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SHORT COMMUNICATION

Content of metals in flounder, *Platichthys flesus* L., and Baltic herring, *Clupea harengus membras* L., from the southern Baltic Sea

Kamila Pokorska, Mikołaj Protasowicki, Kinga Bernat, Monika Kucharczyk

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Abstract. Selected metal concentrations in the muscles, liver, and kidney of flounder, *Platichthys flesus* L., and Baltic herring, *Clupea harengus membras* L., from the southern Baltic Sea were measured, and the relationships between the fish species and the metal concentrations in the organs and muscles were analyzed. The metal concentrations found in tissues varied as follows: Al – 0.73-5.78; Cd – 0.004-1.035; Cu – 0.1-18.5; Fe – 1.54-301.02; Hg – 0.015-0.084, Li – <0.001-0.044; Mn – 0.07-1.06; Ni – <0.01-0.31; Pb – <0.001-0.221; Zn – 3.19-44.60 mg kg^{-1} wet weight. This research showed that the metal concentrations in the muscles of the investigated fish species were lower than the maximum levels set by EU legislation.

Keywords: bioaccumulation, fish, trace elements

Seafood is a good source of amino acids, fatty acids, protein, carbohydrates, vitamins, and minerals. Metals, such as iron, copper, zinc, and manganese, are essential since they play important roles in biological systems, whereas mercury, lead, and cadmium are toxic, even in trace amounts. To maintain the quality of public food supplies, levels of metals in the aquatic environment should be monitored regularly to check water quality and animal health (Yilmaz and Yilmaz 2007). The accumulation of elements in the tissues of fish living in aquatic environment depends on many factors. These include metal contents in water and food organisms, exposure time, environmental conditions (e.g., pH, alkalinity, salinity), feeding habits, age, and fish size (Łuczyńska and Brucka-Jastrzębska 2005). The aim of this study was to analyze selected metal levels in the muscles, liver, and kidney tissues of two Baltic fishes and to determine the relationships between the fish species and metal concentrations in the tissues.

The Baltic herring, *Clupea harengus membras* L., (n = 20) and flounder, *Platichthys flesus* L., (n = 20) were caught in 2009 in the southern Baltic Sea. Samples of muscles, liver, and kidney were frozen and kept at -20°C until analysis. The samples were digested in 3 mL HNO_3 (65%) in Teflon bombs in a microwave oven (CEM MDS 2000). The mercury content was determined using the cold vapor technique in a Bacharach Coleman Mass 50 mercury analyzer. Lead and cadmium were measured using a Perkin-Elmer 4110 ZL GF-AAS, while other metals were measured with a Jobin Yvon JY-24 ICP– AES. Metal concentration in tissues is presented as mg kg^{-1}wet weight. The accuracy and precision of the applied analytical methods were verified against the

K. Pokorska [✉], M. Protasowicki, K. Bernat, M. Kucharczyk
Department of Toxicology
Faculty of Food Sciences and Fisheries
West Pomeranian University of Technology in Szczecin
Papieża Pawła VI 3, 71-459 Szczecin, Poland
Tel./Fax: +48 91 449 65 56, +48 91 449 65 40
e-mail: Kamila.Pokorska@zut.edu.pl

Table 1
Mean metal concentrations with standard error in muscles, kidney, and liver of flounder and Baltic herring from the southern Baltic Sea (mg kg^{-1} wet weight)

	Muscles		Kidney		Liver	
Metals	Flounder	Herring	Flounder	Herring	Flounder	Herring
Al	1.72 ± 0.58	2.76 ± 1.03	1.99 ± 0.11	1.97 ± 0.78	1.05 ±0.17	0.86 ± 0.07
Cu	0.33 ± 0.16	0.41 ± 0.24	1.43 ± 0.26	1.12 ± 0.12	17.07 ± 1.24	3.92 ± 0.80
Fe	3.52 ± 1.51	6.07 ± 1.79	97.63 ± 13.99	253.31 ± 67.47	96.65 ± 8.11	158.23 ± 28.35
Li	0.017 ± 0.007	0.010 ± 0.010	0.044 ± <0.001	n.d	0.010 ± 0.009	0.015 ± <0.001
Mn	0.19 ± 0.12	0.30 ± 0.09	0.62 ± 0.17	0.41 ± 0.05	0.97 ± 0.11	0.96 ± 0.10
Ni	0.02 ± 0.02	0.02 ± 0.01	0.22 ± 0.12	0.14 ± 0.01	0.07 ± 0.07	0.07 ± 0.01
Zn	4.62 ± 0.71	5.69 ± 1.47	26.77 ± 2.80	15.11 ± 2.26	38.45 ± 6.63	24.47 ± 0.39
Cd	0.009 ± 0.006	0.016 ± 0.023	0.062 ± 0.018	0.985 ± 0.070	0.227 ± 0.079	0.494 ± 0.199
Hg	0.036 ± 0.017	0.032 ± 0.017	0.029 ± 0.006	0.040 ± 0.004	0.027 ± 0.005	0.046 ± 0.007
Pb	0.053 ± 0.052	0.021 ± 0.038	0.030 ± 0.004	0.019 ± 0.015	0.022 ± 0.008	0.013 ± 0.001

certified reference material Fish Paste 2. Statistical analysis was performed using Statistica software, version 9. In all cases, statistical significance was estimated at $P \leq 0.05$.

