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Toxic metal risk with fish consumption for women of childbearing age

Schwermetallrisiko für Frauen im gebärfähigen Alter durch Fischkonsum

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Summary

An adequate nutrition is very important for women of childbearing age and pregnant women, and the consumption of fish is of great importance. In fish consumption, the heavy metal risk must be considered at the species level. The levels of toxic metals (Mn, Fe, Ni, Cu, Zn, Se, Co, Al, As, Cd, Hg, Pb and Sn levels) were determined in three pelagic fish species bluefish *(Pomatomus saltatrix),* anchovy *(Engraulis encrasicolus)* and sardine *(Sardina pilchardus)* from the Marmara Sea (Turkey). Estimated weekly intake (EWI), Hazard index (HI) and Target hazard quotient (THQ) were calculated for 150 g fish consumption. The health risks were assesment in childbearing age women. A hazard caused by mercury has been identified in all fish species for these consumer group. The values of HI and THQ indicate that the consumption of these fish species may pose health risks in in childbearing age women.

Keywords: Heavy metals, toxic elements, health risks, fish, THQs

Zusammenfassung

Eine angemessene Ernährung ist für Frauen im gebärfähigen Alter und Schwangere besonders wichtig. Eine große Bedeutung hat der Fischverzehr. Beim Fischkonsum muss das Schwermetallrisiko auf der Speziesebene beurteilt werden. Die Konzentrationen der toxischen Metalle (Mn, Fe, Ni, Cu, Zn, Se, Co, Al, As, Cd, Hg, Pb und Sn) wurden in drei pelagischen Fischarten, Blaubarsch *(Pomatomus saltatrix),* Europäische Sardelle *(Engraulis encrasicolus)* und Sardine *(Sardina pilchardus),* aus dem Marmarameer (Türkei) bestimmt. Die geschätzte wöchentliche Aufnahme (EWI), der Gefahrenindex (HI) und der Schädigungsquotient (THQ) wurden für 150 g Fischkonsum berechnet. Die Gesundheitsrisiken wurden für Frauen im gebärfähigen Alter bewertet. Eine Gefährdung durch Quecksilber wurde in allen Fischarten für diese Verbrauchergruppe identifiziert. Die Werte vom Gefahrenindex und Schädigungsquotient zeigten, dass der Verbrauch dieser Fischarten gesundheitliche Risiken bei Frauen im gebärfähigen Alter darstellen kann.

Schlüsselwörter: Schwermetalle, toxische Bestandteile, Gesundheitsrisiken, Fische, Schädigungsquotient

Introduction

Fish and fish products, which are known as an important source of protein, essential fatty acids, vitamins and minerals, are among the foods recommended by dietitians. Regular consumption of seafood is very important for consumer health. Despite the many benefits of seafood, it can be a source of adverse health effects due to environmental pollution. Trace elements such as copper, iron, zinc, chromium and cobalt, which are cofactors for enzymes, play a key role in the metabolism of the organism. These elements, which are so important in trace amounts, are toxic to the organism at high concentrations (Özden & Erkan, 2005). In contrast, elements such as cadmium, arsenic, lead and mercury are only toxic for organisms. The consumer of sea food may involve risks due to these substances (Türkmen et al., 2008). Presence and concentration of toxic metals in seafood depends on many factors such as geographical location, species and size, nutritional forms, environmental pollution, etc. (Jović & Stanković, 2014). Blue fish *(Pomatomus saltatrix)*, anchovy *(Engraulis encrasicolus)* and sardine *(Sardina pilchardus)* are pelagic fish.

