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THE RELATIONSHIP BETWEEN THE CONTENT OF LEAD AND CADMIUM IN MUSCLE TISSUE AND THE SIZE OF FISH FROM LAKES IN THE OLSZTYN LAKE DISTRICT OF NORTHEAST POLAND

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ABSTRACT. Concentrations of lead and cadmium were measured in the muscle of four fish species: pike, *Esox lucius* L., Eurasian perch, *Perca fluviatilis* L., roach, *Rutilus rutilus* (L.), and bream, *Abramis brama* (L.) collected from four lakes in the Olsztyn Lake District of northeast Poland. The fish were caught in the 1999-2000 period. Heavy metals contents were determined using the flameless atomic absorption spectrophotometry method (GF AAS). The mean lead content in the muscle of pike, perch, roach, and bream was 0.084, 0.098, 0.094, and 0.083 mg kg^{-1}, respectively. Positive correlation coefficients ($P< 0.001$) were noted between Pb concentration and the body weight and total length of roach and perch ($0.481 < r < 0.676$, respectively). Negative correlation factors between Pb content and the body weight and length of pike ($r = - 0.378$, $P < 0.01$ and $r = - 0.549$, $P < 0.001$) and bream ($r = - 0.557$ and $r = - 0.519$, $P < 0.001$, respectively) were noted. The mean content of cadmium in the muscle of pike, perch, roach, and bream ranged from 0.0023 to 0.0025 mg kg^{-1}. There were positive correlations between the levels of Cd in the muscle of roach and perch and body weight ($r = 0.401$, $P < 0.01$ and $r = 0.323$, $P < 0.05$, respectively) and total length ($r = 0.436$, $P < 0.01$ and $r = 0.354$, $P < 0.05$, respectively). The correlation coefficients between body weight and total length and the content of cadmium in pike and bream were $– 0.228< r < 0.075$.

Key words: LEAD, CADMIUM, FISH SIZE, NORTHERN PIKE (*ESOX LUCIUS*), PERCH (*PERCA FLUVIATILIS*), ROACH (*RUTILUS RUTILUS*), BREAM (*ABRAMIS BRAMA*)

INTRODUCTION

Change in the Hg, Pb, and Cd levels in the aquatic trophic chain, most of all in fish, is a very important issue that impacts consumer health (FAO/WHO 1972, Radwan et al. 1990a, b, Protasowicki 1991, Pourang 1995, Belinsky 1996, Litwińczuk et al. 2000). The occurrence of heavy metals in the aquatic environment can result from a variety of activities. The presence of heavy metals in the muscle tissue of fish can reflect the extent of ecosystem contamination (Dobicki 1990, Szulkowska-Wojaczek et

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al. 1992, Srebočan et al. 1993, 1997, Kļaviņš et al. 1998, Voigt 2000, Food and Environmental Hygiene Department HKSAR 2002).

Previous research has shown that differentiation between lead and cadmium levels in fish is related to species (Barak and Mason 1990a, b, Allen-Gil and Martynov 1995, Liang et al. 1999, Andres et al. 2000). Other authors found that variable fish parameters, such as age and size (body weight and length), had an effect on lead and cadmium concentrations in fish tissues (Håkanson 1984, Kroupa and Hartvich 1990, Pružina et al. 1993, Berninger and Pennanen 1995, Kostecki 2000).

The purpose of the present study was to evaluate the effect of biometric parameters (body weight and total length) on lead and cadmium content in the muscle of four fish species inhabiting reservoirs in highly non-industrialized regions and to evaluate the dependence between concentrations of these elements within species.

MATERIAL AND METHODS

Pike, *Esox lucius* L., Eurasian perch, *Perca fluviatilis* L., roach, *Rutilus rutilus* (L.), and bream, *Abramis brama* (L.) were collected from four sampling sites in the Olsztyn Lake District of northeast Poland (Fig. 1). The fish were caught between October 1999 and October 2000. They were euthanized and the body weight and total length were recorded for each specimen (Table 1).

TABLE 1

Characteristics of the fish studied (n – number of samples)

Species	n	Number of fish	Body weight (g)		Total length (cm)	
			Range	Mean ± SD	Range	Mean ± SD
Pike	48	48	155 - 5235	1271.8 ± 927.7	28.7 - 92.0	53.8 ± 11.3
Perch	48	156	22 - 927	329.8 ± 287.1	12.6 - 38.7	25.1 ± 8.3
Roach	48	178	26 - 540	219.8 ± 185.6	14.1 - 35.0	23.8 ± 7.2
Bream	48	48	284 - 1614	937.3 ± 377.9	29.8 - 50.1	41.1 ± 5.0

