Marine Pollution Bulletin 109 (2016) 667–671

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Baseline

# Potential human health risk assessment of trace metals via the consumption of marine fish in Persian Gulf

Abolfazl Naji [a,*], Farhan R. Khan [b], Seyed Hassan Hashemi [c]

[a] Department of Fisheries, Faculty of Marine Science and Technology, Hormozgan University, Bandar Abbas, Iran
[b] Department of Science and Environment, Roskilde University, Roskilde, Denmark
[c] Department of Environment, Branch of Hormozgan Province, Bandar Abbas, Iran

ARTICLE INFO

*Article history:*
Received 2 January 2016
Received in revised form 30 April 2016
Accepted 3 May 2016
Available online 15 May 2016

*Keywords:*
Trace metals
Seafood
Pollution
Estimated daily intake
Target hazard quotient

ABSTRACT

This study was carried out to evaluate the concentration of trace metals (Cd, Cu, Ni, Pb and Zn) in the muscle of four fish species from the Persian Gulf. Trace metals were analyzed using atomic absorption spectroscopy and consumption rates advisory for minimizing chronic systemic effects in children and adults were estimated. The metals concentrations in analyzed fish samples were lower than legal limits. Cadmium target hazard quotient values suggested that the threshold to avoid the potential risk for children health is an exposure level lower than 3 meals per week. Hazard index values based on four metals (not including Pb) for the child age class were higher than those of the adult age class, suggesting that children may suffer from a higher health risk. This study provides information about the consumption limits of certain metals, in particular Cd, necessary for minimizing potential health risks resulting from human consumption.



In most Asian countries fish are an important dietary constituent providing protein, fatty acids as well as trace elements and vitamins (Copat et al., 2013; Hajeb et al., 2009). In Iran an estimated 380,000 tons of fish were caught in 2009, with approximately 90% belonging to southern waters of Iran (mainly Persian Gulf) (Saei-Dehkordi et al., 2010). There are also reports of contamination in these fish from chemicals released into the environment, including trace metals, but to date the balance between benefits and risk due to ingestion of chemical contaminants has been poorly characterized (Copat et al., 2012, 2013; Domingo et al., 2007). Therefore, in recent years the fish consumption advisories for human populations have become increasingly important, as has the role of environmental monitoring projects that provide baselines assessments for determining the health risks to both fish species and human populations (Agah et al., 2009; Copat et al., 2013; Naji et al., 2014).

Whilst some trace metals are essential (e.g. Cu or Zn) at high enough concentrations all metals can be toxic. Thus trace metals have been recognized as one of the most important pollutant groups in the aquatic environment affecting numerous eco-toxicological endpoints in various fish species, including organ specific toxicity, reduced fecundity and mortality. Trace metals are readily assimilated and bioaccumulated in aquatic organisms and can be passed between trophic levels, including humans consuming contaminated food (Copat et al., 2013; Naji and Ismail, 2012; Naji et al., 2010; Taweel et al., 2013). Whilst there are studies assessing the metal concentrations in fish from the Persian Gulf (Agah et al., 2007, 2009, 2012; Saei-Dehkordi et al., 2010), to the best of our knowledge, there are no specific studies linking this to the consequences for human health. Thus the main objectives of this study were to (1) investigate metal concentrations (Cd, Cu, Ni, Pb and Zn) in local marine fish (Longtail tuna, Kluzinger's mullet, Indian mackerel, Pickhandle barracuda) and (2) estimate the potential risk for human health via their consumption.

The Persian Gulf is characterized by warm and saline water with a total area of 240,000 $km^2$. It has an average depth of 35 m which decreases from east to west with maximum depth of 90 m in the Strait of Hormuz. The average seawater temperature of the Persian Gulf is 28–30 °C, but it can rise up to 35.8 °C, and the oxygen content can vary from 4 to 7 mg $l^{-1}$. High evaporation result in increasing salinity with values as high as 40 ppt (Agah et al., 2007, 2012; Naser, 2013).

