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POLLUTION EFFECTS ON WILDLIFE: ROE DEER ANTLERS AS NON-DESTRUCTIVE BIOINDICATOR

Concentrations of Hg, Pb, Cd, Cu, Zn and Al in antlers of roe deer from three hunting districts of Lower Silesia, Poland, collected during the hunting seasons 1993–1994 (N = 23) are reported. The heavy metals pollution indexes for these districts were calculated, taking the level of contamination of Bialowieza National Park as a reference. Results were compared with indexes calculated for other areas of Poland and Europe. For Wroclaw district, the indexes for Cr and Pb in 1974 were close to those for heavy polluted regions of Upper Silesia and decreased markedly recently after the closing down the chromium smelter in the nearest proximity. The results presented prove that heavy metal concentrations in antlers of roe deer can reflect the changes in pollution of environment and therefore antlers, which are renewed each year, may be considered as bioindicator of environmental pollution.

1. INTRODUCTION

During the last few decades, the contamination of the natural environment caused by the human industrial activity systematically increased, posing a real danger for human and wildlife health. Among the most frequent and dangerous environmental pollutants, being themselves terato- or cancerogenic or affecting the function and metabolism of biologically vital elements, are such heavy metals as mercury, lead, cadmium, arsenic, nickel and chromium.

For many years people have used various species of animals, e.g. canaries in the coal mines [1], or plants [2] as indicators of environmental contamination.

Several animal tissues and organs such as liver, kidneys, bones, feathers, hair or antlers can be used as bioindicators [3]–[8]. The last two can be considered the most suitable because of their non-destructing character. Moreover, they are temporarily renewed (annual dropping and building up antlers of cervidae). The roe deer (*Capreolus capreolus* L.), common cervidae of the Central and Eastern Europe territo-

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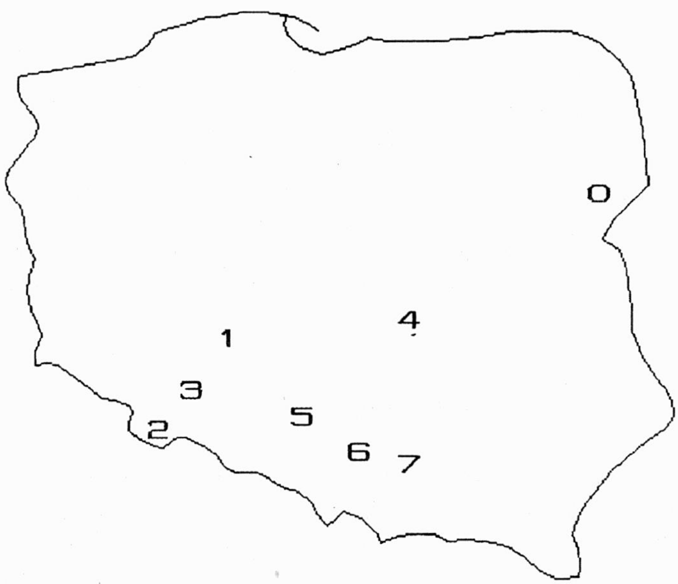
ries, seems to be particularly suitable bioindicator, especially because of its non-migrative behaviour.

Another advantage of such a non-destructive bioindicator is the pssibility of assessment of contamination of the natural environment in the past by analysis of historical collections of trophies [9].

2. MATERIAL AND METHODS

Twenty-three roe antlers were collected in the three hunting districts of the Lower Silesia, Poland, during the hunting seasons (May–September) 1993–1994. The locations of the three hunting districts of Lower Silesia and other districts of interest are shown in the figure.



Location of the districts of interest in Poland:
0 – Bialowieza Forest, *1*– Wroclaw District, *2* – Miedzylesie Woodlands,
3 – Niemcza District, *4* – Rogow Woodlands,
5 – Upper Silesia Region, *6* – Ojcow National Park, *7* – Niepolomice Forest

The first district, i.e. Wroclaw (hunting district no. 94), is situated some 20 km S-E of Wroclaw in the forestless region being under strong influence of mainly chemical industry and two smeltries located within the range of 15 km. The second district, i.e. Miedzylesie, hunting district no. 81, is located in the coniferous forest covering the Snieznik Ridge on the Polish-Czech border, about 110 km south of Wroclaw. The region can be considered as moderately polluted, mainly by trans-border import of industrial pollution (SO_2 included) from Czech Republic and from Polish colliery in the Nowa Ruda region. The third district, Niemcza, hunting district no. 121, is situated about 50 km SSE of Wroclaw in the Niemcza Heights. The region can be considered as relatively clean since at the moment there is no heavy industry there. However, for many years there were a nickel mine and smeltery working in the near vicinity (about 15 km).