Muscle tissues were taken from the dorsal section, placed in polyethylene bags, and kept frozen at -25°C until analysis. In the case of small perch and roach (body weight < 160 g), each sample was prepared from tissues taken from two to nine specimens of approximately the same size, in order to enhance the amount of material for parallel analyses. Whereas in the case of large perch and roach, each sample was pre-

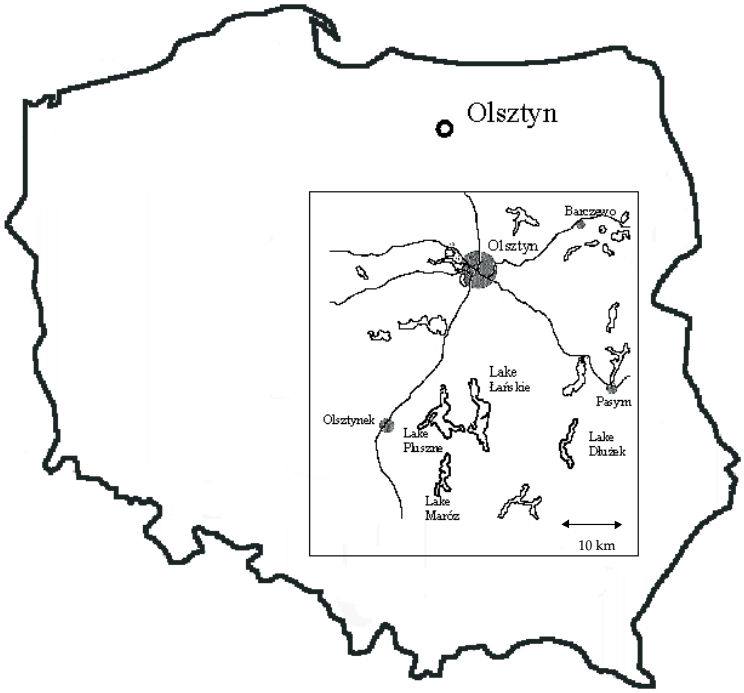

Fig. 1. Sampling area.

pared from tissue taken from one or two fish, while with pike and bream, each sample was prepared from tissue taken from only one fish.

The fish muscle tissue samples (about 10 g) were dry-digested at 300°C for 6 h, after which the temperature was raised to 450°C. The white, cold ash was dissolved in 1M HNO_3 (Suprapur-Merck). Then each sample was transferred with deionized water to a 25 ml glass volumetric flask.

The contents of lead and cadmium were measured with flameless atomic absorption spectrometry in a graphite cuvette (GF AAS) (PERKIN ELMER with ZEEMAN background correction). The absorption wavelength was 283.3 nm for lead and 228.8 nm for cadmium. Correlation coefficients were measured in order to detect any relationships between the concentration of lead and cadmium in muscle tissue and fish size (body weight and total length). Linear regression equations and correlation coefficients were determined to show the relationship between lead content and cadmium levels in the muscle of the same fish. The lead and cadmium content in the muscles of fish are expressed in mg kg^{-1} wet weight.

The analysis method was tested by measuring these elements in reference material: BCR CRM 422 (lyophilized sample of cod, *Gadus morhua* L., muscle) with a certified content of lead and cadmium (Pb – certified 0.085 ± 0.015 mg kg^{-1}, obtained 0.088 ± 0.007 mg kg^{-1}, n = 4 and Cd – certified 0.017 ± 0.002 mg kg^{-1}, obtained 0.018 ± 0.001 mg kg^{-1}; n = 4) (Quevauviller et al. 1993).

RESULTS

The mean concentrations of lead in the muscle of the studied fish ranged from 0.083 mg kg^{-1} (bream) to 0.098 mg kg^{-1} (perch) (Table 2). Lead content varied within species in the case of pike, perch, and roach. There was lower differentiation in the lead contents of bream muscle. A positive correlation was noted between lead content and the body weight or length of perch and roach (Table 2). However, negative correlations between Pb contents and body weight and length were noted in pike and bream muscle tissues.

The cadmium contents of the muscle of selected fish species are presented in Table 2. They ranged from 0.0023 mg kg^{-1} (roach) to 0.0025 mg kg^{-1} (perch). The largest intraspecies differentiation was detected in perch, then in pike and bream. The differentiation of cadmium concentrations in roach was lower. Positive correlation coefficients between cadmium levels in the muscle and the fish weight and length were found; however, no significant correlations were found in pike and those in bream were negative and weak (Table 2).

