Agah et al., 2009). Furthermore, Mohammadnabizadeh et al. (2013) also reported that the water pollution of the Hara area is affected by different industrial by-products near this area (cement, plant, paint, lead, zinc, and aluminum factories), disposal of untreated sewage directly into the water or through rivers, and also the release of petroleum components from commercial ships, small boats, and a refinery into the water (Mohammadnabizadeh et al., 2013).

Cd, as a well-known human carcinogen, is frequently bound to small metallothionein proteins and accumulates mainly in the kidneys and liver (Ahmed et al., 2016; Huque et al., 2014; Liu et al., 2018). The FAO/WHO established 500 μg/kg ww as the maximum limit for Cd in fish (Alimentarius, 2015).

As shown in Table 1, the rank order of Cd concentration in fillets of silver pomfret fish in different countries was Bangladesh (6220 μg/kg ww) > Malaysia (2400 μg/kg ww) > Pakistan (976.5 μg/kg ww) > Iran (101.21) > China (20 μg/kg ww) > India (12.95 μg/kg ww) (Table 1). Our results showed that the Cd concentration in silver pomfret fillets in Bangladesh, Malaysia, and Pakistan is higher than the permitted level recommended by WHO/FAO, while the concentrations in Iran, China, and India met the regulation standards. Cd is generally distributed within the earth’s crust and the aquatic ecosystem (Korkmaz et al., 2019). Natural activities like volcanic discharges and erosion of rocks, and anthropogenic activities including burning of coal and oil (fossil fuels), industrial and urban wastes, are recognized to be significant sources of Cd release to the atmosphere and freshwater (Ahmed et al., 2016). Smelting of Zn, Pb or Cu and use
of fertilizers containing PTEs are also considered as minor sources of Cd release to the aquatic environment (Bosch et al., 2016). Huque et al. (2014) reported that the main source of Cd in silver pomfret fish might come from urban activities, agricultural activities (application of fertilizers, pesticides, and sewage sludge) and accidental leakage or emission of crude petroleum (Huque et al., 2014). The fast progressing industrialization and economic improvement, as well as different shipping and carriage activities in Malaysia, have resulted in increasing concentrations of Cd in water (Salam et al., 2019). Furthermore, Ahmed et al. (2016) noted that increases in the development of industries, urbanization and agriculture practices has had a considerable impact on the Cd content in fish samples from Pakistan (Ahmed and Levent, 2016).

2.5. Zn

Zn, in spite of being an essential element in the human body (Ahmed and Levent, 2016) becomes toxic if it surpasses the permitted value (30,000 μg/kg ww) established by FAO/WHO (Jarapala et al., 2014; Junianto and Apriliani, 2017).

The rank order of Zn concentrations in fillets of silver pomfret fish in different countries was Bangladesh (22,250 μg/kg ww) > India (6625 μg/kg ww) > China (6404.29 μg/kg ww) > Malaysia (4830 μg/kg ww) > Iran (3589.61 μg/kg ww) > Pakistan (2619.18 μg/kg ww) (Table 1). The Zn level in all the investigated countries (Table 1) is lower than the permissible limit (30,000 μg/kg ww) established by FAO/WHO for fish (Alimentarius, 2015). Zn can be found in sewage from factories, household wastewater and fishes (Huque et al., 2014). The wide range of variation observed among these countries could be attributed to geographical locations, agricultural practices, number of industries and factories near the aquatic environment and the regulations governing these countries (Basim and Khoshnood, 2016). Furthermore, seasonal differences in sampling could affect the levels of measured Zn regarding alterations in temperature and its accessibility in the aquatic ecosystem (Fallah et al., 2011; Hamada et al., 2018).

