

Fish as a health food – ecotoxicological viewpoint

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Summary

Fish body metal (Cd, Pb, Zn, Cu, Al, Cr, Ni, Fe, Mn, Sr, Co) contents measurements, target organ and tissue distribution pattern analysis, bioaccumulation and biomagnification studies have been undertaken on a wide range of fish species belonging to various trophic levels within fish community from the Tikvesh reservoir in the R. Macedonia. The results of the current study indicated liver, kidney and gonads as target organs for metal accumulation and muscles as the tissue with the lowest concentrations of metal residues. Fish caught throughout 2006-2008 in the investigated area could be recommended as health food concerning metal burden as Macedonian alimentary standards for Cd and Pb in edible tissues have not been exceeded.

Key words: fish, metals, Tikvesh reservoir, R. Macedonia.

Introduction

In the past, a few accidental leaks of toxic waste into the hydro-ecosystems in the lower part of the Vardar River gave rise to discussions within the experts' community on possible threats to human health as a result of eating contaminated fish. With the help of some executive state agencies, fishing and fish trade were even prohibited on certain locations, which, ultimately as a consequence, unquestionably worsened the economic situation of the population directly involved in fishing as a source of their incomes and indirectly of the whole society as well.

This paper has not got any pretensions to give judgements on the grounds for making such a decision, nor to analyse the consequences and damages caused by these incidents. From an eco-toxicological aspect, the goal was to clarify some dilemmas on the actual exposure of people to possible metal poisoning via eating freshwater fish and to give an answer to the question whether fish really is health-safe food.

Materials and methods

The material for this research was collected in the lower part of the Vardar River in period 2006-2008. Dissection and preparation of samples were done following the standard procedure (US EPA, 1991, APHA, 1995). The concentration measurements of Cd, Pb, Cu, Zn and Al were performed on AAS, in fire, and Pb was checked on a graphite kivetete. The results presented in this paper show the mean values (n+10) +-SD. Bio-accumulation was checked by linear progression of non-transformed results. Comparisons between the samples were done using independent t-test in two populations, and variance analysis using ANOVA. Statistical significance was allocated at p=0.05 or less.

Results and discussion

Fish are organisms that grow all their lives and for most of their species a linear or exponential relation between their age and weight/length can be established. The enumerated parameters were correlated with metal concentrations in the muscles and the livers of 20 barbus units (*Barbus meridionalis Risso*) 100-1720g in weight, 118-596mm in length and 0+ - 4+ years of age, taken from two locations (Demir Kapija and Gevgelija) in the lower part of the Vardar River. It is evident from Table 1 that for none of the metals analysed a significant positive correlation was established with the units' age, weight and length, in other words – these results confirm the current attitude (Spry and Wiener, 1991, Dietz *et al.*, 1996, Carru *et al.*, 1996) that it does not come to progressive accumulation of Zn, Mn, Fe, Cu, Cr, Pb, Sr and Al together with ageing or growing, or that there are efficient mechanisms of detoxification or of elimination of accumulated metals in fish organisms. These results are encouraging from a health-care, but also from an ecological point of view, for they prove that commercial and bio-manipulation catch of fish for nutrition does not imply any risk increase and that it meets alimentary standards.

The analysis of accumulated metal tissue distribution is shown on the example of the gobio (*Gobio gobio Linnaeu*) from the location of Veles, the Vardar River which, based on a very high metal pollution Index (1.5), is characterised by Todorovic *et al.* (2000) as an ecosystem greatly polluted with metals.

The results (Table 2.) show that the musculature is definitively tissue with the lowest contents of accumulated heavy metals, within the limits of Macedonian alimentary norms, while the highest concentrations of metal residuum were observed in the liver and the gonads.

Tab. 1. Concentration correlation coefficients of Zn, Mn, Fe, Cu, Cr, Pb, Sr and Al in the muscles and livers vs. weight, length and age of 20 barbus units (*Barbus meridionalis* Risso)

Koeficijenti korelacije koncentracija Zn, Mn, Fe, Cu, Cr, Pb, Sr i Al u mišićnom tkivu i jetri nasuprot težini, dužini i starosti 20 barbus jedinica (Barbus meridionalis Risso)

	Muscles			Liver		
	Weight	Length	Age	Weigh	Length	Age
Zn	0.46	0.51	0.38	-0.54	-0.66*	0.69*
Mn	-0.87*	-0.7*	-0.42	-0.34	-0.48	-0.54
Fe	0.006	0.16	-0.4	0.36	0.52	0.51
Cu	-0.72*	-0.78*	-0.85*	-0.14	0.009	0.009
Cr	0.41	0.34	0.39			
Pb	0.05	0.16	-0.38	-0.63*	-0.64	-0.52
Sr	0.08	0.03	0.31	-0.42	-0.55	-0.6
Al	0.29	0.3	0.07	-0.33	-0.22	-0.14