For the year 2015, the Turkish Fishery Statistics gave the amount of captured marine fish as 345765.0 tons. Total catch was 4135.7 tons for bluefish, 90885.9 tons for anchovy, and 16693.4 tons for sardine in Turkey (Turkish Statistical Institute, 2016). These species have significant consumption potential and value of high economic. It is generally consumed as fresh. These fish species are mainly located in the Marmara Sea. The main problem of the Marmara Sea is pollution of the ecosystem. The domestic wastes of densely-populated cities (İstanbul with seventeen million and İzmit with two million inhabitants) in the north eastern region of the Marmara Sea, maritime traffic and the wastes of heavy industrial plants in İzmit Gulf are the main causes of pollution. There are data about toxic metals pollution of the Marmara Sea coast (Keskin et al., 2007; Tepe et al., 2008; Türkmen et al., 2008). Fishes, especially fatty fish are good indicators for monitoring the metal accumulation in the marine environment over a longer time (Türkmen et al., 2008). The consumption of contaminated fish with toxic metals can cause cancer and destruction of the immune system in adults. Neurotoxicity andnephrotoxicity is frequently observed. The exposure to toxic metals of pregnant women has been associated with endocrine and/or immune system disorders in children (Herreros et al., 2008). In recent years, many factors, such as differences in the quantity and frequency of consumption of contaminated food in individuals, support the idea that exceedance the recommended levels of pollutants by various regulatory agencies does not always pose a risk to human health. Therefore, evaluating the potential health risks for different consumer groups has become important (Copat et al. 2013). Little information is available in literature on quantify the health risks associated with the consumption of caught fishes from Marmara Sea (Özden & Erkan, 2016).

The purpose of this article is to determine the level of toxic metal contamination of the three fish species caught in the Marmara Sea and to examine the health risks associated with these metals in women of childbearing age.

Material and Methods

Samples

The blue fish, anchovy and sardine were purchased from the İstanbul wholesale fish market during the catching season. Catching season is autumn, winter and spring for bluefish and anchovy, winter, spring and summer for sardine. Specimens were collected with various fishing methods (bluefish; gillnet, anchovy and sardine; purse seine) by fishermen from Marmara Sea in Turkey. Fish were placed in polystyrene foam boxes with ice and transported to the laboratory for 2 hours. Fish samples (bluefish n = 20, anchovy n = 200, and sardine n = 200) were collected on a monthly basis throughout the catching season, muscle tissue (gutted and filleted) was homogenized with Knife Mill Grindomix GM 200 (Haan-Germany) for analyses. Homogenized samples were placed in individual polythene bags andwere frozen until further processing. Determination of manganese (Mn), iron (Fe), nickel (Ni), copper (Cu), zinc (Zn), selenium (Se), cobalt (Co), aluminium (Al), arsenic (As), cadmium (Cd), total mercury (Hg), lead (Pb) and tin (Sn) in each fish species was performed according to US EPA (2007).

Metal analysis

Determinations of toxic metals were carried out with a Thermo electron X2 inductively coupled plasma mass spectrometry (ICP-MS) (Model X series, Winsford-Cheshire UK). ICP-MS operating conditions: Nebulizer gas flow 0.91 L/min, Radio frequency (RF) 1200 W, Lens voltage 1.6 V, Cool Gas 13.0 L/min, Auxiliary Gas 0.70 L/min. For each sample, between 0.3 and 0.5 g of tissue (wet weight) was weighed and placed in a Teflon digestion vessel with 7 mL of concentrated (65 %) nitric acid (HNO_3) and 1 mL 30 % hydrogen peroxide (H_2O_2). The sample in the vessel containing concentrated nitric acid was then subjected to a microwave program as follows: Step 1: 25–200 °C for 10 min at 1000 W; Step 2: 200 °C for 10 min at 1000 W. Digests were finally made up with deionized water to 25 mL in acid-washed standard flasks. Calibration standards were purchased from High-Purity Standards (P.O. Box 41727 Charleston, SC 29423, USA). The standards were diluteed appropriately and used to calibrate the ICP-MS before metal determinations in samples. All metal concentrations were determined on a µg/g wet weight (w.w.) basis. Maximum, minimum and average of measured values are presented and evaluated.

