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Original Scientific Paper

Assessment of Mercury intake through fish consumption among different population groups in Serbia

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A R T I C L E I N F O

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A B S T R A C T

Fish are the major sources of healthful long-chain omega-3 fats and are also rich in other nutrients. On the other hand, fish contain many harmful substances which can be transferred through the food chain with undesirable effects on human health. Mercury is one of the toxic elements that does not have an essential biological function but can cause harmful effects on the nervous system, primarily in children. Having in mind the toxicity of mercury and the fact that fish is the main source of mercury in human diets, the aim of this study was to assess mercury intake by fish consumption in different Serbian population groups. In the period 2023-2024, 723 samples of different fish types were analysed by inductively coupled plasma mass spectrometry (ICP MS). The highest concentration of mercury was found in tuna – maximum 0.969 mg kg^{-1}, mean 0.274 mg kg^{-1}. The fish with the lowest mercury content was trout, with a mean of 0.009 mg kg^{-1}. The obtained results were used to calculate the weekly intake of mercury/methylmercury in three population groups in Serbia – toddlers, adults and pregnant women. The intake of methylmercury in the adult population and in pregnant women was almost the same – 0.067 and 0.065 µg kg^{-1} body weight per week, respectively, while it was twice as high in toddlers. Generally, mercury intake through fish consumption in Serbia is very low, so far from tolerable weekly intakes, and this gives an opportunity to increase the share of fish in the Serbian diet in order to achieve positive effects from fish consumption.

1. Introduction

Fish is a very important food in the human diet because it is rich in essential nutrients, primarily omega-3 fatty acids, vitamins and minerals, which have a beneficial effect on the cardiovascular system, brain, vision and immune system. However, considering the pollution of aquatic ecosystems, fish also contain toxic substances, such as persistent organohalogen compounds and heavy metals. Among the heavy metals, the presence of mercury (Hg) is mainly associated with fish.

Mercury is found in nature as elemental, and in inorganic and organic compounds. Mercury and mercury compounds were used in the production of plastic materials and caustic soda, in thermometers and electrical switches, and as fungicides, and today, Hg is still used in dental amalgam. Of the organic compounds in the environment, methylmercury (MeHg) is the most common and most toxic (*ATSDR,*

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1999). The International Organization for Research on Cancer (IARC) classifies MeHg in group 2B, i.e., as a possible human carcinogen, while elemental Hg and inorganic Hg compounds are not classified as carcinogens (*IARC*, 1993). Methylation of Hg is the result of microbial activity and is of primary importance for the circulation of Hg in the environment and for Hg toxicity, because methylation results in a stable liposoluble compound with good resorptive properties that passes through the blood-brain and placental barriers (*Ersoy and Çelik*, 2010; *Merritt and Amirbahman*, 2009; *Saei-Dehkordi et al.*, 2010). Thanks to accumulation in aquatic organisms and their predators, MeHg levels in these animals reach several times higher than those in water.

The dominant intake of Hg in humans is through food, and over 90% of ingested Hg comes from fish and fish products. Methylmercury is very well resorbed from the digestive tract (90%), while the resorption of inorganic Hg compounds is very low, only about 8%. The half-life of Hg in humans is 70 days, and it is excreted in saliva, urine, faeces and milk. The toxic effect of Hg is caused by it binding to sulfhydryl and other groups of proteins and by changing their structure and function (*ATSDR*, 1999). Much information about the toxicity of MeHg was obtained after the accidents in Iraq (*Bakir et al.*, 1973) and the Japanese cities of Minamata and Niigata (*Irukayama et al.*, 1977). Inorganic compounds of Hg and elemental Hg have low toxicity due to poor resorption. The exceptions are $HgCl_2$ and Hg vapor, which can be absorbed through the lungs and enter the bloodstream directly. Unlike Hg^{2+}, which is predominantly nephrotoxic and accumulates in the kidneys, organic Hg is neurotoxic. Methylmercury damages neurons and leads to diffuse encephalopathy causing sensory, motor and cognitive disorders. Given that Hg passes through the placenta, a teratogenic effect can occur. Genotoxicity in the form of chromosomal aberrations caused by the binding of Hg to sulfhydryl groups on RNA and DNA has also been proven (*ATSDR*, 1999; *WHO*, 1990). It is important to note that MeHg can cause harmful effects on the nervous system, primarily in children, even at relatively low levels of exposure (*Davidson et al.*, 1995; *Grandjean et al.*, 1997).