The Persian Gulf is considered one of the most highly anthropogenically impacted regions in the world. It is estimated that >40% of the coasts of the Gulf has been developed (Hamza and Munawar, 2009; Naser, 2013). In terms of pollution, the water quality of the Persian Gulf is influenced by various industrial and urban outputs in which wastewater directly discharges into the sea or enters via rivers (Agah et al., 2007; Naser, 2013). Besides pollution through riverine inputs from adjacent countries (Iran, Iraq, Kuwait, Saudi Arabia, and the Emirates, Bahrain, Qatar and Oman), the Gulf has been exposed to various additional contaminants. Dredging and reclamation, hypersaline water discharges from desalination plants and oil pollution are examples of anthropogenic stresses that contribute to environmental degradation

* Corresponding author.
*E-mail address:* abolfazlnaji@gmail.com (A. Naji).

http://dx.doi.org/10.1016/j.marpolbul.2016.05.002

**Table 1**
Characteristics of the fish samples used in this study (presented as mean value ± standard deviation (S.D.)).

| Species | n | Length (cm) | Weight (g) | Feeding | Habitat |
|---|---|---|---|---|---|
| Longtail tuna (*Thunnus tonggol*) | 12 | 81.32 ± 8 | 4340.0 ± 320 | Carnivorous | Pelagic |
| Kluzinger's mullet (*Liza klunzingeri*) | 10 | 32.58 ± 2 | 338.3 ± 15 | Detritivorous | Demersal |
| Indian mackerel (*Rastrelliger kanagurta*) | 15 | 21.76 ± 2 | 114.7 ± 7 | Carnivorous | Pelagic |
| Pickhandle barracuda (*Sphyraena jello*) | 10 | 50.02 ± 5 | 563.6 ± 65 | Carnivorous | Pelagic |

**Table 2**
Quality assurance for trace metal analysis determined by the use of certified reference material TORT-2 lobster hepatopancreas (National Research Council, Canada). Measured concentrations (presented as mean value (μg $g^{-1}$ (d.w.) ± S.D, n = 3) are compared to certified concentrations (μg $g^{-1}$ (d.w.)). For each metal recovery (in %) was >90% and within acceptable limits of the certified concentrations. Instrument characteristics for each metal (elemental wavelength (nm) and limit of detection (LOD, μg $l^{-1}$)) are also provided.

| Element | Wavelength | LOD | Measured concentration | Certified concentration | Recovery |
|---|---|---|---|---|---|
| Cd | 228.6 | 1 | 28.03 ± 0.3 | 26.70 ± 0.6 | 105 ± 1 |
| Cu | 324.8 | 1 | 102.80 ± 3 | 106.00 ± 10 | 97 ± 3 |
| Ni | 232.0 | 2 | 2.45 ± 0.15 | 2.50 ± 0.19 | 98 ± 6 |
| Pb | 217.0 | 2 | 0.33 ± 0.05 | 0.35 ± 0.13 | 94 ± 12 |
| Zn | 213.9 | 3 | 174.60 ± 4 | 180.00 ± 6 | 97 ± 2 |

in the Persian Gulf (Sheppard et al., 2010). Being located in a major area for the petroleum industry, oil extraction, the passage of oil tankers, in addition to natural shallow depths, limited circulation, high salinity and temperature have a destructive impact on its marine ecosystem (Agah et al., 2007). The turnover and flushing time have been estimated to be in the range of 3–5 years indicating that pollutants are likely to reside in the Persian Gulf for a considerable time (Sheppard et al., 1992).

The present study focused on four of the most heavily consumed and economically important fish species in Iran. A total of 47 freshly caught marine fish (n = 10–15 individuals per species, Table 1) were purchased during April and May 2015 from a major retail outlet in the Bandar Abbas (one of the most important fishing ports of the Persian Gulf). Individuals of each species had similar body length and weight. Upon purchase, fish were transported to the laboratory and rinsed four times with distilled water. Muscle tissues from each individual was dissected and placed in plastic zip-lock bags and stored at −20 °C for metal analysis. Dissected tissues were then oven-dried to a constant weight at 80 °C for 24 h, ground gently with an agate pestle and mortar, homogenized through a 100-μm nylon mesh sieve, and then stored in glass bottles (Gu et al., 2015).

The moisture content of the tissue samples was determined in triplicate (Helrich, 1990). To avoid contamination, all laboratory equipment used during metal analysis was first rinsed with distilled water and left in 10% $HNO_3$ for 24 h, then rinsed again (twice) with double-distilled water and left to dry at room temperature within a fume hood. Sample preparation for metal analysis followed the method of Hajeb et al., 2009 and Yap et al., 2015. Approximately 0.5 g of homogenized fish tissue was weighed and digested in a 10 ml combination (4:1 ratio) of concentrated $HNO_3$ (AnalaRgrade, R&M Chemicals 65%) and $HClO_4$ (AnalaR grade, R&M Chemicals 70%). Samples were heated first at low temperature (40 °C) for 1 h and then at 140 °C for 3 h. The digested material was filtered through a 0.22 μm acid-resistant cellulose nitrate membrane. At the end of the digestion procedure, the solution was transferred to a 50 ml volumetric flask and diluted with double deionized water. Blank acid-only digestions and certified reference material (CRM) (Lobster Hepatopancreas Reference Material for Trace Metals, TORT-2, Canada) were similarly prepared as quality control and assurance. Samples were analyzed for Cd, Zn, Ni, Cu, and Pb using an air-acetylene flame atomic absorption spectrophotometer (FAAS, SpectrAA Model VARIAN240). Multiple-level calibration standards were used to generate calibration curves against which sample concentrations were calculated. Limits of detection (LODs) were measured using the expression $3S_{blank} / S$, where $S_{blank}$ is the standard deviation of at least five replicate measurements of blanks and S is the slope of the calibration curve (Palmieri et al., 2005). Procedural blanks were monitored every five samples during the analysis. Analysis of the certified references material was consistently comparable with the certified concentrations (>90% recovery for all metals, Table 2). The LOD values and wavelengths of Cd, Zn, Ni, Cu and Pb are presented in Table 2.