Terms and abbreviations used in the risk assessment is as follows:

- Weekly fish consumption **(WFC):** g/week/person: 150 g fish for one portion/week
- Concentration of contaminant **(C):** µg/g
- Body weight **(BW):** 64.2 kg for women between 25 and 34 years old and 70.4 kg for women between 35–44 years old (Bora Başara et al., 2013)
- **Estimated weekly intake (EWI): WFC x C/ BW**
- **Hazard Index (HI):** Calculated weekly intake for certain contaminant/provisional tolerable weekly intake (Antonijevic et al., 2011). Provisional Tolerable Weekly Intake **(PTWI)** is presented in table 1.
- HI > 1, unacceptable risk.
- Exposure frequency **(EF):** 365 days/year
- Exposure duration **(ED):** 76 years (Bora Başara et al., 2013)
- Food ingestion rate **(FIR):** 150 g/person/day
- Oral reference dose **(RFD):** see table 1.
- The averaging exposure time for non-carcinogens **(TA):** 365 days/year x ED.
- **Target hazard quotient (THQ): (EF x Ed x FIR x C / RFD x BW x TA) x 0.001**

In this study, 10 % of the total As represent the inorganic As content to calculate the EWI, HI and THQ (Qin et al., 2015), 100 % of the total Hg was used for calculating the EWI, HI and THQ of organic Hg (EFSA, 2012).

Results and Discussion

The ranges and mean concentrations of trace metals expressed in µg/g w.w. for each fish species are presented in table 2. The metal concentrations in muscle of the analysed species in other scientific research it is shown in table 3. The value of HI and THQ for all trace metals, except mercury were found in the tolerable values for women of different childbearing ages. The Total-HI and Total-THQ value in all fish species showed the health risk for women of different childbearing age (Table 4, 5 and 6).

The manganese concentration found in this study was in the range of 0.47 µg/g up to 1.53 µg/g for bluefish, 0.84–1.64 µg/g for anchovy and 1.46–2.29 µg/g for sardine muscle tissues. In literature, many researchers have reported different manganese values for the same fish species caught from different seas. As can be seen in table 3, these values were higher than that reported by Burger & Gochfeld (2005) and Uluözlü et al. (2007) for bluefish and reported by Copat et al. (2013) for anchovy. Unlike them, Tüzen (2009) reported a higher value for bluefish and anchovy.

Manganese is required for normal metabolism of amino acids, proteins, lipids and carbohydrates. Manganese also acts as a cofactor for a variety of enzymatic reactions and is necessary for the function of many organ systems. On the other hand, exposure to high levels of Mn causes a type of neurotoxicity commonly referred to as manganism (Liu et al., 2008). Recommended daily intake of manganese is 70 µg/kg body weight (Oforko et al., 2012) weekly intake is 490 µg/kg body weight. The weekly Mn intake levels in the three fish investigated (Table 4, 5 and 6) for childbearing age women were under the limit.

In this study, iron content was found between 11.99–24.58 µg/g for bluefish, 14.47–20.25 µg/g for anchovy, and 12.12–33.98 µg/g for sardine. Similar iron contents for anchovy were reported by other authors (Turan et al., 2009). Our values higher than the iron value were reported by Uluözlü et al. (2007) and Tüzen (2009) for anchovy and for bluefish. Iron deficiency causes anemia, and fish is a major source of iron for adults and children. JECFA (1983) reported provisional maximum tolerable daily intake (PMTDI) for iron of 0.8 mg/kg of body weight (maximum tolerable weekly intake = 5600 µg/week/kg bw). The HI of fish consumption, namely the ratio of estimated weekly intake to provisional tolerable weekly intake (EWI/PTWI) was estimated for childbearing age women consumers and no risk emerged.

The lowest and highest nickel levels of mean values in muscle tissues of the fish species were 0.36 µg/g in anchovy and 0.66 µg/g in sardine. The World Health Organization (WHO, 1994) recommends 100–300 µg nickel for daily intake. According to mean value of measured data, the intake of nickel by a serving of bluefish, anchovy and sardine are 60 µg, 54 µg, and 99 µg, respectively. Ni is a nutritionally essential trace metal and Ni is toxic at higher concentrations and shows a carcinogenic side effect when consumed in high amounts (Malik et al., 2010; Jović & Stanković, 2014). There is no PTWI or PMTDI for Ni but the WHO recommends a TDI of 5 µg/kg bw, i. e., 2.1 mg/week for a 60-kg person (WHO, 1993). The adequate value for childbearing age women did not exceed in all samples.

