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Dietary exposure to toxic and essential trace elements by consumption of wild and farmed *carp* (*Cyprinus carpio*) and Caspian *kutum* (*Rutilus frisii kutum*) in Iran

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HIGHLIGHTS

- Some metals in wild and farmed *Cyprinus carpio* and *Rutilus frisii kutum* muscle from Caspian Sea were measured.
- *Pb*, *Cd*, *Hg* and *Mn* concentration in wild samples was significantly higher than those in farmed ones.
- There was no significant difference of *Fe*, *Zn*, *Cu*, *Co*, *Ni*, *Se* between wild and farmed Carp and Kutum.
- The highest concentration of analysed metals in both fish species was found for *Fe*, followed by *Zn* and *Cu*.

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ABSTRACT

This study was conducted to determine and compare the concentrations of mercury (*Hg*), cadmium (*Cd*), arsenic (*As*), lead (*Pb*), nickel (*Ni*), iron (*Fe*), zinc (*Zn*), copper (*Cu*), manganese (*Mn*), cobalt (*Co*), and selenium (*Se*) in the muscle of wild and farmed *carp* (*Cyprinus carpio*) and wild and farmed Caspian *kutum* (*Rutilus frisii kutum*) collected from south-western Caspian Sea areas of Iran between December 2014 and March 2015. In addition, risk assessment of consumers to exposure to metals through fish consumption was estimated. In all the samples, the arsenic concentration was lower than the detection limit. The *Pb*, *Cd*, *Hg* and *Mn* concentrations were significantly higher in the wild fish samples compared to the farmed fish samples. There was no significant difference in the *Fe*, *Zn*, *Cu*, *Co*, *Ni* and *Se* concentrations of the wild and farmed *carp* and the wild and farmed Caspian *kutum*. Iron displayed the highest concentration of all the analysed metals in both the wild and farmed fish, followed by *Zn* and *Cu*. The highest *Hg*, *Cd*, *Pb*, *Ni*, *Fe*, *Zn*, *Cu*, *Mn*, *Co* and *Se* concentrations were 0.056, 0.011, 0.065, 0.120, 4.151, 3.792, 2.948, 2.690, 0.037 and 0.162 μg g^{-1}, respectively. The estimated daily intake of all metals was acceptable, and the hazard quotient values showed that consumption of the analysed fish posed no health risk to consumers.

1. Introduction

Fish is considered to be a valuable food source because it contains nutritional compounds, such as polyunsaturated fatty acids, particularly omega-3 and omega-6 fatty acids, high quality protein, vitamins and trace elements (Tacon and Metian, 2013; Domingo, 2016). Fish consumption reduces the risk of cardiovascular diseases and many health advantages have been documented for this foodstuff (Raatz et al., 2013; Oliveri Conti et al., 2015). Therefore, recently, per capita fish consumption has increased simultaneously with the growing knowledge about its nutritional and therapeutic benefits (Gu et al., 2015).

The occurrence of chemical contaminants, such as heavy metals, in aquatic ecosystems is a worldwide concern (Ahmed et al., 2015).

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Excessive amounts of heavy metals in the food chain can create various health problems for humans and have a negative impact on the ecosystem (Shahbazi et al., 2016). These contaminant components in marine environments can originate from natural sources and other variety of sources, including agricultural drainage, industrial effluent discharge, sewage discharge, accidental chemical waste spills and gasoline from fishing boats. Some of the metals may also be transported in air, and can originate from long range transport (Velusamy et al., 2014). In addition, the oil industry is one of the most significant contributors of the heavy metals found in marine animals (Jafari, 2010; Moallem et al., 2010). The presence of heavy metals, such as lead (*Pb*), cadmium (*Cd*) and vanadium (*V*), is an indication of oil pollution (Dsikowitzky et al., 2013).

When metals are discharged into the aquatic ecosystem, they dissolve in the water. Fish take up these metals directly through the epithelium of the skin, the gills and the alimentary canal. The consumption of metal-contaminated food is another source of heavy metals in fish (Squadrone et al., 2013; Negi and Maurya, 2015). The level of metal accumulation in fish organs and tissues depends on various biotic and abiotic factors, such as ecological needs, sex, age, size, life cycle and history, feeding habits, habitat preferences and water parameters, such as acidity and duration of exposure to heavy metals and homeostatic regulation activity (Velusamy et al., 2014; Farahani et al., 2015; Maktabi et al., 2015). In addition, seasonal differences, nourishment source and biological variations might cause fluctuations in the heavy metal levels within tissue (Dadar et al., 2016a). Metal accumulation is higher in some types of fish and fish tissues; therefore, it is recommended that humans not consume these foods (Jiang et al., 2016). The metal accumulation in muscle is lower than in other fish organs, such as the gills, the skin and the liver (Yılmaz et al., 2010). Thus, muscles are not usually the best markers for determining the level of heavy metal contamination. However, muscles are the part of fish most often consumed by humans, and the occurrence of heavy metals in fish tissue is a concern (Maktabi et al., 2015). Therefore, from the perspective of public health and to ensure fish safety, it is necessary to monitor heavy metal levels in fish tissues (Culha et al., 2016; Mehanna et al., 2016). Oral bioaccessibility of heavy metals differs and could infunce on health risks for the consumers (Cano-Sancho et al., 2015).

