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CONTENT OF HEAVY METALS IN LIVERS, KIDNEYS AND MUSCLES OF GAME IN SOUTH-WEST POLAND

Concentrations of mercury, cadmium and lead in livers, kidneys and muscles of red deer, roe deer, wild boar and hare collected in industrial and non-industrial regions of Lower Silesia, Poland, during the hunting seasons 1995–1996 and 1996–1997 are reported. In industrial areas, percentage of samples containing specific heavy metals in concentrations exceeding their admissible levels is higher than that in non-industrial areas. Selected organs of the game accumulate heavy metals whose concentrations are species-dependent. In the examined organs of the game from non-industrial regions, the highest level of mercury is determined in hare kidneys, and the lowest – in roe deer liver. The highest concentrations of cadmium are accumulated in red deer kidneys, and the lowest – in roe deer liver, while lead shows the highest levels in roe deer liver, but the lowest in red deer liver. The calculated accumulation index in industrial and non-industrial areas proves that in the case of hare the largest accumulations of mercury and cadmium occur in kidneys, while those of lead and chromium in liver. This preliminary research confirms the assumption that selected organs of some game may reflect environmental contamination, thus they can be recognized as bioindicators.

1. INTRODUCTION

For last few decades the pollution of natural environment has enormously increased, posing a real danger to human and wildlife health or even life. Since free-living animals are totally integrated with environment, some of their tissues and organs can be recognized as bioindicators [1]–[20]. The content of heavy metals in the livers, kidneys and muscles of the game is analysed not so often as in domestic animal organs although some game like deers, wild hogs or small game are essential in human diet in some countries [15], [21], [22].

2. MATERIAL AND METHODS

Samples from 12 red deer, 23 roe deer, 17 wild boars and 46 hares were collected in three hunting districts situated in industrial (I) and non-industrial (NI) regions of

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Lower Silesia, Poland, during the hunting seasons 1995/96 and 1996/97. Location of hunting districts of interest was precisely indicated earlier [20].

The samples collected and placed in tight, aseptic polyethylene bags were stored in refrigerator at –273 °C before analysis. After unfreezing, ca 1 g of each sample was homogenized and analysed for cadmium, lead and mercury.

In order to evaluate heavy metal concentrations, small amounts (0.2 g) of each sample were decomposed in concentrated HNO_3 (2.5 cm^3) under the pressure of 3000 kPa in teflon vessels at 130 °C according to STOEPPLER and BACKHAUS method [23]. In homogeneous samples, the water content was measured (24 h, 105 °C). Total mercury was measured by the method of atomic absorption spectrophotometry (AAS Perkin-Elmer 2280) after its reduction to elemental mercury. The other elements were detected by means of Perkin-Elmer 5000 spectrophotometer equipped with graphite furnace.

The accuracy of the analytical methods involving 6 homogeneous replicates of the same sample was 9.2 and 13.6 %, as the coefficient of variation. The accuracy was tested in two intercalibration exercises.

3. RESULTS AND DISCUSSION

The results of analyses are presented in tables 1–9 and compared with the results obtained for other parts of Poland as well as for industrial and non-industrial areas of other countries. Our results are compatible with the results published by other authors [3], [4], [6]–[10], [21].

Accumulation of heavy metals depends not only on game species, but also on organs and tissues of animals tested. Of course, accumulation of heavy metals in various organs and tissues of animals substantially depends on contamination of environment (tables 10–12).

In non-industrial regions of Lower Silesia, the highest concentration of mercury was stated both in big and small game kidneys. The highest individual value of the mercury content was measured in hare kidneys, both in industrial and non-industrial regions (tables 2 and 7).

The accumulation index $I_a = C_I / C_{NI}$, where C_I denotes an average content of element in the same organ in an industrial area, and C_{NI} the same value but in non-industrial area, proves that the highest concentrations of mercury and cadmium as well as lead and chromium occur in hare's kidney and liver, respectively (table 12).

Comparative studies of the content of mercury in roe deer kidneys from non-industrial regions of south-west Poland and from formerly industrially active region of Italy (Tuscany, closed down mercury mines and smelters) have shown that the content of mercury in the samples from the region with naturally high level of mercury in environment exceeds over 3.3 times the content of mercury from Polish samples. This proves decisively that the roe deer can be recognized as a good bioindicator of contamination of environment with mercury (table 1).