According to the available data, the intake of fish in Serbia is relatively small. Carp, trout, hake, mackerel, sardine, sprat and tuna are the most commonly consumed fish species. The aim of this work was to evaluate the intake of Hg through consumed fish in different population groups of Serbia (toddlers, adults, pregnant women), based on the examination of the content of Hg in fish and the estimated intake of fish.

2. Materials and methods

A total of 723 samples of fish and fish products from the Serbian market were tested in the period 2023-2024 for Hg concentration. The following types of fish were tested: hake (n= 253), mackerel (n= 88), sprat (n= 28), tuna (n= 34), salmon (n= 72), sea bass (n= 30), sea bream (n= 33), carp (n= 26), trout (n= 48), as well as canned sardine (n= 19) and canned tuna (n= 92).

After homogenization, the samples were prepared by microwave digestion using nitric acid (67% Trace Metal Grade, Fisher Scientific, Bishop, UK). The determination of the ^{202}Hg isotope was performed using inductively coupled plasma mass spectrometry (ICP-MS) on an iCap Qc instrument (Thermo Scientific, Bremen, Germany), in the kinetic energy discrimination (KED) mode. Basic operating conditions of the instrument were: RF power (1550 W); cooling gas flow (14 L/min); nebulizer flow (1 L/min); collision gas flow (1 mL/min); dwell time (10 ms). Standard stock solution containing 1000 mg/L of Hg was purchased from CPAchem (Bogomilovo, Bulgaria). This solution was used to prepare standards for five-point calibration curves (including zero). A multi-element internal standard (6Li, 45Sc, 71Ga, 89Y and 209B) was used to correct the results due to fluctuations in the system itself. A reference material (NIST 1577c - beef liver, Gaithersburg, Maryland, USA) was used for quality control of the assay.

Descriptive statistics data analysis was performed using Microsoft Office® Excel.

3. Results and discussion

Levels of Hg in different fish and fish products from the Serbian market are shown in Table 1. Results are presented as mean ± standard deviation (sdev).

The Hg content was not exceeded the maximum permitted amounts prescribed by the current Rulebook of the Republic of Serbia (*Serbia*, 2025) in the analysed samples. As expected, considering the fish size, age and diet, the highest concentration of Hg was found in tuna – a maximum of 0.969 µg g^{-1}, mean of 0.274 µg g^{-1}. The fish with the lowest Hg content was trout, with a mean of 0.009 µg g^{-1}.

Table 1. Concentration of Hg in fish and fish products on the market in Serbia

Fish/ fish products	**Number of samples**	**min Hg, µg g^{-1}**	**max Hg, µg g^{-1}**	**mean Hg ± sdev, µg g^{-1}**
Hake	253	0.002	0.222	0.032 ± 0.027
Mackerel	88	0.009	0.128	0.031 ± 0.020
Sprat	28	0.008	0.049	0.019 ± 0.014
Tuna	34	0.017	0.969	0.274 ± 0.240
Salmon	72	0.001	0.043	0.017 ± 0.009
Sea bass	30	0.001	0.077	0.038 ± 0.015
Sea bream	33	0.014	0.089	0.036 ± 0.020
Carp	26	0.003	0.042	0.011 ± 0.010
Trout	48	0.002	0.023	0.009 ± 0.005
Caned sardines	19	0.005	0.105	0.034 ± 0.028
Canned tuna	92	0.008	0.804	0.077 ± 0.108

The obtained data are comparable to the results available in the professional literature. Some deviations can be explained by variations in the examined fish (species and subspecies), and the different origins and ages of the fish (*Brodziak-Dopierała and Fischer*, 2023; *U.S. Food and Drug Administration*, 2012; *Nina Bilandžić et al., 2017, FRIDA, 2025.*)