TABLE 2

Heavy metal concentrations (mg kg^{-1} wet weight) and correlation between fish size (body weight or total length) and contents of Pb and Cd in fish muscle

Species	Pb			Linear correlation coefficient rPb		Cd			Linear correlation coefficient rCd	
	Range	Mean ± SD	V (%)	Weight (g)	Length (cm)	Range	Mean ± SD	V (%)	Weight (g)	Length (cm)
Pike	0.020 - 0.202	0.084 ± 0.047	55.69	-0.378**	-0.549***	0.0006 - 0.0066	0.0024 ± 0.0012	49.91	0.001^{ns}	0.075^{ns}
Perch	0.032 - 0.214	0.098 ± 0.050	50.94	0.501***	0.481***	0.0004 - 0.0092	0.0025 ± 0.0019	74.55	0.323*	0.354*
Roach	0.012 - 0.263	0.094 ± 0.060	64.43	0.633***	0.676***	0.0010 - 0.0041	0.0023 ± 0.0007	31.80	0.401**	0.436**
Bream	0.027 - 0.182	0.083 ± 0.035	42.21	-0.557***	-0.519***	0.0008 - 0.0070	0.0024 ± 0.0011	47.01	-0.228^{ns}	-0.217^{ns}

*Variability coefficient is presented as V (%); *significant correlation P < 0.05; **highly significant correlation P < 0.01; ***very significant correlation P < 0.001; ^{ns} non-significant correlation*

The correlation coefficients and regression equations indicated that there was only a significant high positive relationship ($P < 0.001$) between lead and cadmium concentration in the muscle of perch, while with the other fish species the correlation coefficients were weak (Table 3).

TABLE 3

Correlation coefficients (r) and regression equations that describe the relationships between lead (x) and cadmium (y) concentrations in fish muscle

Species	Correlation coefficients (r)	Regression equations
Pike	0.227 ^{ns}	y = 0.0057x + 0.0019
Perch	0.603 **	y = 0.0229x + 0.0003
Roach	0.103 ^{ns}	y = 0.0012x + 0.0022
Bream	0.289 *	y = 0.0092x + 0.0016

**Significant correlation P < 0.05; ** very significant correlation P < 0.001; ^{ns} non-significant correlation*

DISCUSSION

The concentrations of lead in the muscle of bream and perch from the Olsztyn Lake District were lower than in the muscle of bream (0.705 mg kg^{-1}) and perch (1.375 mg kg^{-1}) from the Łęczyńsko-Włodawskie Lake District (southern Poland; Litwińczuk et al. 2000). The lead contents were higher (0.45-3.52 mg kg^{-1}) in pike, perch, roach, and bream caught in carp ponds in the Barycza drainage area (Szulkowska-Wojaczek et al. 1992) than in the same species from the Olsztyn Lake District. Svobodová et al. (1993a, b), in turn, found lower Pb concentrations in non-predatory fish (roach and bream) and predatory fish (perch and pike) from the River Laba (0.035 mg kg^{-1} and 0.028 mg kg^{-1}; 0.021 mg kg^{-1} and 0.014 mg kg^{-1}, respectively). The same authors reported higher contents of lead in the muscle of roach, bream, perch and pike from the River Izera (0.203, 0.537, 0.732 and 1.6 mg kg^{-1}, respectively).

In the present study, the correlation between pike length and lead concentration was negative. Pourang (1995) did not report any significant correlations between Pb contents in different tissues and the length of pike and goldfish, *Carassius auratus* (L.). Similarly, Barak and Mason (1990a) reported that the correlation of the length/Pb relationship was not significant in pike, perch, chub, *Leuciscus cephalus* (L.), dace, *Leuciscus leuciscus* (L.), or tench, *Tinca tinca* (L.). However, these authors noted a significant correlation between length and the lead content of the

liver ($P < 0.05$) of roach from River Brett sites only (Barak and Mason 1990b). The relationship observed by Barak and Mason (1990a, b) was not confirmed by the present study. The correlation coefficients between body weight and lead content for the muscle of pike, perch, and roach from the River Kolbäcksån were $r = - 0.03$, $r = 0.40$ ($P < 0.025$), and $r = -0.21$, respectively (Håkanson 1984). A positive correlation ($r = 0.501$) between the concentration of lead in the muscle of perch from the Olsztyn Lake District and body weight was comparable to the linear correlation coefficient for perch found by Håkanson (1984). However, the correlation between weight and lead content in the muscle of pike and roach was much higher than in the survey reported by Håkanson (1984).

Berninger and Pennanen (1995) obtained mean negative correlation coefficients between the body weight, length, or age of perch and the level of lead ($r = - 0.46$, $- 0.48$ and $- 0.42$, $P \leq 0.01$). Pružina et al. (1993) observed that in the muscle of the smaller roach (120-190 g) the lead content (0.0693 mg kg^{-1}) was about four times higher than in tissue from larger specimens (251-351 g). Similarly, the lead content in the muscle of roach from the Dzierżno Duże Dam Reservoir (Poland) changed depending on body weight and exhibited a decreasing tendency as fish body weight increased (Kostecki 2000). The preceding results from other publications are not confirmed by the present study (Table 2).