Copper is a necessary trace element that at low levels can result in anaemia, gastrointestinal disturbances, bone development abnormalities, and death. Zinc is an essential element in our diet. Zinc deficiency and high zinc intake in

TABLE 1: *The PTWI and RFD values used in the calculation.*

	PTWI (µg/week/kg)		RFD (µg/g/day)	
Mn	70	Oforko et al., 2012	1.4×10^{-1}	Qin et al., 2015
Fe	5600	Conte et al., 2015	7.0×10^{-1}	Qin et al., 2015
Ni	35	Oforko et al., 2012	2.0×10^{-2}	Qin et al., 2015
Cu	3500	Conte et al., 2015	4.0×10^{-2}	Qin et al., 2015
Zn	7000	Oforko et al., 2012	3.0×10^{-1}	Qin et al., 2015
Se	7	WHO, 2008	5.0×10^{-3}	Qin et al., 2015
Co	700	Naseri et al., 2014	3.0×10^{-4}	Qin et al., 2015
Al	2000	Sipahi et al., 2014	1.0	Qin et al., 2015
As	15	EFSA, 2009a	3×10^{-4}	Qin et al., 2015
Cd	2.5	EFSA, 2009b	1×10^{-3}	Qin et al., 2015
Hg	1.3	EFSA, 2012	1.0×10^{-4}	Qin et al., 2015
Pb	25	EFSA, 2010	15×10^{-4}	Qin et al., 2015
Sn	14000	EFSA, 2005	6×10^{-1}	Qin et al., 2015

TABLE 2: *The mean concentration and range (µg/g) of toxic metal contamination in bluefish (n = 20), anchovy (n = 200) and sardine (n = 200).*

	Bluefish	Anchovy	Sardine
Mn	0.82 (0.47– 1.53)	1.20 (0.84– 1.64)	1.83 (1.46– 2.39)
Fe	16.71 (11.99–24.58)	16.59 (14.47–20.25)	21.54 (12.12–33.98)
Ni	0.40 (0.23– 0.57)	0.36 (0.23– 0.51)	0.66 (0.35– 0.95)
Cu	3.40 (1.20– 7.50)	1.65 (1.23– 1.95)	2.70 (1.40– 5.20)
Zn	21.43 (19.20–23.00)	28.00 (23.00–36.00)	34.67 (25.00–43.00)
Se	0.35 (0.31– 0.41)	0.29 (0.25– 0.35)	0.70 (0.37– 0.97)
Co	0.11 (0.05– 0.19)	0.14 (0.03– 0.22)	0.11 (0.06– 0.15)
Al	2.49 (1.89– 3.54)	1.98 (1.28– 2.64)	1.22 (0.75– 1.61)
As	0.17 (0.10– 0.26)	0.19 (0.17– 0.50)	0.49 (0.22– 0.95)
Cd	0.06 (0.05– 0.08)	0.12 (0.09– 0.15)	0.09 (0.03– 0.15)
Hg	0.47 (0.41– 0.55)	0.38 (0.18– 0.65)	0.53 (0.25– 0.98)
Pb	0.34 (0.21– 0.55)	0.19 (0.10– 0.30)	0.28 (0.10– 0.45)
Sn	0.14 (0.03– 0.35)	0.11 (0.01– 0.30)	0.02 (0.01– 0.03)

TABLE 3: *The comparison of metal concentrations (µg/g) in muscle of the analysed species in other scientific research (Ranau et al., 2001; Blanco et al., 2008; Burger Gochfeld, 2005; Keskin et al. 2007; Uluözlü et al. 2007; Yusà et al., 2008; Tüzen, 2009; Copat et al. 2013; Makedonski et al. 2017).*

Species	Mn	Fe	Ni	Cu	Zn	Se	As	Cd	Hg	Pb
Bluefish	0.23–6.90	68.6–110	1,87–3.89	0.63–2.78	10–93.4	0.55	0,26 –0.27	0.043 –0.23	0.028–0.09	0.108–0.87
Anchovy	0.26–9.10	75.7– 95.6	1.93–2.63	1.96–3.49	6.58–38.8	0.53	0.159–5.25	0.0010–0.27	0.02 –0.55	0.005–0.3
Sardine				0.56				0.003 –0.10	0.03 –0.3	0.02 –0.36