2.6. Cu

High ingestion levels of Cu can cause serious health problems including kidney and liver disorders such as Wilson’s disease (AHMED and Levent, 2016; Korkmaz et al., 2019), although in small amounts it is essential for several functions in the body (Yasmeen et al., 2016).
The rank order of Cu concentration in fillets of silver pomfret fish in different countries was Bangladesh (3330 μg/kg ww) > India (1095.57 μg/kg ww) > Iran (583.92 μg/kg ww) > Pakistan (544.72 μg/kg ww) > China (208.79 μg/kg ww) > Malaysia (40 μg/kg ww) (Table 1). The FAO/WHO suggested 30,000 μg/kg ww as the maximum limit for Cu in fish (Alimentarius, 2015). In the case of Cu, there is no concern because its concentration from all investigated countries was considerably lower than the standard limit. Industrial practices are identified as the main sources regarding pollution of the aquatic environment by Cu in different countries (Sobhanardakani et al., 2012). Geographical location, seasonal differences, urbanization, and the disposal of untreated factory wastes into the sea can influence the Cu concentration observed in the studied countries (Basim and Khoshnood, 2016).

2.7. Fe

Fe is a vital element for human health (Huque et al., 2014; Yasmeen et al., 2016). However, excessive intake of Fe could lead to type-2 diabetes as well as age-related illnesses like Parkinson and Alzheimer’s (Huque et al., 2014; Korkmaz et al., 2019).

The rank order of Fe concentration in fillets of silver pomfret fish in different countries was Bangladesh (98,020 μg/kg ww) > Pakistan (2219.68 μg/kg ww) > Iran (2216 μg/kg ww) > China (1630 μg/kg ww) > Malaysia (40 μg/kg ww) (Table 1). The observed Fe concentrations in silver pomfret fish from all studied countries (Table 1) were much lower than allowable standards set by FAO/WHO (300,000 μg/kg ww). Fe is the most abundant element in the earth’s crust and its presence in the food chain is evident (Huque et al., 2014; Yasmeen et al., 2016). These differences may be attributed to various factors such as geological variations (season and natural activities) and differences in contamination resulting from industrial and agricultural practices as well as the analytical methods utilized (Fallah et al., 2011).

2.8. Ni

Ni is a natural component of Earth’s crust (Korkmaz et al., 2019). Chronic intake of Ni could result in increased risk of lung cancer (Fallah et al., 2011; Korkmaz et al., 2019). The rank

![Graph showing 95th percentile TTHQ for India (Adults) and India (Children) due to ingestion of silver pomfret fish containing PTEs.](image-url)
of Ni concentration in fillets of silver pomfret fish in different countries was Iran (1424.87 μg/kg ww) > India (680 μg/kg ww) > Pakistan (180 μg/kg ww) > China (20 μg/kg ww) (Table 1). Ni levels in silver pomfret fillets of all examined countries were considerably lower than the maximum limit of 70,000–80,000 μg/kg ww recommended by USFDA (Tabinda et al., 2010). In the case of Iran, Mohammadnabizadeh et al. (2014) stated that the water pollution of the Hara area is affected by different industrial by-products near this area (cement, plant, paint, lead, zinc, and aluminum factories), disposal of untreated sewage directly to the water or through rivers and also the release of petroleum components from commercial ships, small boats, and a refinery into the water (Mohammadnabizadeh et al., 2014). Agah et al. (2009) also reported that growing industrial pressures on the Persian Gulf environment have resulted in increases in the concentration of different PTEs in fishes (Agah et al., 2009). Furthermore, Sreenivasa Rao and Longvah (2016) stated that diverse anthropogenic activities like combustion, mining, domestic wastes, emission from factories, metalloid activities, and industrial sewage lead to inputs of PTEs like Ni into marine environments (Sreenivasa Rao and Longvah, 2016).

2.9. Cr

Cr (III) is also an element that humans need in small quantities (Huque et al., 2014) while Cr(VI) can result in several health problems such as kidney and liver damage (Afshan et al., 2014).