In addition to investigating lead, the study also dealt with cadmium concentrations. The cadmium content in the tissue of perch increased as lead levels increased ($P < 0.001$). Moreover, a significant weak correlation of Pb-Cd was noted in pike, bream ($P < 0.05$), and roach muscles. Nevertheless, the cadmium levels were lower than those of lead. Dobicki (1990) found considerably higher amounts of cadmium in the muscle tissue of roach, bream, and perch caught in a water-bearing area in Wrocław, Poland where the mean content of cadmium ranged from 0.38 mg kg^{-1} to 0.44 mg kg^{-1} (roach). The cadmium values reported by Pružina et al. (1993) were higher in the muscle of perch (0.0035 mg kg^{-1}) and lower in roach (0.0018 mg kg^{-1}) than those from the present study (Table 2). In other studies (Kostecki 2000), the roach from the Dzierżno Duże Dam Reservoir (Poland) contained higher cadmium contents (0.033 mg kg^{-1}) than did the fish from the Olsztyn Lake District. Similarly, higher cadmium contents were found by the same author in the muscle of pike and perch (0.04 and 0.067 mg kg^{-1}, respectively). The same author observed that the

decrease of cadmium levels in the muscle of roach as fish weight increased was insignificant. No significant correlations between length and cadmium content in either the flesh or the liver of roach, perch, or pike ($p > 0.05$) were found by Barak and Mason (1990a, b). In fish from the River Kolbäcksån, no relationship between cadmium concentration and body weight was found, except for the negative correlation in roach muscle ($r = - 0.30$) (Håkanson 1984). No correlation ($r = 0.07$ and $r = 0.01$, respectively) between cadmium content in muscles of pike and perch and body weight was found by the same author. Only in the case of the examined pike was a similar correlation coefficient obtained (Table 2). On the other hand, as opposed to the earlier studies by Berninger and Pennanen (1995), the Cd concentration in the muscle of perch from Olsztyn Lake District was correlated positively with the size of the fish, while Protasowicki et al. (1983) reported a similarly weak non-significant correlation for cadmium content in the muscle of bream and fish weight ($r = - 0.137$).

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STRESZCZENIE

ZWIĄZEK POMIĘDZY ZAWARTOŚCIĄ OŁOWIU I KADMU W TKANCE MIĘŚNIOWEJ A WIELKOŚCIĄ RYB Z POJEZIERZA OLSZTYŃSKIEGO

Celem pracy było określenie wpływu wielkości ryb (masa i długość ciała) na zawartość ołowiu i kadmu w tkance mięśniowej ryb pochodzących z wybranych jezior Pojezierza Olsztyńskiego. Badany materiał stanowiły 4 gatunki ryb: szczupak *Esox lucius* L., okoń *Perca fluviatilis* L., płoć *Rutilus rutilus* L. i leszcz *Abramis brama* L., pochodzące z połowów przeprowadzonych od października 1999 do października 2000. Zawartość metali ciężkich oznaczano techniką bezpłomieniowej spektrometrii absorpcji atomowej. Średnie stężenie ołowiu w tkance mięśniowej szczupaka, okonia, płoci i leszcza wynosiło odpowiednio: 0,084, 0,098, 0,094 i 0,083 mg kg^{-1} (tab. 2). W przypadku płoci i okonia stwierdzono dodatnie współczynniki korelacji ($0,481 < r < 0,676$, $P < 0,001$) pomiędzy zawartością ołowiu a masą i długością ciała ryb. Ujemne współczynniki korelacji między stężeniem ołowiu a masą i długością ciała ryb zanotowano w przypadku szczupaka (odpowiednio $r = - 0,378$, $P < 0,01$ i $r = - 0,549$, $p<0,001$) oraz leszcza (odpowiednio $r = - 0,557$ i $r = - 0,519$, $P < 0,001$). Średnia zawartość kadmu w mięśniach badanych ryb mieściła się w granicach od 0,0023 do 0,0025 mg kg^{-1} (tab. 2). Stwierdzono dodatnie współczynniki korelacji pomiędzy zawartością kadmu w tkance mięśniowej płoci i okonia a masą (odpowiednio $r = 0,401$, $P < 0,01$ i $r = 0,323$, $P < 0,05$) i długością ciała ryb (odpowiednio $r = 0,436$, $P < 0,01$ i $r = 0,354$, $P < 0,05$). W przypadku szczupaka i leszcza wykazano, że współczynnik korelacji pomiędzy masą i długością ciała tych ryb a zawartością kadmu wynosił – $0,228< r < 0,075$.