TABLE 4: *EWI, HI and THQ values for bluefish.*

	EWI	HI	THQ	EWI-max	HI-max	THQ-max
25–34 years old (body weight: 64.2 kg)						
Mn	1.92	0.004	0.002	3.57	0.007	0.004
Fe	39.04	0.007	0.008	57.43	0.010	0.012
Ni	0.93	0.027	0.007	1.33	0.038	0.010
Cu	7.94	0.002	0.028	17.52	0.005	0.063
Zn	50.08	0.007	0.024	53.74	0.008	0.026
Se	0.83	0.118	0.024	0.96	0.137	0.027
Co	0.25	0.000	0.119	0.44	0.001	0.211
Al	5.83	0.003	0.001	8.27	0.004	0.001
As	0.40	0.026	0.019	0.61	0.040	0.029
Cd	0.15	0.059	0.021	0.19	0.075	0.027
Hg	1.10	0.845	1.569	1.29	0.988	1.836
Pb	0.79	0.031	0.075	1.29	0.051	0.122
Sn	0.33	0.000	0.000	0.82	0.000	0.000
Total		**1.130**	**1.896**		**1.365**	**2.368**
35–44 years old (body weight: 70.4 kg)						
Mn	1.75	0.004	0.002	3.26	0.007	0.003
Fe	35.60	0.006	0.007	52.37	0.009	0.011
Ni	0.85	0.024	0.006	1.21	0.035	0.009
Cu	7.24	0.002	0.026	15.98	0.005	0.057
Zn	45.67	0.007	0.022	49.01	0.007	0.023
Se	0.75	0.108	0.022	0.87	0.125	0.025
Co	0.23	0.000	0.108	0.40	0.001	0.193
Al	5.31	0.003	0.001	7.54	0.004	0.001
As	0.36	0.024	0.017	0.55	0.037	0.026
Cd	0.13	0.054	0.019	0.17	0.068	0.024
Hg	1.00	0.770	1.431	1.17	0.901	1.674
Pb	0.72	0.029	0.068	1.17	0.047	0.112
Sn	0.31	0.000	0.000	0.75	0.000	0.000
Total		**1.031**	**1.729**		**1.245**	**2.159**

TABLE 5: *EWI, HI and THQ values for anchovy.*

	EWI	HI	THQ	EWI-max	HI-max	THQ-max
25–34 years old (body weight: 64.2 kg)						
Mn	2.82	0.006	0.003	3.84	0.008	0.004
Fe	38.76	0.007	0.008	47.32	0.008	0.010
Ni	0.85	0.024	0.006	1.19	0.034	0.006
Cu	3.86	0.001	0.014	4.56	0.001	0.016
Zn	65.42	0.009	0.031	84.11	0.012	0.040
Se	0.68	0.097	0.019	0.81	0.115	0.023
Co	0.32	0.000	0.151	0.51	0.001	0.245
Al	4.63	0.002	0.001	6.17	0.003	0.001
As	0.69	0.046	0.033	1.168	0.078	0.056
Cd	0.28	0.112	0.040	0.35	0.140	0.050
Hg	0.90	0.689	1.280	1.52	1.168	2.170
Pb	0.44	0.018	0.042	0.70	0.028	0.067
Sn	0.25	0.000	0.000	0.69	0.000	0.000
Total		**1.012**	**1.628**		**1.597**	**2.687**
35–44 years old (body weight: 70.4 kg)						
Mn	2.57	0.005	0.003	3.50	0.007	0.004
Fe	35.35	0.006	0.007	43.15	0.008	0.009
Ni	0.78	0.022	0.006	1.08	0.031	0.008
Cu	3.52	0.001	0.013	4.15	0.001	0.015
Zn	59.66	0.009	0.028	76.70	0.011	0.037
Se	0.62	0.089	0.018	0.74	0.105	0.021
Co	0.29	0.000	0.138	0.47	0.001	0.223
Al	4.23	0.002	0.001	5.63	0.003	0.001
As	0.63	0.042	0.030	1.07	0.071	0.051
Cd	0.26	0.102	0.037	0.32	0.128	0.046
Hg	0.82	0.628	1.167	1.38	1.065	1.979
Pb	0.40	0.016	0.039	0.64	0.026	0.061
Sn	0.23	0.000	0.000	0.63	0.000	0.000
Total		**0.923**	**1.485**		**1.456**	**2.453**