Metals levels in the fish muscle of each species are presented in Table 3 on a dry weight basis, with weight used for consumption modelling shown in parenthesis. Trace metals concentrations analyzed in the muscle tissue followed the order of Zn > Cu > Pb ≈ Ni > Cd and was consistent for all four species. The concentration of Cd in this study varied from 0.22 to 0.44 μg $g^{-1}$. The highest to lowest values of Cd were observed as follows: Kluzinger's mullet > Indian mackerel > Longtail tuna > Pickhandle barracuda. The concentration of Cu measured in this study varied from 5.14 to 10.67 μg $g^{-1}$. Maximum Cu values were found in Pickhandle barracuda. The lowest concentration was detected in Kluzinger's mullet. Copper was found to be the second most abundant metal in the fish species in this study. The concentration of Ni in fish tissues sampled varied from 2.49 to 5.13 μg $g^{-1}$. The maximum value of Ni was present in Kluzinger's mullet followed by Pickhandle barracuda, Longtail tuna and then Indian mackerel. The maximum concentration of Pb detected in this study was in Pickhandle barracuda (6.46 μg $g^{-1}$) followed by Longtail tuna (6.06 μg $g^{-1}$), Kluzinger's mullet (4.73 μg $g^{-1}$) and Indian mackerel (2.43 μg $g^{-1}$). Zinc was the most abundant trace element in tissue samples from this study. The maximum Zn concentration was determined in Pickhandle barracuda (36.17 μg $g^{-1}$), and the lowest Zn concentration observed in Kluzinger's mullet (19.58 μg $g^{-1}$). The mean Zn concentration of tissue samples analyzed in this study was 30.65 μg $g^{-1}$.

Overall, studied metal concentrations in analyzed fish muscle samples were lower than legally defined limits. The present Cd ranges did not exceed the food safety guidelines (FSG) (1.00 mg $kg^{-1}$ (w.w.)) set by WHO (1989), and the European Union (EC, 2006). The highest Cu concentration were present in Pickhandle barracuda and the lowest in Kluzinger's mullet, but again Cu concentrations were well below the FSG suggested by WHO (1996) (30 mg $kg^{-1}$ (w.w.)). Similarly, the

**Table 3**
Trace metal concentrations found in the muscle tissue of each species presented as μg $g^{-1}$ (d.w.) ± S.D. (n = 10–15, see Table 1). Wet weight concentrations used in estimated daily intake (EDIm), maximum allowable fish consumption rate ($CR_{lim}$), target hazard quotient (THQ) and hazard index (HI) models are found in parenthesis and were derived using the % moisture determined for muscle tissue for each species.

| Species | Moisture (%) | Cd | Cu | Ni | Pb | Zn |
|---|---|---|---|---|---|---|
| Longtail tuna | 0.76 | 0.22 ± 0.25 (0.04) | 9.78 ± 0.7 (1.95) | 3.90 ± 0.05 (0.78) | 6.06 ± 0.10 (1.21) | 30.89 ± 2.71 (6.20) |
| Kluzinger's mullet | 0.78 | 0.44 ± 0.09 (0.09) | 5.14 ± 0.26 (1.02) | 5.13 ± 0.15 (1.03) | 4.73 ± 0.15 (0.94) | 19.58 ± 0.79 (3.9) |
| Indian mackerel | 0.73 | 0.36 ± 0.05 (0.07) | 8.86 ± 0.86 (1.77) | 2.49 ± 0.16 (0.50) | 2.43 ± 0.08 (0.50) | 35.97 ± 5.33 (7.2) |
| Pickhandle barracuda | 0.76 | 0.17 ± 0.06 (0.03) | 10.67 ± 0.4 (2.13) | 4.09 ± 0.01 (0.82) | 6.46 ± 0.01 (1.30) | 36.17 ± 1.02 (7.2) |