Table 2 shows the estimated weekly intake of Hg in three population groups in Serbia based on the obtained concentrations of Hg in fish and fish products and the estimated intake of individual fish (*EFSA Database*, 2024). As Hg in fish is mainly found in the form of MeHg, i.e., up to 100% is in this form (*Norwegian Scientific Committee for Food and Environment*, 2019), we corrected the values obtained for Hg intake by a factor of 1.075 (atomic mass of Hg – 200.56 g mol^{-1}, molecular mass of MeHg – 215.63 g mol^{-1}) and obtained the weekly intake of MeHg. The EFSA Scientific Panel on Contaminants in the Food Chain (CONTAM) has established a tolerable weekly intake (TWI) of 1.3 µg kg^{-1} body weight (bw) for MeHg and 4 µg kg^{-1} bw for inorganic Hg (EFSA, 2012).

Based on the results, it can be concluded that the intake of MeHg in the adult population and in pregnant women is almost the same, while it is twice as high in children. Nevertheless, the calculated hazard index (HI = weekly intake of MeHg/TWI) for the population of children is low, just 0.10, which leads us to the conclusion that there is no unacceptable risk of consuming fish from the aspect of toxic effects of ingested Hg, i.e., the risk is acceptable. The HIs obtained in studies around the world also show a low risk, and its value is primarily determined by the food consumed, i.e., the prevalence of fish in the dietary habits of certain countries. As Serbia belongs to the countries with a low proportion of fish in the diet, it is understandable that the intake of Hg is low, but on the other hand, the benefit from the positive nutritional characteristics of fish as a food is also low.

From the available literature data, it can be concluded that Hg intake is correlated with the share of fish in the diet. Significantly higher amounts of Hg intake were obtained in countries where the diet mostly is based on fish or in locations with a highly polluted environment. Thus, the population of the

Table 2. The estimated weekly intake of Hg/MeHg for three population groups in Serbia

Population group	**Mean fish intake, g kg^{-1} bw per day**	**Hg intake, µg kg^{-1} bw per week**	**MeHg intake, µg kg^{-1} bw per week**
Toddlers	0.564	0.115	0.124
Adults	0.226	0.062	0.067
Pregnant women	0.233	0.061	0.065

bw - body weight

Faroe Islands consumes an average 3.6 µg kg^{-1} bw of Me per week (*Weihe et al.*, 1996), while the estimated intake of Hg in Greenland is as much as 846 µg Hg per week, which for a person weighing 70 kg would represent an intake of 12.1 µg kg^{-1} bw per week or 9.3 times the tolerable intake (*Johansen et al.*, 2000).

A study of Hg intake in Portugal showed that the population aged 17 to 74 years averaged 1.25 µg kg^{-1} bw/week, while the intake of women aged 18 to 45 years was slightly lower – 1.13 µg kg^{-1} bw/week (*Vasco et al.*, 2025). *Lee et al.* (2006) estimated that the weekly intake for a South Korean adult with an average bw of 55 kg is 0.21 µg kg^{-1} bw. The average Hg daily intake of children in the Jinhu area of China was 0.14 µg kg^{-1} bw, which in relation to TWI represents 74% of the recommended safe intake level (*Sun et al.*, 2011). In the adult population of France, the estimated intake of 0.895 µg kg^{-1} bw was lower than the tolerable value (*Leblanc et al.*, 2005), but at the same time, higher than the estimated intake in Serbia in our study. Low values of Hg intake were obtained by *Puklova et al.* (2010) in the Czech Republic. They estimated that the Hg weekly food intake averages only 0.08 µg/kg bw. The authors explain such a low value by the small proportion of fish in the diet of the Czech population. Also, higher values of the estimated intake of Hg in Serbia were obtained in a study in which 20 European countries participated in the period 2004-2011, when levels were, for the adult population 0.24 µg kg^{-1} bw, and for children 0.32 µg kg^{-1} bw (*EFSA*, 2012).

4. Conclusion

This study aimed to evaluate the intake of Hg/MeHg through the consumption of fish and fish products among different population groups in Serbia. Compared to tolerable values, there is no unacceptable risk of harmful effects of Hg ingested through fish. The HI for all three population groups is far below 1, with a maximum of 0.10 for children. There is, therefore, an opportunity to increase the share of fish in the diet in order to achieve positive effects, both nutritional and health, without significantly increasing the risk of the toxic effect of Hg as an undesirable component of fish flesh.

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