The Caspian Sea, with an area of 378,400 km^2 and a basin volume of 78,170 km^3, is the largest lake in world. Average and maximum depths of this lake are 210 m and 1025 m, respectively (Dumont, 1998). It is located in the northern section of Iran, and in that country, its shoreline is 650 Km long. *Carp* (*Cyprinus carpio*) and Caspian *kutum* (*Rutilus frisii kutum*) are two of the main types of fish caught in this sea. Due to the high demand for these fish, some consumer need is addressed by fish farms. There is a limited data concerning trace elements and heavy metal concentrations in wild and farmed Caspian *kutum* and *Carp*. Therefore, this study aimed to identify and compare the levels of lead (*Pb*), cadmium (*Cd*), arsenic (*As*), mercury (*Hg*), iron (*Fe*), zinc (*Zn*), copper (*Cu*), manganese (*Mn*), cobalt (*Co*), nickel (*Ni*) and selenium (*Se*) in the muscle of farmed and wild *carp* and farmed and wild Caspian *kutum* fish collected from the South-western coast of the Caspian Sea and adjacent fish farms. It also aimed to assess the risk of exposure to heavy metals due to the consumption of these types of species.

2. Materials and methods

2.1. Chemical and reagents

Chemical reagents and heavy metal standards were analytical grade and bought from Merck (Darmstadt, Germany). All used glassware were washed with detergent and rinsed several times with tap water and soaked in 10% nitric acid solution overnight. Afterwards; they were rinsed with double distilled water prior to utilization for preventing of metal contamination.

2.2. Samples collection

Sampling was conducted between December 2014 and March 2015. Ten samples of wild *carp* (*Cyprinus carpio*) and 10 samples of wild Caspian *kutum* (*Rutilus frisii kutum*) were collected from three places in the south-western part of the Caspian Sea (Fig. 1). The farmed *carp* and Caspian *kutum* samples (n = 10 of each) were collected from three fish farms near the south-western part of the Caspian Sea. All the fish samples had approximately the same weight. The samples were transported to the laboratory in boxes containing ice, and then they were stored in a freezer at −20 °C until further analysis.

2.3. Sample digestion

To prepare the samples for testing, the frozen fish samples were transferred to a refrigerator for 24 h so they could thaw slowly. Each fish sample was cut into small pieces using a stainless steel knife. The epaxial muscle on the dorsal surface (without skin) of the fish samples was completely removed and washed with double-distilled water. The obtained tissues were chopped, homogenized and dried in an oven (Memmert, Germany) at 60 °C for 24 h. Two grams of the dried specimen were digested using the wet method. The weighted samples were placed in a 100 ml flask. Ten mL of 70% high purity HNO3 and 65% HClO4, 4:1 v/v were added to the samples, and then left overnight in order to digest gently. Subsequently, digestion was carried out on a hot plate at 150 °C to clear the solution that was obtained. After cooling, deionized water was added until the solution reached a volume of 50 mL. Finally, the metal concentrations were determined (AOAC, 1995).

2.4. Metal analysis

The concentrations of the heavy metals and trace elements were determined using a graphite furnace atomic absorption spectrophotometer (Thermo Scientific's iCE 3300, Waltham, MA, USA). In

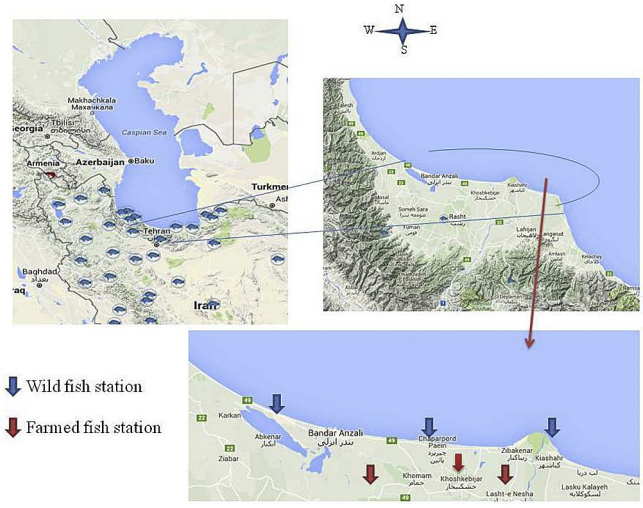

Fig. 1. Geographical map of Iran showing the sampling locations of fish in the in the south-western part of the Caspian Sea.