Collected antlers were washed with tap water, rinsed with distilled water and dried. Analytical samples, ca 1 g, were obtained by drilling of both beams with a 6.5 mm diameter steel bit some 10 mm above roses. After homogenisation of resulting dust, samples were analysed for aluminium, cadmium, chromium, copper, lead, mercury and zinc.

For evaluation of heavy metal concentrations, homogeneous antler samples (0.05–0.1 g) were decomposed with concentrated HNO_3 (2.5 cm^3) under pressure (3000 kPa) in teflon vessels at 130 °C according to STOEPPLER and BACKHAUS [10]. Homogeneous subsamples were utilised for the measurement of the water content (24 h, 105 °C). Total mercury was detected by atomic absorption spectrophotometry (AAS Perkin-Elmer 2280) after its reduction to elemental mercury with an aqueous solution of $SnCl_2$ (10%), $NH_2OH{\cdot}HCl$ (6%), NaCl (6%) and H_2SO_4 (0.5 M) and air current stripping. The other elements were detected by means of a Perkin-Elmer 5000 AAS equipped with graphite furnace.

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

3. RESULTS AND DISCUSSION

The results of the analysis are reported in table 1 and compared with the results obtained earlier for the same area and for Bialowieza National Park. Because of the abundance of literature data, the data from the last region have been used by the authors as a basis for calculation of the *pollution index*, I_{Me}, which can be defined as the ratio of the concentration of particular heavy metal in the roe deer antlers from the examined and reference regions [4]. Arithmetic mean of pollution indexes, called the *total index*, points the rank of the examined place on the list of polluted territories.

For Lower Silesia the pollution index (I_{Me}) was calculated for Cd, Cr, Cu, Pb and Zn and compared with the index for the other regions of Poland as well as for some industrial and non-industrial regions in Sweden [5] and Scotland [7] (table 2).

The first district – Wroclaw. Calculated indexes of heavy metal pollution for roe deer antlers collected over the period of 1974–1986 ($I_{Pb} = 5.4$, $I_{Cr} = 6.9$) are very high and almost equal to those representing the most polluted regions of south Poland ($I_{Pb} = 3.9$, $I_{Cr} = 3.3$ for Upper Silesia and $I_{Pb} = 2.1$, $I_{Cr} = 6.3$ for Ojcow National Park).

Table 1

Concentrations of heavy metals (mg/kg, d.w.) in roe deer antlers from Lower Silesia and Bialowieza Districts

	Wroclaw District				Miedzylesie Woodlands			
	n	*x*	*S.D.*		*n*	*x*	*S.D.*	Range
Hg	7	0.099	0.028	0.050–0.136	6	0.063	0.033	0.025–0.098
Cd	7	0.108	0.053	0.034–0.177	6	0.034	0.030	0.017–0.075
Pb	7	2.26	0.92	1.31–3.92	6	1.94	0.63	0.85–2.72
Cu	7	6.7	1.3	4.6–8.5	6	5.8	2.8	1.8–8.1
Zn	7	111	28	88–153	6	86	24	63–126
Cr	7	3.66	1.92	2.12–7.80	6	2.63	0.51	2.52–3.37
Al	7	257	121	129–440	4	306	37	270–345
	Niemcza District				Bialowieza Forest			
	n	*x*	*S.D.*	Range		*x*		
Hg	10	0.064	0.038	0.018–0.115		NA		
Cd	10	0.053	0.034	0.032–0.110		0.55		
Pb	10	1.66	0.77	0.62–2.60		3.75		
Cu	10	7.2	2.9	0.5–12.3		6.85		
Zn	10	83	16	67–118		94		
Cr	10	2.48	0.54	1.45–3.30		0.87		
Al	8	219	59	153–320		NA		