Table 1

Mercury, cadmium and lead concentrations in roe deer kidneys (in mg/kg of wet weight)

Hg				Cd				Pb				Reference
n	*x*	*SD*	*R*	*n*	*x*	*SD*	*R*	*n*	*x*	*SD*	*R*	
18	0.030	0.033	ND –0.132	16	0.581	0.351	0.264 –1.308	18	0.218	0.198	ND –0.624	This paper Poland, NI
18	0.100	0.164	0.012 –0.627	18	0.374	0.300	0.024 –1.140	18	0.049	0.034	0.019 –0.145	This paper Italy, I
10	0.036	0.032	0.006 –0.069	8	1.5	1.3	0.062 –3.0	10	0.140	0.09	0.05 –0.370	[6], NI Poland
				10	1.775			10	0.30			[9], NI Germany
				10	4.47			10	0.90			[9], I Germany
				38	2.429		0.359 –9.114	38	1.62		0.06 –31.12	[4], NI Slovenia
				60	3.118		0.205 –9.145	60	1.31		0.05 –8.55	[4], I Slovenia
				77	2.8	2.8						[3] Norway
				60	1.422		0.125 –3.196	60	0.18		0.07 –0.97	[21], NI Poland

n – total number of samples, *x* – mean value, *SD* – standard deviation, *R* – range, NI – non-industrial region, I – industrial region, ND – not determined.

Table 2

Mercury, cadmium and lead concentrations in roe deer livers (in mg/kg of wet weight)

Hg				Cd				Pb				Reference
n	*x*	*SD*	*R*	*n*	*x*	*SD*	*R*	*n*	*x*	*SD*	*R*	
23	0.011	0.018	ND –0.086	23	0.351	0.308	0.073 –1.420	22	0.146	0.163	ND –0.690	This paper Poland, NI
10	0.011	0.009	0.002 –0.023	10	0.087	0.044	0.040 –0.170	10	0.09	0.05	0.030 –0.190	[6], NI Poland
				10	0.21			10	0.26			[9], NI Germany
				10	0.77			10	0.42			[9], I Germany
				38	0.232		0.033 –0.854	38	0.44		0.05 –3.28	[4], NI Slovenia
				64	1.275		0.027 –7.198	64	0.96		0.05 –7.85	[4], I Slovenia
				35	0.19			35	0.05			[7], Germany
				17	1.51	1.06	0.38 –3.95					[8], I Germany
				77	0.4	0.5						[3] Norway
				60	0.240		0.027 –0.766	60	0.12		0.02 –0.35	[21], NI Poland

Table 3

Mercury, cadmium and lead concentrations in roe deer muscles (in mg/kg of wet weight)

Hg				Cd				Pb				Reference
n	*x*	*SD*	*R*	*n*	*x*	*SD*	*R*	*n*	*x*	*SD*	*R*	
14	0.009	0.009	ND –0.029	14	0.204	0.100	0.095 –0.411	13	0.034	0.050	ND –0.176	This paper Poland, NI
59	0.001		0.000 –0.004	99	0.009	0.010	0.005 –0.064	99	0.170	0.340	0.020 –2.600	[6], NI Poland
				38	0.008		0.003 –0.084	38	0.66		0.05 –16.46	[4], NI Slovenia
				65	0.029		0.027 –7.198	65	0.31		0.05 –7.76	[4], I Slovenia
				60	0.013		0.003 –0.075	60	0.08		0.02 –0.20	[21], NI Poland

Table 4

Mercury, cadmium and lead concentrations in red deer kidneys (in mg/kg of wet weight)

Hg				Cd				Pb				Reference
n	*x*	*SD*	*R*	*n*	*x*	*SD*	*R*	*n*	*x*	*SD*	*R*	
11	0.027	0.020	ND –0.069	11	2.16	1.47	0.044 –5.26	11	0.443	0.351	0.031 –1.240	This paper Poland, NI
62	0.024	0.016	0.005 –0.054	62	2.13	1.49	0.31 –7.30	62	0.231	0.115	0.030 –0.650	[6], NI Poland
				38	2.429		0.359 –9.114	38	1.62		0.06 –31.12	[4], NI Slovenia
				60	3.118		0.205 –9.145	60	1.31		0.05 –8.55	[4], I Slovenia
				18	0.8	0.8						[3] Norway
				103	2.44	0.67						[1], NI Canada
				92	10.55	1.75						[1], I Canada
				60	1.158		0.135 –3.214	60	0.14		0.04 –1.80	[21], NI Poland

The concentration of cadmium in the organs and tissues of *Cervidae* confirms a widely known fact that this element is accumulated mainly in kidneys, and to much less extent in liver. In the case of red deer and roe deer, the degree of contamination of kidneys, livers and muscles can be arranged as 40:4:1 and 3:2:1, respectively.