diet pose a harmful to human health. The copper concentration found in this study was in the range of 1.65 µg/g up to 3.40 µg/g for fish muscle tissues. According to Turkish Food Codex (2011), the maximum copper level permitted for sea fishes is 20 mg/kg (µg/g). The results of this study were found below these limits. The minimum and maximum zinc levels in fish muscle tissues were found as 21.43 µg/g in bluefish and 34.67 µg/g in sardine, respectively. The maximum zinc level permitted for fishes is 50 mg/kg (µg/g) according to Turkish Food Codex (2011). Maximum Zn level in edible parts of fish in this research was found to be below the permissible standards. Provisional tolerable weekly intake was established for copper as 3500 µg/kg bw and for zinc as 7000 µg/kg bw, i.e., for childbearing age women, equalling to 225–449 and 246–493 mg copper and zinc/week for a 64.2 to 70.4-kg person. Thus, the intake of copper and zinc in analysed fish species was well below this limit.

The levels of selenium in tissue of the analysed fish species were in the range of 0.29–0.70 µg/g. Selenium is found in the structure of the antioxidant glutathione peroxidase, which plays a role in the prevention of certain metabolic diseases and cancer types. The biological importance of selenium is that it is a cofactor of this enzyme (FAO/WHO, 2004). The PTWI of selenium has been set at 7 µg/kg bw (WHO, 2008), equalling 449 µg and 493 µg selenium /week for 64.2 and 70.4 childbearing age women. The weekly intake of selenium from analysed fish species in table 4, 5, and 6 has been calculated, were found below of limit in three fish species.

The levels of cobalt in tissue of the analysed fish species were in the range of 0.11-0.14 µg/g. The concentration of cobalt reported 0.02–0.67 µg/g for muscles of fish from Indian fish markets (Sivaperumal et al., 2007), 0.40 µg/g for muscles of Atlantic bonito *(Sarda sarda)*, 0.38 µg/g for muscles of horse mackerel *(Trachurus trachurus)*, 0.25 µg/g for muscles of whiting *(Merlangius merlangus)* (Mendil et al., 2010). The essential form of Co is cobalamin, which is a critical component of vitamin B12. However, chronic oral administration of high levels of Co for the treatment of anemia can cause goiter (Jović & Stanković, 2014). PTWI not reported for cobalt, but is used a Maximum Tolerable Daily Intake (MTDI) of 100 µg/kg bw (= 700 µg/kg bw in a week). As shown in tables 4, 5 and, the intake of cobald for childbearing age women is rather low.

The levels of aluminium in tissue of the analysed fish species were in the range of 1.98–2.49 µg/g. The concen-

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TABLE 6: *EWI, HI and THQ values for sardine.*