Tab. 2. Distribution of accumulated metals in the tissues and the organs of gobio (*Gobio gobio* Linnaeus) from the location of Veles of river Vardar

Distribucija akumuliranih metala u tkivima i organima gobio (Gobio gobio Linnaeus) na lokaciji Veleš rijeke Vardar

	Zn	Mn	Cu	Cr	Cd	Ni	Pb	Al
Muscles	7.68	1.28	0.7	0.52	0.01	-	0.87	9.15
	+-	+-	+-	+-			+-	+-
	2.22	0.59	0.19	0.2			0.1	1.21
Gills	24.28	4.66	1.44	1.53	0.13	0.23	1.05	11.34
	+-	+-	+-	+-	+-	+-	+-	+-
	3.39	0.86	0.25	0.33	0.03	0.07	0.5	3.45
Gonads	63.26*	2.04	2.73	3.15*	-	-	1.88	32.13*
	+-	+-	+-	+-			+-	+-
	5.74	1.33	1.87	1.08			0.2	13.3
Liver	21.39	1.05	1.32	0.75	0.26*	0.36	4.02*	15.12
	+-	+-	+-	+-	+-	+-	+-	+-
	9.06	0.46	0.41	0.07	0.06	0.2	2.6	6.34

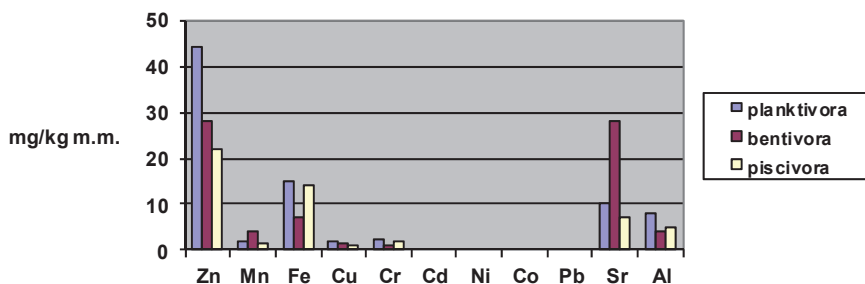
n=10; concentrations stated as mg/kg undrained (fresh) mass (i.e. weight); - below detection limit

*statistically significant the most (one-way ANOVA, p=0.05 or less)

These results are in accordance with conclusions of many authors (Salanki et al., 1982, Stripp et al., 1990, Berningen and Pannanen, 1994) that the liver and kidneys are the target organs for the accumulation of metals in fish, which is explained with efficient regulatory mechanisms: elimination via faeces (Berningen and Pannanen, 1994), high metallothionein concentrations (which efficiently bind Cd and Pb thus serving as detoxifiers) in the liver and kidneys, low affinity of SH muscle fibre groups to Pb and the fact that in fish, as well as in humans, only 1-

6% Cd and up to 10% of other metals resorbed via bowel mucous reaches muscles (Ohti and Chtenior, 1991). Spry and Wiener (1991) even draw a conclusion that, unlike methyl-Hg, Pb and Cd do not accumulate in the skeletal musculature in significant concentrations, therefore contamination of fish with these metals presents no particular risk to human health.

From a health aspect, it is very important to establish whether bio-magnification of metals occurs in the alimentary chains within the hydro-ecosystem, or whether the residuum accumulates progressively from lower towards higher trophic categories.



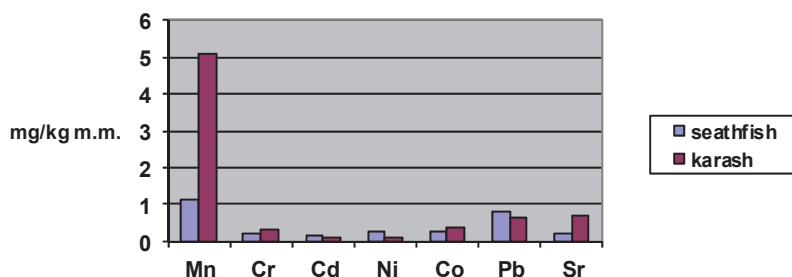
Graph. 1. Comparative review of the contents of metals in the musculature of a planktivore – plaska (*Alburnus alburnus*), bentivores – barbell (*Barbus barbuss* Linnaeus) and black mrena (*Barbus meridionalis* Risso), and a piscivore – seathfish (*Silurus glanis* Linnaeus), from the location of Pepeliste from the river Vardar
*Komparativni prikaz sadržaja metala u muskulaturi planktivora – uklija (*Alburnus alburnus*), bentivore – mrena (*Barbus barbuss* Linnaeus) i crna mrena (*Barbus meridionalis* Risso) i piscivore – som (*Silurus glanis* Linnaeus), sa lokacije Pepelište iz rijeke Vardar*

N=10 (5x2); all the concentrations expressed as mg of metal per kg undrained fish mass
*statistically significant the most (one-way ANOVA, p=0.05 or less)

**the actual statistical values are: Zn: 50.5* / 37 / 26; Mn: 3 / 4.5* / 2.5; Fe: 16.5 / 9 / 25; Cu: 2.5 / 2 / 1; Cr: 3.5 / 1 / 3; Sr: 12 / 36* / 8; Al: 12* / 7 / 8

Special interest for such examinations without doubt also lies in the fact that a great number of economically and nutritionally most attractive species belong to the piscivores, which are on the top of the ichthyofauna's trophic pyramid.