Table 2

Heavy metal pollution index and total index for the regions of interest

Location	Zn	Pb	Cd	Cr	Cu	Total index	Sampling period	References
Poland								
Bialowieza National Park						1.00	1961–1979	[4]
Ojcow National Park	1.37	2.05	3.09	6.30	NA	3.20	1968–1973	[3]
Upper Silesia Region	1.55	3.89	1.73	3.31	0.76	2.25	1951–1973	[4]
Niepolomice Forest	1.23	1.18	0.91	1.13	NA	1.11	1972–1975	[4]
Rogow Woodlands	1.31	0.40	0.06	NA	NA	0.59	1985	[6]
Wroclaw District	0.29	5.44	NA	6.90	9.77	5.60	1974–1986	[8]
Wroclaw District	1.18	0.60	0.20	4.20	0.98	1.43	1993–1994	present work
Miedzylesie Woodlands	0.91	0.52	0.06	3.02	0.85	1.07	1993–1994	present work
Niemcza District	0.88	0.44	0.10	2.85	1.05	1.06	1993–1994	present work
Sweden								
Garpenberg	1.11	0.93	2.00	NA	NA	1.35	1968–1983	[5]
Bogesund	0.87	0.50	1.03	NA	NA	0.82	1968–1983	[5]
United Kingdom								
Cumbria	NA	0.79	0.15	NA	NA	0.47	1985–1986	[7]

The values of the pollution indexes determined recently for the Wroclaw Region are markedly lower ($I_{Pb} = 0.6$, and $I_{Cr} = 4.2$) which can be explained by distinct reduction of industrial pollution by one of the non-iron metal smeltry located near the town of Olawa and closing down of the other near the village of Siechnica.

Unfortunately, chromium compounds are strongly bonded to the soil and significant decrease in their concentration will not be seen for a long time. Moreover, acid precipitation lowers pH of the soil and causes increase in the concentrations of heavy metals in ground water; for this reason plants, being the main food of cervidae, ultimately absorb more metals [9], [11], [12]. Restrictions placed on the use of copper compounds ($CuSO_4$) as pesticides in the state farms caused almost 10-fold reduction of I_{Cu} in this region (from 9.8 in 1974 to about 1 in 1994).

The second district – Miedzylesie. Low values of the pollution indexes for lead ($I_{Pb} = 0.5$) and particularly for cadmium ($I_{Cd} = 0.1$) can be compared with those for clean – unindustrialized region of Poland – $I_{Pb} = 0.4$ and $I_{Cd} = 0.1$ for the Rogow Forestland, or Scotland $I_{Pb} = 0.8$ and $I_{Cd} = 0.1$. However, the observed degradation of coniferous forest in this region is probably caused by acid precipitation due to trans-border 'import' of industrial pollutions (SO_2).

The third district – Niemcza. Similarly as for the second district, there is no heavy industry in the area at the moment and elevated pollution index for Cr ($I_{Cr} = 2.9$) can be explained by increased accumulation of chromium in soil due to the former activity of nickel smeltry (closed down at the end of eighties).

The authors have initiated investigations allowing comparison of the concentrations of heavy metals in antlers, livers and kidneys belonging to the same specimens.

4. CONCLUSIONS

The preliminary results seem to confirm the assumption that heavy metal concentrations in roe deer antlers can reflect the level of environmental contamination [4], [13], [14] and support the choice of the antlers as non-destructive bioindicator for annual monitoring of environmental contamination.

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WPŁYW SKAŻEŃ NA ŚRODOWISKO NATURALNE: POROŻA SARN JAKO NIEDESTRUKCYJNY BIOWSKAŹNIK

W pracy przedstawiono wyniki pomiarów stężenia Hg, Pb, Cd, Cu, Zn i Al w porożach sarn pozyskanych ($N = 23$) w latach 1993–1994 w trzech obwodach łowieckich Dolnego Śląska. Opierając się na danych literaturowych dotyczących zanieczyszczenia Puszczy Białowieskiej, wyliczono wskaźniki zanieczyszczenia metalami ciężkimi dla badanych obszarów Dolnego Śląska.

Otrzymane wyniki porównano ze wskaźnikami zanieczyszczenia dla innych rejonów Polski oraz Europy. W rejonie Wrocławia wyliczone wskaźniki zanieczyszczenia chromem i ołowiem były w latach 70-tych porównywalne ze wskaźnikami dla najbardziej zanieczyszczonych terenów Górnego Śląska i zmalały znacznie po likwidacji hut metali kolorowych w najbliższej okolicy.

Przedstawione wyniki wskazują, że zawartość metali ciężkich w porożu sarn może odzwierciedlać zmiany w stopniu skażenia środowiska naturalnego i potwierdza możliwość użycia odnawianego corocznie poroża jako niedestrukcyjnego biowskaźnika zanieczyszczenia środowiska.