Table 5

Mercury, cadmium and lead concentrations in red deer livers (in mg/kg of wet weight)

Hg				Cd				Pb				Reference
n	*x*	*SD*	*R*	*n*	*x*	*SD*	*R*	*n*	*x*	*SD*	*R*	
12	0.016	0.008	ND –0.028	12	0.213	0.098	0.015 –0.420	12	0.584	0.532	0.107 –1.530	This paper Poland, NI
80	0.007	0.006	0.002 –0.035	80	0.114	0.095	0.009 –1.000	75	0.188	0.118	0.010 –0.710	[6], NI Poland
				38	0.232		0.033 –0.854	38	0.44		0.05 –3.28	[4], NI Slovenia
				64	1.275		0.027 –7.198	64	0.96		0.05 –7.85	[4], I Slovenia
				17	0.1	0.08						[3] Norway
				141	0.23	0.08						[1], NI Canada
				114	0.99	0.35						[1], I Canada
				60	0.237		0.010 –1.000	60	0.11		0.01 –1.01	[21], NI Poland

Table 6

Mercury, cadmium and lead concentrations in red deer muscles (in mg/kg of wet weight)

Hg				Cd				Pb				Reference
n	*x*	*SD*	*R*	*n*	*x*	*SD*	*R*	*n*	*x*	*SD*	*R*	
8	0.027	0.018	ND –0.039	6	0.057	0.061	ND –0.172	6	0.059	0.064	ND –0.18	This paper Poland, NI
403	0.001	0.001	ND –0.010	267	0.010	0.017	0.005 –0.180	270	0.086	0.070	0.001 –0.45	[6], NI Poland
				38	0.008		0.003 –0.084	38	0.66		0.05 –16.46	[4], NI Slovenia
				65	0.029		0.003 –0.373	65	0.31		0.05 –7.76	[4], I Slovenia
				103	ND							[1], NI Canada
				34	0.17	0.1						[1], I Canada
				60	0.017		0.003 –0.125	60	0.10		0.01 –0.87	[21], NI Poland

Table 7

Mercury, cadmium and lead concentrations in hare kidneys (in mg/kg of wet weight)

Hg				Cd				Pb				Reference
n	*x*	*SD*	*R*	*n*	*x*	*SD*	*R*	*n*	*x*	*SD*	*R*	
17	0.100			17	1.62			17	0.406			This paper Poland, NI
26	0.226			26	3.98			26	0.390			This paper Poland, I
				30	0.37			30	0.37			[9], NI Germany
				30	7.87			30	1.815			[9], I Germany
9	0.10	0.07										[10], NI Poland
9	0.26	0.13										[10], I Poland

Table 8

Mercury, cadmium and lead concentrations in hare livers (in mg/kg of wet weight)

Hg				Cd				Pb				Reference
n	*x*	*SD*	*R*	*n*	*x*	*SD*	*R*	*n*	*x*	*SD*	*R*	
17	0.056			17	1.16			17	0.409			This paper Poland, NI
29	0.066			29	0.95			29	0.556			This paper Poland, I
				30	0.10			30	0.95			[9], NI Germany
				30	1.09			30	4.675			[9], I Germany

Table 9

Mercury, cadmium and lead concentrations in wild boar livers (in mg/kg of wet weight)

Hg				Cd				Pb				Reference
n	*x*	*SD*	*R*	*n*	*x*	*SD*	*R*	*n*	*x*	*SD*	*R*	
17	0.029	0.025	ND –0.116	17	0.50	0.34	0.02 –1.48	17	0.405	0.349	0.10 –1.31	This paper Poland, NI
				122	0.205		0.005 –0.680					[6], NI Poland
				60	0.229		0.057 –0.825	60	0.14		0.02 –0.92	[21], NI Poland

Table 10

Percent of samples exceeding the animal tolerance for lead
(Polish Standards – 1 mg/kg of wet weight [17])

Species	Region	Liver		Kidney	
		n	%	*n*	%
Hare	I	29	20.7	26	3.8
Hare	NI	17	11.8	17	5.9
Wild boar	NI	17	5.9	17	5.9
Roe deer	NI	22	0	18	0
Red deer	NI	12	25	11	9.1

n – total number of samples, I – industrial region, NI – non-industrial region.