The rank order of Cr concentration in fillets of silver pomfret fish in different countries was Bangladesh (13,510 μg/kg ww) > India (840.45 μg/kg ww) > Pakistan (428.12 μg/kg ww) > Iran (313 μg/kg ww) > China (83.70 μg/kg ww) (Table 1). The maximum permissible Cr level set by the FAO-WHO in fish is 1500–2000 μg/kg. As shown in Table 1, only the Cr concentration in Bangladesh is higher than the regulated limit. Cr is a naturally occurring element located in soil, rocks, animals, and plants (Jarapala et al., 2014). Regarding Bangladesh, Huque et al. (2014) and Ahmed et al. (2016) reported that in this country, as one of the developing countries, the coastal and marine areas might be contaminated with Cr.
due to presence of numerous factories discharging untreated industrial waste into the water ecosystems (Ahmed et al., 2016; Huque et al., 2014).

Sreenivasa Rao and Longvah (2016) also stated that extensive anthropogenic and industrial activities, especially textile, leather and steel factories in India, have resulted in high incidence of Cr (VI), which is quickly released from soil to the aquatic environment and can threaten aquatic organisms (Jarapala et al., 2014).

2.10. Se

Se is an essential micronutrient that can be introduced to the human body via fish consumption (Jarapala et al., 2014). However, the intake of large contents of Se can lead to disorders in the body such as reproductive failure (Ahmed et al., 2016; Xia et al., 2013).

The rank of Se concentration in the fillets of silver pomfret fish in different countries was India (1305.06 μg/kg ww) > China (550 μg/kg ww) (Table 1). The mean concentrations of Se in two Indian studies were higher than the maximum level of 1000 μg/kg proposed by FAO-WHO for this PTE in fish (Alimentarius, 2015). Sreenivasa Rao and Longvah (2016) and Sreenivasa Rao et al. (2014) revealed that various human activities like domestic waste disposal, combustion, mining, metallurgical activities, emission, and industrial sewage lead to input of PTEs such as Se inputs into the marine ecosystem of India (Sreenivasa Rao and Longvah, 2016).

2.11. Co

Cobalt, as a component of vitamin B12, is an essential element for humans. However, high intake of Co can lead to heart, thyroid and lung dysfunction in addition to dermatitis (Jarapala et al., 2014).

The rank order of Co concentration in fillets of silver pomfret fish in different countries was Pakistan (250 μg/kg ww) > India (45 μg/kg ww) > China (10 μg/kg ww) (Table 1). The FAO recommended 150–1000 μg/kg ww as maximum limits for cobalt in fish (Nauen, 1983). According to Table 1, the concentration of Co in silver pomfret fish from these investigated countries is in the range of the FAO standard limit. Co is introduced into the aquatic environment via industrial pollutants and fertilizers. Fish can absorb Co via the water medium they live in (Kelle et al., 2018). Raza et al. (2003) noted that the presence of a high amount of PTEs such as Co might be due to uncontrolled industrial effluents (especially textiles) discharged into the sea through rivers and streams over the past few years (Raza et al., 2003).

2.12. Methyl Hg

Methyl mercury (Me-Hg), as the organic and most toxic form of Hg, is identified as one of the most dangerous neurotoxic contaminants (Agah et al., 2010; Anual et al., 2018; Salam et al., 2019).

The maximum allowable limit is 500 μg/kg for Hg in fish according to FAO/WHO (Alimentarius, 2015). The rank order of Hg concentration in fillets of silver pomfret fish in different countries was Malaysia (779.44 μg/kg ww) > Iran (144.58 μg/kg ww) > China (13.34 μg/kg ww) (Table 1). Considering the Hg concentration in silver pomfret fillet of different countries, it is found that only Malaysia did not meet the regulated standards. Hg can potentially enter into marine ecosystems due to natural and human activities including disposal of industrial wastes, urban sewage, and pesticides (Agah et al., 2010; Liu et al., 2013).

Jeevanaraj et al. (2019) reported that Malaysia possesses a high degree of industrialization and urbanization, and some of its harbors are greatly polluted by oil leakage because of international delivery activities, finally discharging Hg into the aquatic environment, and stimulating bio-accumulation through fish (Jeevanaraj et al., 2019).