Graph. 1. and Graph. 2. give a comparative review of the contents of accumulated metals in the muscles and livers of fish that belong to various trophic levels. It can be clearly seen that for none of the examined metals a statistically significant concentration increase within the alimentary chain was established, which is in accordance with numerous literature data (Pujin *et al.*, 1990, Maletin *et al.*, 1996, Dietz *et al.*, 1996, Djukic *et al.*, 1998). It is evident that the explanation lies in the biology and ecology of the species from different trophic categories. Namely, in the hydro-ecosystems where pH value ranges around 7, the most divalent cations precipitate and in that way they are temporarily immobilised in the sediment. Since pH values of water in the lower part of the Vardar River vary just within the range 7-8 (Hydrological annuals 1997, 1998, 1999), the bentivore species are exposed to heavy metals via gill filtration, exclusively the contact layer of water in which they live, but also via direct mobilisation of metals from the sediment (Davis *et al.*, 1997). Laboratory examinations (Vighi, 1981, Memmert, 1987) showed that fish resorb Pb, Cd, Ni, Zn and methyl Hg directly from water, far more than from contaminated food.



Graph. 2. Comparative review of the contents of metals in livers of seathfish (*Silurus glanis* Linnaeus) and karash (*Carassius carassius* Linnaeus) from the location Demir Kapija of river Vardar

Komparativni pregled sadržaja metala u jetri soma (*Silurus glanis* Linnaeus) i karaša (*Carassius carassius* Linnaeus) sa lokacije Demir Kapija na rijeci Vardar

n=10 (95x2); all the concentrations expressed as mg of metal per kg fresh (undrained) fish mass;

*statistically significant the most (one-way ANOVA, p=0.05 or less)

**the actual statistical values are: Mn: 1.2 / 6.7*; Cr: 2.5 / 3; Cd: 2 / 1; Ni: 3 / 1; Co: 3 / 4; Pb: 8 / 6.5; Sr: 1.5 / 7*

According to Macedonian regulations (Official Gazette of RM, 1992), metal MACs in edible parts of fish were specified, but only for As, Pb, Cd, Hg and methyl Hg. In the period 2006-2008, around 500 muscular samples of various fish

species collected on 16 locations of the Vardar River were analysed. Only 25 samples (mostly of benthic species) exceeded MAC for Pb (1 mg/kg fresh mass), while 35 of them exceeded MAC's half (0.5mg/kg fresh mass), about 10% of all the samples. However, none of muscular samples contained Cd concentrations higher than MAC (0.1mg/kg fresh mass). Moreover, in about 400 samples, Cd concentrations were below the detection limit (0.015mg/kg fresh mass). Such data are in accordance with the results of systematic monitoring of the surface waters (Hydrological annuals 1997, 1998, 1999) according to which MAC excess of Pb (0.1mg/l) and Cd (0.01mg/l) for III-IV water classes was not noticed in the examined period on any location of the Vardar River (Official Gazette of RM, 31/82, 1982).

Conclusion

Based on all the aforementioned, we can make a conclusion that freshwater fish, especially predators, are health-safe food from the aspect of heavy metal pollution providing that only muscles are to be used for human nutrition.

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Riba kao zdrava hrana – sa ekotoksikološkog stanovišta

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Abstract

Mjerenje sadržaja metala (Cd, Pb, Zn, Cu, Al, Cr, Ni, Fe, Mn, Sr, Co) kod riba, analiza širenja u ciljanim organima i tkivima, istraživanja vezana za bioakumulaciju i biomagnifikaciju sprovedena su na velikom nizu ribljih vrsta koje pripadaju različitim trofičkim nivoima unutar ribljih zajednica iz Tikveškog akumulacionog jezera u R. Makedoniji. Rezultati ovog istraživanja ukazali su na jetru, bubrege i polne žlijezde kao ciljane organe za nakupljanje metala i mišiće kao tkivo sa najnižom koncentracijom ostataka metala. Riba ulovljena u toku 2006-2008. godine u istraživanom području mogla se preporučiti kao zdrava hrana s obzirom na sadržaj metala pošto makedonski prehrambeni standardi za Cd i Pb u jestivim tkivima nisu bili prekoračeni.

Ključne riječi: riba, metali, Tikveško akumulaciono jezero, R. Makedonija.