Table 11

Percent of samples exceeding the animal tolerance for cadmium
(1 mg/kg of wet weight kidney, 0.5 mg/kg of wet weight liver [4])

Species	Region	Liver		Kidney	
		n	%	*n*	%
Hare	I	29	93.1	26	96.2
Hare	NI	17	64.7	17	64.7
Wild boar	NI	17	35.3	17	70.6
Roe deer	NI	23	17.4	16	18.7
Red deer	NI	12	0	11	72.7

n – total number of samples, I – industrial region, NI – non-industrial region.

Table 12

Accumulation index of heavy metals I_a
for various organs of hare

Element	Liver	Kidney
Hg	1.18	2.26
Cd	0.82	2.45
Pb	1.36	0.96
Cu	0.94	1.03
Cr	3.03	0.70

$I_a = C_I/C_{NI}$, where C_I and C_{NI} are heavy metal concentrations in industrial and non-industrial regions.

Lead also accumulates the most in liver and kidneys, and in the case of roe deer the proportion of its content in kidneys, livers and muscles is like 6:4:1. For red deer, however, we find that the proportion of lead content in kidneys, livers and muscles is 8:10:1. The situation of small game, living and grazing in the close proximity of roads

and motorways, is radically different due to pollution of the land by exhaust gases, especially lead (table 10).

Various concentrations of the metals measured in the same organ of game and domestic animals of the same family can be caused not only by dietary differences, but also by different specific and individual metabolism [17], and this can explain a wide range of the concentrations of metals in various organs and tissues.

From the results obtained the following conclusions can be drawn:

1. The hare and roe deer kidneys can be recognized as a very sensitive mercury indicator.

2. Cadmium accumulates the most in red deer kidneys and the least in the roe deer livers (tables 2 and 4).

3. The highest concentration of lead was determined in roe livers, and the lowest in red deer livers.

Tables 10 and 11 show that in industrial regions the percentage of samples containing selected heavy metal in the quantities exceeding an admissible level is higher than that in non-industrial areas.

This preliminary research confirms the assumption that selected organs of some game may reflect the level of environmental contamination and can be recognized as bioindicators.

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REFERENCES

[1] GLOOSHENKO V.C., DOWNES R.F., BROWN H.E., ADDISON E.M., HICKIE J., *Cadmium levels in Ontario moose and deer in relation to soil sensitivity to acid precipitation*, Sci. Total Environ., 1988, 71, 173–186.

[2] STANSLEY W., ROSCOE D.E., HAZEN R.E., *Cadmium contamination of deer livers in New Jersey*, Sci. Total Environ., 1991, 107, 71–82.

[3] FROSLIE A., HAUGEN A., HOLT G., NORHEIM G., *Levels of cadmium in liver and kidneys from Norvegian Cervides*, Bull. Environ. Contam. Toxicol., 1986, 37, 453–460.

[4] DOGANOC D.Z., GAČNIK K.Š., *Lead and cadmium in meat and organs of game in Slovenia*, Bull. Environ. Contam. Toxicol., 1995, 54, 166–170.

[5] RINTALA R. et al. and HIRVI T., *Heavy metals in muscle, liver and kidney from Finnish reindeer in 1990– 91 and 1991– 92*, Bull. Environ. Contam. Toxicol., 1995, 54, 158–165.

[6] FALANDYSZ J., *Some toxic and trace metals in big game hunted in the northern part of Poland in 1987–1991*, Sci.Total Environ., 1994, 141, 59–73.

[7] HOLM J., *Investigation of roe deer – Criteria for use as a bioindicator in specimen banking*, Sci.Total Environ., 1993, 139/140, 237–249.

[8] MÜLLER P., *Cadmium-Konzentrationen bei Rehpopulationen (Capreolus capreolus) und deren Futterpflanzen*, Z. Jagdwiss., 1985, 31, 146–153.

[9] LUTZ W., UECKERMANN E., *Residues of cadmium and lead in livers and kidneys of roe deer and hare in Northrine-Westphalia,* Trans. 18th IUGB Congress, Kraków, 1987, Świat-Press, Kraków–Warszawa, 1991, 401–403.

[10] ŻARSKI T.P., SAMEK M., KRYŃSKI A., ROKICKI E., DĘBSKI B., KOLAR P., *Mercury contamination of free living and domestic animals environment,* Proc. 7th Int. Congress on Animal Hygiene, Leipzig, 1991, Vol. I, 336–340.

[11] PERZANOWSKI K., BRYLIŃSKI R., LUFT A.H., TYRANKIEWICZ J., *The contamination of roe deer tissues with heavy metals,* Trans. 18th IUGB Congress, Kraków, 1987, Świat-Press, Kraków–Warszawa, 1991, 405–407.

