ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 18, No. 3 2011

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RELATIONSHIPS BETWEEN MACRO- AND MICROELEMENTS AND HEAVY METALS IN SELECTED ORGANS OF RUDD (*Scardinius erythrophthalmus* L.) FROM LAKES MIEDWIE AND ZELEWKO

ZALEŻNOŚCI POMIĘDZY ZAWARTOŚCIĄ MAKRO- I MIKROELEMENTÓW ORAZ METALI CIĘŻKICH W WYBRANYCH NARZĄDACH WZDRĘGI (*Scardinius erythrophthalmus* L.) Z JEZIOR MIEDWIE I ŻELEWKO

Abstract: The aim of this study was to determine the levels of selected metals (Al, Cu, Fe, Mn, Zn, Ca, K, Mg, Na, Pb, Cd) in gills, gonads, kidneys, livers, skin with scales and muscles of rudd from lakes Miedwie and Zelewko. The relationships between fish sex and metal concentrations in their tissues were also investigated. Na, Zn, Mn, Pb had the highest affinity to the gills, Fe to kidney, Cu to liver, while Al and Ca were accumulated mostly in the skin. Some significant ($p \le 0.05$) variations in metal concentrations in selected tissues were dependent on fish sex. The data indicate that the rudds from both examined lakes were not polluted with metals. The average content of toxic metals (Cd, Pb) in the muscle tissue of the examined fish were within the limits for fish and fishery products specified by EU Legislation, so the fish were safe for human consumption.

Keywords: macro- and microelements, heavy metals, *Scardinius erythrophthalmus*

Heavy metals from natural and anthropogenic sources are constantly released into aquatic ecosystems. They pose a serious threat to organisms because of their toxicity, long persistence, bioaccumulation and biomagnification in food chains [1]. Trace elements may exert beneficial or harmful effects on plants, animals and humans. These elements get their way into aquatic systems (rivers, lakes or oceans) through atmospheric fallout, dumping wastes, accidental leaks, runoff or terrestrial systems (industrial and domestic effluents) and geological weathering. Fish are located at the

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end of the aquatic food chain, and many accumulate metals and pass them to human beings through food, causing chronic or acute diseases [2]. Rudd (*Scardinius erythrophthalmus,* L.) is a medium-sized cyprinid fish native to European freshwaters. In Poland, usually up to 25–30 cm in length and 300–400 g in weight [3, 4], it is a very popular fish species in Pomeranian lakes. The aim of this study was to compare metal concentrations in rudd from two West Pomeranian lakes: Miedwie and Zelewko, which are linked by the river Plonia. Lake Miedwie is the fifth largest lake in Poland and the second largest in the Province of Western Pomerania. It is a reservoir of drinking water for Szczecin, with its 34.9 km^2 area, 19.3 m mean depth, and 43.8 m maximum depth. The largest tributary to the lake is the river Plonia, inflowing from the south and leaving the lake on its western side to feed Lake Zelewko. Zelewko is a small lake with its 7.5 km^2 area, 3.7 m mean depth, and 6.5 m maximum depth [5].

Material and methods

Samples of rudd of both genders were collected from lakes Miedwie and Zelewko, during autumn 2006. A total of 30 individuals were collected, and kept in a freezer (–20 ^oC) until dissected. To dissect organs, the fish were thawed, their length and weight were measured, and then dissection of organs: gills, gonads, kidneys, livers, muscles and skin was carried out. Gender was determined by inspection of gonads. The tissue samples were placed into clean dry polyethylene bags and frozen at –20 ^oC until analysed. Fish tissue samples of approximately 1 g (except for muscle 2 g) were digested with 3 cm^3 HNO_3 (65 %) in Teflon bombs in a microwave digestion system (MDS 2000). The samples were quantitatively transferred into polypropylene bottles, made up to 20 cm^3 with deionised water. All tissue samples and reagent blanks were prepared in triplicate. Metal concentrations were measured by Graphite Furnace Atomic Absorption Spectrometry (GF-AAS) (Cd and Pb) and by Inductively Coupled Plasma – Atomic Emission Spectrometry (ICP-AES) (Al, Cu Fe, Mn, Zn, Ca, K, Mg and Na). The accuracy of the methods applied was checked with a certified reference material (Fish paste 2). The results were processed using statistical methods (ANOVA). The analysis involved the Duncan’s test at the significance level ($p \le 0.05$).