	EWI	HI	THQ	EWI-max	HI-max	THQ-max
25–34 years old (body weight: 64.2 kg)						
Mn	4.27	0.009	0.004	5.59	0.011	0.006
Fe	50.33	0.009	0.010	79.40	0.014	0.016
Ni	1.55	0.044	0.011	2.23	0.064	0.016
Cu	6.31	0.002	0.023	12.15	0.003	0.043
Zn	81.00	0.012	0.039	100.47	0.014	0.048
Se	1.63	0.212	0.047	2.26	0.323	0.065
Co	0.26	0.000	0.123	0.35	0.001	0.167
Al	2.85	0.001	0.000	3.77	0.002	0.001
As	1.14	0.076	0.055	2.22	0.148	0.106
Cd	0.20	0.081	0.029	0.35	0.140	0.050
Hg	1.23	0.947	1.758	2.29	1.761	3.271
Pb	0.66	0.026	0.063	1.05	0.042	0.100
Sn	0.05	0.000	0.000	0.07	0.000	0.000
Total		**1.440**	**2.161**		**2.524**	**3.889**
35–44 years old (body weight: 70.4 kg)						
Mn	3.89	0.008	0.004	5.10	0.010	0.005
Fe	45.90	0.008	0.009	72.40	0.013	0.015
Ni	1.41	0.040	0.010	2.03	0.058	0.015
Cu	5.75	0.002	0.021	11.08	0.003	0.040
Zn	73.86	0.011	0.035	91.62	0.013	0.044
Se	1.49	0.212	0.042	2.06	0.295	0.059
Co	0.23	0.000	0.112	0.32	0.000	0.152
Al	2.60	0.001	0.000	1.60	0.001	0.000
As	1.04	0.070	0.050	2.02	0.135	0.096
Cd	0.18	0.074	0.026	0.32	0.128	0.046
Hg	1.12	0.863	1.603	2.09	1.606	2.983
Pb	0.60	0.024	0.057	0.96	0.038	0.091
Sn	0.04	0.000	0.000	0.06	0.000	0.000
Total		**1.313**	**1.971**		**2.301**	**3.546**

tration of aluminium reported 0.159–0 µg/g for anchovy from open North Sea (Ranau et al., 2001). Aluminium is a ubiquitous component of many foods (e. g. fruit, vegetables, cereals, seeds, meat and seafood). Aluminium is overall of lower toxicity than many other metals. It is very poorly taken up from the gastrointestinal tract following ingestion. Alzheimer's disease and may be associated with other neurodegenerative diseases in humans. The tolerable weekly intake (TWI) established by EFSA for ingested aluminium from all sources is 1 mg/kg body weight (EFSA, 2008). However, in 2011, JECFA have increased their PTWI for aluminium to 2 mg/kg body weight (JECFA, 2011). The weekly intake value of Al with bluefish, anchovy and sardine consumption found significantly lower in childbearing age women.

The arsenic level in tissue of analysed fishes was in the range of 0.17 up to 0.49 µg/g. The concentration of arsenic reported in fish species from Adriatic Sea ranged between 0.56 and 10.03 µg/g fresh weight (Jureša & Blanuša, 2003). Contaminants in fish can pose health risks to the fish themselves and their predators. Arsenic poisoning is relatively rare in wildlife.

Most arsenic in fish is organic arsenic, which is less toxic than inorganic arsenic species.

Cadmium may accumulate in the human body and may induce kidney dysfunction, skeletal damage and reproductive deficiencies. Lead is known to induce reduced cognitive development and intellectual performance in children and increased blood pressure and cardiovascular disease in adults (FAO/WHO, 2004). The levels of cadmium in tissues of the analysed fish species were in the range of 0.06–0.12 µg/g. The maximum Cd level permitted for marine fish samples is 0.05 µg/g according to the European Community (European Commission Regulation, 2006). Cadmium levels in the present study were in good agreement with reported literature data and with the data from the international organizations.The lowest and the highest total lead content in muscle was found as 0.19 and 0.34 µg/g in anchovy and bluefish. The maximum level of lead in seafood establishes by the European Community (European Commission Regulation, 2006) is 0.3 mg/kg (µg/g) w.w. The values obtained from the analysed samples showed good agreement with values reported in the literature are below the level set by various health organizations (European Commission Regulation, 2006). The levels of tin in tissue of the analysed fish species were in the range of 0.02–0.14 µg/g. Tin levels in the literature have been reported in the range of 0.109–0.143 µg/g for muscle of fish from the Northeast China (Qin et al., 2015). According to FAO/WHO (2004), the average weekly intake for women of childbearing age was estimated to be 0.96 mg and 1.06 mg for As ($PTWI_{As}$ = 15 µg/kg body weight/week), 0.16 mg and 1.76 mg for Cd (TWI_{Cd} = 2.5 µg/kg body weight/week), 1.61 mg and 1.76 mg for Pb ($PTWI_{Pb}$ = 25 µg/kg body weight/week), 898.8 mg and 985.6 mg for Sn ($PTWI_{Sn}$ = 14000 µg/kg body weight/week). These values do not suggest a health problem.