[12] DUTKA S., *Factor analysis of total element concentrations in surface soils of Poland,* Sci. Total Environ., 1992, 121, 39–52.

[13] ZILLIOUX E.J., PORCELLA D.B., BENOIT J.M., *Mercury cycling and effects in freshwater wetland ecosystems,* Environ. Toxicol. Chem., 1993, 12, 2245–2264.

[14] HUNTER B.A., JOHNSON M.S., *Food chain relationships of copper and cadmium in contaminated grassland ecosystems,* OIKOS, 1982, 38, 108–117.

[15] MUSANTE C.L., ELLINGWOOD M.R., STILWELL D.E., *Cadmium contamination of deer livers in Connecticut,* Bull. Environ. Contam. Toxicol., 1993, 51, 838–843.

[16] LUTZ W., *Ergebinsse der Untersuchungen von Rehen (Capreolus capreolus) und Haasen (Lepus europaeus Pallas) auf Schwermetalle und chlorierte Kohlenwasserstoffe in Nordrhein-Westfallen,* Z. f. Jagdwiss., 1985, 31(3), 153–175.

[17] FALANDYSZ J., CENTKOWSKA D., LORENC-BIAŁA H., *Metale (Cd, Pb, Cu, Zn, Fe, Mn i As) w mięśniach, wątrobie i nerkach zwierząt rzeźnych i zwierzyny łownej z rejonu Polski Północnej,* 1984, Roczniki PZH, 1987, XXXVIII, nr 4 i 5, 347–354.

[18] LORENZ K., CHYLA A., GÓRSKI J., *Impacts of environmental pollution in the creation of anomalous roe deer antlers,* Trans. 18th IUGB Congress, Kraków, 1987, Świat-Press, Kraków–Warszawa, 1991, 399–400.

[19] LORENZ K., *Zwierzęta dziko żyjące jako bioindykatory skażenia środowiska rtęcią,* Raport Inst. Inż. Ochr. Środowiska Politechniki Wr., Spr. 63/96, Wrocław, 1996.

[20] CHYLA A., LORENZ K., GAGGI C., RENZONI A., *Pollution effects on wildlife: Roe deer antlers as non-destructive bioindicator,* Environment Protection Engineering, 1996, 22, No. 3–4, 65–70.

[21] MICHALSKA K., ŻMUDZKI J., *Zawartość metali w tkankach dzików, saren i jeleni w regionie wielkopolskim,* Medycyna Wet., 1992, 48(4), 160–162.

[22] ŻMUDZKI J., MICHALSKA K., *Odległość od rany postrzałowej a zawartość ołowiu w tkankach dzików, saren i jeleni,* Medycyna Wet., 1992, 48(3), 127–129.

[23] STOEPPLER M., BACKHAUS F., *Pretreatment studies with biological and environmental materials. I. Systems for pressurised multisample decomposition,* Fresenius Z. Anal. Chem., 1978, 291, 116–120.

ZAWARTOŚĆ METALI CIĘŻKICH W WĄTROBACH, NERKACH I MIĘŚNIACH ZWIERZYNY ŁOWNEJ W POŁUDNIOWO-ZACHODNIEJ POLSCE

Zbadano zawartość rtęci, kadmu i ołowiu w wątrobie, nerkach i mięśniach zwierzyny łownej (jeleń europejski, sarna, dzik i zając) z terenów Dolnego Śląska. Uzyskane wyniki są zbieżne z danymi opublikowanymi w innych krajach. Wybrane organy wewnętrzne dzikich zwierząt akumulują metale ciężkie w różnym stopniu, w zależności od gatunku zwierząt. W rejonach nieuprzemysłowionych najwyższy stopień akumulacji rtęci wykazują nerki zajęcy, najniższy zaś wątroby saren. Kadm jest gromadzony najsilniej w nerkach jeleni, najsłabiej w wątrobach saren. Najwyższy stopień akumulacji ołowiu wykazują wątroby saren, a najniższy – wątroby jeleni. Akumulacja metali ciężkich w organach zwierząt dziko żyjących w istotny sposób zależy od stopnia skażenia nimi środowiska naturalnego. W środowisku

uprzemysłowionym procent prób zawierających wybrane metale ciężkie w ilości ponadnormatywnej jest większy niż w środowisku nieuprzemysłowionym. Uzyskane wyniki wskazują, że wybrane organy wewnętrzne badanych gatunków zwierząt łownych mogą stanowić bioindykatory skażenia środowiska naturalnego metalami ciężkimi.