The total length of the specimens ranged from 20.5 to 25.5 cm for herring, and from 28.0 to 32.8 cm for flounder. The ranges of body weight were from 56 to 124 g for herring, and from 223 to 416 g for flounder. The concentrations of the elements analyzed (mean ± SD) in the fish tissues are listed in Table 1. The highest mean concentration of aluminum in the fish caught in the Baltic Sea was noted in the muscles of herring, whereas the lowest values of this element were noted in the livers of the same fish species. Mean concentrations of copper in the analyzed fish tissues ranged from 0.3 to 17.1 mg kg^{-1}. The data presented indicate that the highest level of iron was found in the kidney of herring. The concentration of lithium in the muscles of all fish was very low (0.010 mg kg^{-1} – herring, 0.017 mg kg^{-1} – flounder). The mean concentrations of manganese observed in the analyzed fish tissues ranged from 0.19 to 0.97 mg kg^{-1}. Generally, manganese presented mostly in the liver. The lowest mean concentration of nickel (0.02 mg kg^{-1}) in the fish caught in the Baltic Sea was in the muscles of both species, whereas the highest values were noted in the kidney of flounder (0.22 mg kg^{-1}). The zinc content levels in fish tissue ranged from 3.2 to 44.6 mg kg^{-1}. The concentration of cadmium in the muscles of all fish was very low, whereas it was high in the kidney of herring (0.985 mg kg^{-1}). The high mean concentration of lead in the fish caught in the Baltic was found in the muscles of flounder (0.053 mg kg^{-1}), but the maximum observed values still did not exceed acceptable levels. The mercury concentration values detected in the analyzed fish tissues ranged from 0.027 to 0.046 mg kg^{-1}.

Nfon et al. (2009) reported similar concentrations of Al in herring (0.2-3.5 mg kg^{-1}) caught in the Baltic Sea during the 1991-1993 period as those in the same fish species in the current study. Copper accumulated to a greater degree in liver, in which the content was always higher that in kidney and muscles. Marquez et al. (1998) also observed the highest Cu concentration in the liver. Protasowicki (1991) noted higher Cu concentrations in muscles (0.91 mg kg^{-1}) and liver (5.35 mg kg^{-1}) in herring, and Polak-Juszczak (2009) observed higher copper concentrations in the muscles of herring (0.45 mg kg^{-1}) caught in 2003. The iron content in herring muscles reported in the literature ranges from 5.85 to 14.3 mg kg^{-1} (Nfon et al. 2009), which is similar to the amounts in the present study. Burger and Gochfeld (2005) reported slightly higher manganese contents (0.26 mg kg^{-1}) in comparison to the present study. Higher zinc concentrations were noted in the liver, while the lowest were detected in the

muscle tissues of the fishes studied. The same results were obtained by Marquez et al. (1998) in fish from the southern Shetland region. This finding concurs with those of other studies regarding the differences between heavy metal accumulation in fish tissues (Romeo et al. 1994). Protasowicki (1991) observed higher amounts of zinc in the muscles (9.0 mg kg^{-1}) and liver (35.1 mg kg^{-1}) of Baltic herring. According to standards set forth in Commission Regulation (EC) No. 1881/2006 and (EC) No. 629/2008, the average lead, cadmium, and mercury concentrations in selected fish muscles were low. Burger and Gochfeld (2005) observed similar cadmium concentration in flounder muscles (0.010 ± 0.002 mg kg^{-1}). Protasowicki (1991) detected higher amounts of cadmium in muscles (0.062 mg kg^{-1}) and livers (0.615 mg kg^{-1}) of Baltic herring. The cadmium levels in flounder liver from the Noordwijk were much lower than in the current study (0.075 mg kg^{-1}) (Boer et al. 2001). Burger and Gochfeld (2005) noted similar amounts of this element (0.06 mg kg^{-1}) in flounder muscles. A high concentration of lead, in relation to the values revealed in the present research, was observed by Protasowicki (1991) in herring muscles (0.48 mg kg^{-1}) and liver (0.70 mg kg^{-1}). The muscle tissue of the studied fish contained a lower mercury content than that in the flounder analyzed by Burger and Gochfeld (2005), who reported the content of this metal at a level of 0.05 mg kg^{-1}. The Baltic herring examined by Protasowicki (1991) contained similar mercury content in muscles (0.019 mg kg^{-1}) and liver (0.037 mg kg^{-1}). Boer et al. (2001) examined mercury concentrations in flounder liver and observed more than threefold higher amounts of this element (0.10 mg kg^{-1}).

The bioaccumulation of Al, Cd, Cu, Fe, Hg, Li, Mn, Ni, Pb, and Zn varied among muscle, liver and kidney. The kidney and liver generally had the highest metal concentrations, especially of Cu, Fe, and Zn because these organs store these elements. Muscles accumulate much lower concentrations of these metals. Although some insignificant differences were found between the analyzed tissues, the differences were generally significant. The bioaccumulation of the monitored metals also varied between fish species. These differences in bioaccumulation between fish species stem from their affinity for metal uptake from the aquatic environment and their place in the food chain. The maximum accepted concentrations for Cd, Hg, and Pb were not exceeded in any of the muscles tested.

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