The lowest and highest mercury levels in muscle tissues of analysed fish species were found as 0.38 µg/g in anchovy and 0.53 µg/g in sardine. The maximum Hg level permitted for fish products and muscle tissues of various fishes is 0.50 mg/kg (µg/g) w.w according to European Food Safety Authority (European Commission Regulation, 2006). Mercury mean values in analysed fish samples were found to be lower than legal limits. In the literature mercury levels in fish samples have been reported in the range of 0.01–0.50 µg/g in marine fishes in Malaysia (Hajeb et al., 2009), 0.001–1.1 µg/g for top fish consumed in southern Europe (Mieiro et al., 2016). Methylmercury is reported to damage developing fetus and young children. Fish consumption is the only significant source of methylmercury. Maternal exposures can threaten the fetus because chemicals can be transferred across the placenta to the developing fetus (Burger & Gochfeld, 2005). The analysed total mercury may be converted to methylmercury and inorganic mercury by applying conversion factors based on the methylmercury/total mercury proportion derived from literature data, using a conservative approach. For fish meat, fish products, fish offal and unspecified fish and seafood a conversion factor of 1.0 uses for methylmercury and 0.2 for inorganic mercury. For crustaceans, molluscs and amphibians the conversion factor is 0.8 for methylmercury and 0.5 for inorganic mercury. For all other food categories apart from 'Fish and other seafood', total mercury it is accepted as inorganic mercury. Tolerable weekly intake (TWI) for methylmercury was reported as 1.3 µg/kg b.w. (EFSA, 2012).

The minimum, maximum and average values of the three fish analysed in this study were found above the limit values for cadmium. When HI and THQ values calculated for cadmium are examined, it is seen that there is no health risk associated with 150 g consumption of these fish in women of childbearing age (Table 4, 5, and 6). Similarly, the detected maximum and average lead values in bluefish and sardine, the detected maximum lead value in anchovy were found above the declared limit for lead. The HI and THQ values calculated for lead is below 1 and does not constitute any health risk. The detected maximum mercury value in bluefish and anchovy, additionally the detected mean value in sardine were determined above legal limit for mercury. Contrary to the calculated HI and THQ value for lead and cadmium, the calculated HI and especially THQ value for mercury indicated a significant health risk these fish for women of childbearing age. Similarly, THQ of Hg in albacore *(Thunus alalunga),* rosefish *(Sebastes norvegicus),* and thornback ray *(Raja clavata)* were found more than one (Storelli, 2008). Concentrations of different metals were determined in four species of anchovy (*Coilia* sp.) from the Yangtze River, Taihu Lake, and Hongze Lake in Jiangsu Province, China and the THQ for Cr in anchovy exceeded 1.0 (Liu et al., 2009). In study of Mansilla-Rivera and Rodríguez-Sierra (2011) were found based on metal levels in four specific fish species from the Jobos Bay area and two from La Parguera area (Puerto Rico), health risk estimates determined and THQ values of As and Hg for children and adult found greater than 1. THQ of trace elements in cyprinid fish species from Northeast China were found all less than one for average exposure level and high exposure level (Qin et al., 2015).

Conclusions

The sum (THI and TTHQ) of the calculated HI and THQ for all metals showed that health risks in women of childbearing age could occur with the consumption of these fish species. In our study, were examined the estimation of the contribution of fish consumption to trace metals EWI, HI, and THQ for women of childbearing age (from 25 to 44 years old). Regarding Mn, Fe, Ni, Cu, Zn, Se, Co, Al, As, Cd, Pb, and Sn, no health risk for women of childbearing age consuming one serving of bluefish, anchovy and sardine could be established. The tolerable values were exceeded in THQ of Hg and total THQ. Consequently, it is important to first establish periodical monitoring studies to assess Hg intake due to fish and seafood consumption and maximum residue limits for the different species. Different fish species yielded varying levels con consumption risks, and this not should be ignored. Second, consumers should be informed about risk of fish-based diet.

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Conflict of interest

The authors declare that they have no competing interests.

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