Additionally, Saei-Dehkordi et al. (2011) noted that the high amounts of Hg in fishes captured from the Persian Gulf (Iran) could be attributed to 3–5 years of trade or flushing stage, and pollution stability is probable in this part (Saei-Dehkordi et al., 2010). Furthermore, Agah et al. (2010) reported that most industries are located in western sites of the Persian Gulf, which discharge their polluted wastes to the sea directly or indirectly. Furthermore, sand storms and eastern winds from southern Iraq may influence the soil and clay elements of the sea sedi-
ments in the western areas of the Persian Gulf, which could be a reason for the presence of high amounts of Hg in the silver pomfret fish captured from this area (Agah et al., 2010).

2.13. Health risk assessment

A total target hazard quotient (TTHQ) ≤1 is considered non-carcinogenic and in the safe range, while for TTHQ > 1, adverse health effects are considerable (EPA, 2012). The rank of countries based on the TTHQ in adults was Malaysia (2.500) > Bangladesh (0.886) > Iran (0.144) > China (0.045) > Pakistan (0.020) > India (0.015) (Figs. 2-7), while the corresponding values for children were Malaysia (11.790) > Bangladesh (4.146) > Iran (0.675) > China (0.206) > Pakistan (0.096) > India (0.077) (Figs. 2-7). Adult consumers in Malaysia and children in Malaysia and Bangladesh were at considerable non-carcinogenic risk (EPA, 2012; Gholami et al., 2019; Pirsaheb et al., 2019; Rezaei et al., 2019a) due to ingestion of PTEs via consumption of silver pomfret fish (Table 2). The high TTHQ in Malaysia and Bangladesh can be correlated with the high concentration of PTEs in the targeted food products (Table 1) and high ingestion rate (Appendix A Table S2).

Similarly, some studies were conducted regarding PTEs in foods and associated health risk in adults and children (Atamaleki et al., 2019; Fakhri et al., 2018a, 2019b; Gholami et al., 2019; Rahmani et al., 2018b; Razzaghi et al., 2018); TTHQ in the child consumers was ~4.71 times higher than adults. The higher TTHQ in children is related to their lower BW and hence, children are at a higher health risk than adults (Fakhri et al., 2018b; Heshmati et al., 2018; Rahmani et al., 2018a; Rezaei et al., 2019a; Yousefi et al., 2018).

The differences in concentrations of PTEs in silver pomfret fish, ingestion rate of silver pomfret fish and exposure time, exposure frequency, exposures duration, average lifetime, body weight, and toxicity of PTEs play considerable roles in the health risk of consumers, hence we observed various TTHQ values in the countries investigated (Fakhri et al., 2017a, 2018b; Rahmani et al., 2018a; Rezaei et al., 2019a).

3. Conclusions

In this study, we tried to retrieve all studies on the concentration of PTEs (Fe, Zn, total Cr, Pb, Se, Cd, Ni, Cu, total As, Co and methyl Hg) in fillets of silver pomfret fish. Then the concentra-
tions of PTEs were subjected to meta-analysis according to the type of PTEs and country subgroups; finally, the probabilistic health risk in consumers was calculated. The lowest and highest concentrations in fillets of silver pomfret fish were related to methyl Hg and Fe, respectively. All consumers in Iran, Pakistan, China, and India are in the safe range of health risk due to PTEs in fillets of silver pomfret fish, but adult consumers in Malaysia and children in Malaysia and Bangladesh were at considerable non-carcinogenic risk; therefore, control plans for reducing the concentration of PTEs in fillets of silver pomfret fish are necessary.

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Appendix A Supplementary data

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jes.2020.07.014.

REFERENCES


Fallah, A.A., Zeynali, F., Sai-Dehkordi, S.S., Rahnama, M., Jafari, T.,
2011. Seasonal bioaccumulation of toxic trace elements in economically important fish species from the Caspian Sea using GFAAS. J. für Verb und Leben. 6, 367–374.