Results and discussion

Heavy metals (Pb, Cd, Fe, Mn, Zn, Cu) studied in the present investigations are all regarded as potential hazards to both animal and human health [5]. Pathways of metal uptake by fish may be direct (water via gills) or indirect (diet via the alimentary tract) [6]. The mean concentrations of elements are expressed as μg/g wet weight (Table 1). Metal concentrations in fish organs were dependent on the fishing area. Aluminum, zinc and calcium levels in fish tissues showed no significant differences ($p > 0.05$) amongst lakes. Liver concentrations of the other metals such as: Fe (124.3), Cu (4.20), Na (914.0) and K (1941.0) were higher in Lake Miedwie than in Lake Zelewko (Fe – 47.7; Cu – 1.88; Na – 408.0; K – 902.0) [μg/g w.w.]. Among fish organs, the liver is most often recommended as an environmental indicator of water pollution. This is probably

Table 1

Mean concentrations [µg/g w.w.] and standard deviations of metal in selected organs of rudd (*Scardinius erytrophtalmus*) from Miedwie and Zelewko lakes

Lake	Organs	Al		Zn		Fe		Mn		Cu		Pb		Cd		Ca		Mg		Na		K	
		$\bar{x}$	±SD	$\bar{x}$	±SD	$\bar{x}$	±SD	$\bar{x}$	±SD	$\bar{x}$	±SD	$\bar{x}$	±SD	$\bar{x}$	±SD	$\bar{x}$	±SD	$\bar{x}$	±SD	$\bar{x}$	±SD	$\bar{x}$	±SD
Miedwie	gonads	2.8	2.1	62.7	11.6	11.3	1.9	1.4	1.3	1.46	0.87	ns	ns	0.008	0.006	452	568	203	26	629	74	2 254	265
	kidneys	0.6	0.3	251.8	54.0	126.8	11.5	0.5	0.1	0.76	0.22	ns	ns	0.039	0.017	69	89	113	84	701	485	1 396	955
	liver	1.4	0.3	53.3	25.3	124.3	45.3	0.9	0.2	4.20	1.02	ns	ns	0.012	0.009	133	48	209	29	914	42	1 941	121
	muscle	1.5	0.6	10.8	5.3	2.7	0.8	0.1	0.1	0.25	0.11	ns	ns	0.018	0.014	244	120	345	11	482	53	2 281	22
	skin	101.0	29.5	56.0	15.5	4.4	1.8	4.9	2.3	0.52	0.12	ns	ns	0.034	0.026	59 257	28 740	1 528	352	2 021	115	2 258	41
	gill	58.3	3.9	233.0	93.9	39.4	4.1	8.5	2.6	0.65	0.20	0.06	0.07	0.051	0.028	17 308	4 493	999	294	1 249	166	1 773	308
Zeliwo	gonads	0.8	0.6	41.7	17.2	12.6	4.0	1.7	1.7	0.62	0.50	0.01	0.01	0.002	0.000	74	67	95	7	259	22	1 477	276
	kidneys	1.2	0.6	94.2	30.2	119.6	12.8	0.3	0.0	0.44	0.05	0.01	0.01	0.035	0.013	43	8	69	4	357	24	1 151	72
	liver	3.2	1.3	35.1	7.0	47.7	10.8	1.4	0.5	1.88	0.64	0.03	0.03	0.009	0.004	136	162	103	10	408	26	902	90
	muscle	1.3	0.8	4.3	0.9	1.8	1.1	0.1	0.0	0.06	0.05	ns	ns	0.001	0.001	126	38	157	6	201	25	938	32
	skin	110.4	17.3	29.7	11.9	7.4	5.4	9.5	5.5	0.01	0.18	0.03	0.02	0.027	0.023	46 957	31 689	929	419	1 532	783	1 629	779
	gill	45.0	3.6	248.1	44.0	37.7	5.5	16.2	1.6	0.28	0.17	0.26	0.12	0.020	0.009	15 470	2 111	936	58	1 722	71	2 482	110

nd – below in detection limit.

attributed to the tendency of liver to accumulate high levels of various kinds of pollutants from the environment, as previously reported by Galindo et al [7]. In our study, the content of Mn, Pb, Na, K proved to be much higher in the gills of rudd from Lake Zelewko than from Lake Miedwie, while Cd content in gills was higher in rudds from Lake Miedwie (Table 2).

Table 2

Comparison of metal concentrations in organs of rudd (*Scardinius erytrophtalmus*) between Miedwie and Zelewko lakes

Organs	Al	Z	Fe	Mn	Cu	Pb	Cd	Ca	Mg	Na	K
Gonads											
Kidneys											
Liver			M		M					M	M
Muscle											M
Skin				Z					M	M	M
Gill				Z		Z	M			Z	Z

M – higher content of metal in rudd from Miedwie lake; Z – higher content of metal in rudd from Zelewko lake (Duncan's test $p < 0.5$).

In both lakes Na, Zn, Mn and Pb were accumulated mostly in gills, Fe in kidney, Cu in liver, Al and Ca in skin, while K and Cd showed various tendencies, dependent on lakes (Table 1). The highest zinc accumulation in gills was observed also by Amundsen et al [8]. Zinc is an essential element in most metabolic pathways in humans and its deficiency can lead to loss of appetite, growth retardation, skin changes and immunological abnormalities [9]. The distribution pattern of Mn in both lakes followed the order: gills > skin > gonads >liver > kidneys > muscle; while Fe followed the sequence: kidneys > liver > gills > gonads > skin > muscle. In the other cases tendencies in metal accumulation were not the same. Most elements occurred in the lowest concentrations in the muscle. Similar observations were reported by Amundsen et al [8]. The differences in metal concentrations in the tissues might have resulted from their different capability to induce metal-binding proteins such as metallothioneins [10]. Metal levels differed ($p < 0.05$) between male and female tissues of rudd from both lakes, indicating that rudd gender influenced metal accumulation (Table 3).

Table 3

Significant differences between metal concentrations in organs of female and male of rudd (*Scardinius erytrophtalmus*) (Duncan's test $p < 0.05$)

Lake	Organs	Al	Z	Fe	Mn	Cu	Pb	Cd	Ca	Mg	Na	K
Miedwie	gonads											
	kidneys										m	
	liver					f						
	muscle											
	skin	m			m				m	m		
	gill		m		m		m			f		

Table 3 contd.

Lake	Organs	Al	Z	Fe	Mn	Cu	Pb	Cd	Ca	Mg	Na	K
Zelewko	gonads					f						m
	kidneys							m				
	liver					m						
	muscle											
	skin	m			m			m	m	m	m	m
	gill						f				m	

f – higher concentrations in female; m – higher concentrations in male.

The average concentrations of Al, Mn, Mg, Ca in the skin of fish from both lakes were found to be significantly higher ($p < 0.05$) in males compared to female fish. Gender dependant differences in metal concentrations might have been influenced by a combination of factors, such as dietary preferences, physiological metabolism in relation to the reproductive cycle stage or foraging behaviour [11]. The highest Cu concentrations were found in the liver tissue – similarly as in the study of Papagiannis et al [12]. Aluminium is not considered to be an essential element in humans. In the Polish Standards there is no information about maximum aluminium levels in fish samples. The average content of toxic elements (Pb, Cd) were relatively low. Especially lead was below the detection limit in most organs of the rudd from Lake Miedwie (Table 1). In the muscle tissue, lead and cadmium were within the limits for fish and fishery products specified by EU Legislation [13, 14], so the fish were safe for human consumption.

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ZALEŻNOŚCI POMIĘDZY ZAWARTOŚCIĄ MAKRO- I MIKROELEMENTÓW ORAZ METALI CIĘŻKICH W WYBRANYCH NARZĄDACH WZDRĘGI (*Scardinius erythrophthalmus* L.) Z JEZIOR MIEDWIE I ŻELEWKO

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Abstrakt: Celem pracy było oznaczenie poziomu wybranych metali (Al, Cu, Fe, Mn, Zn, Ca, K, Mg, Na, Pb, Cd) w skrzelach, gonadach, nerce, wątrobie, skórze z łuskami oraz w tkance mięśniowej wzdręg obu płci z jezior Miedwie i Żelewko (Żelewo). Określono również zależności pomiędzy płcią ryb a zawartością metali w ich tkankach. Największe powinowactwo do nerki wykazywały Na, Zn, Fe, Pb, podczas gdy Al i Ca akumulowały się głównie w skórze. Zaobserwowano istotne ($p < 0,05$) zależności pomiędzy zawartością metali w danym narządzie a płcią ryb. Przeprowadzone badania wskazują, że wzdręgi z obu jezior nie były skażone pod względem zawartości metali, a udział pierwiastków toksycznych (Pb, Cd) w mięśniach był poniżej dopuszczalnej wartości w rybach i rybnych produktach konsumpcyjnych określonych przez prawodawstwo Unii Europejskiej.

Słowa kluczowe: makro- i mikroelementy, metale ciężkie, *Scardinius erythrophthalmus*