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CADMIUM AND LEAD LEVELS IN SELECTED GOAT AND SHEEP TISSUES FROM AREAS UNDER DIFFERENT ANTROPOGENIC PRESSURE

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Abstract

The aim of the study was to compare the levels of cadmium and lead in livers, kidneys and wool / hair / of sheep and goats reared in the vicinity of the steelworks in Nowa Huta in Kraków and in the control field, Rożniatów, in which there was no emitters of heavy metals. Samples were collected post mortem from one-year old animals of one breed (within a species) and one sex, who had lived from birth in the studied areas. Both species were fed with the same fodder and have remained in the same places. Wet mineralization was applied (mixture of nitric acid (V) and chloric (VII) (3: 1)) metal determination was done by a FASA method. The levels of the metals depend on the species, on the test areas and on the collected part of the animal. Tissues from sheep contained more cadmium and lead than the tissue of goats. The highest cadmium content was found in the kidney, lower in the liver, the lowest in the hair / wool of tested animals. Goat kidneys from both areas of research and sheep kidneys from Rożniatów meet consumer standards for cadmium. However, 20% of sheep kidneys sampled from Nowa Huta district exceeded the standards for cadmium. The lead content of both species exceeded the limit in all of the kidneys and livers from Nowa Huta district. In Rożniatów the standards were not fulfilled for all kidneys and livers of goats, and all kidneys and 70% of the livers of sheep.

Key words: cadmium, lead, sheep, goat, organs

INTRODUCTION

Versatile and intensive human activities contributed to the accumulation of additional amount of heavy metals and their inclusion in the biogeochemical cycle. Among the elements characterized with the highest cumulation coefficients (10-600) in the environment the most frequently identified are: cadmium, lead, zinc and copper, less frequently mercury and chromium (Oleszek and Maliszewska-Kordybach, 2009). All metals from this group pose a serious hazard for people if they are supplied in the amounts exceeding biological barriers for the organisms on the lower levels of the food chain (Kabata-Pendias and Pendias, 1999). Beside mercury, cadmium and lead have been included in the European Commission Regulation (WE No 1881/2006) stating the highest admissible levels for some pollutants in foodstuffs. These elements in animal and human organisms reveal harmful effect on various internal organs (kidneys, liver, lungs, pancreas or bones) and disturb metabolism of minerals crucial for the organism. They undergo bioaccumulation usually leading to cancer (Bogunia et al., 2008, Czeczot and Majewska, 2010, Cielecka and Dereń, 2011, Giel-Pietraszuk et al., 2012). Among animals the most susceptible to contamination with these metals are sheep, cattle and wild animals because their main fodder are vegetative plant parts (grass, hay, silage) (Węglary, 2007). It has been commonly known, that in the regions polluted by industry and agriculture, heavy metal content in animal tissues may be different than in the ecologically clean areas (Dobrzański et al., 1996, 2005, Kramarova et al., 2005). Analysis of heavy metal concentrations, particularly cadmium and lead in blood, tissues and hair may be important information about the state of the natural environment (Pięta and Patkowski, 2007). The aim of the research was an assessment of cadmium and lead concentrations in kidneys, liver and hair of goats and sheep wool as an element of the environment state assessment in two regions under different severity of anthropopressure.

MATERIAL AND METHODS

The research was conducted in the years 2010-2011 in two regions under anthropopressure of different severity. The first area of investigations was identified in the region of a former ecologically endangered zone, Górka Kościelecka settlement located in the Nowa Huta district of Kraków. The selected area situated 4.5km North West of the steelworks boundary in Nowa Huta. Until 1951 it used to be Kościelniki village near Kraków, which after construction of the steelworks in Nowa Huta and establishing a new Nowa Huta quarter was incorporated into Kraków city. Despite its location in Kraków municipality, the area retained its agricultural character. The most significant pollutant in this region was the Steelworks in Nowa Huta which belonged to the group of eighty industrial plants most arduous for the environment in Poland (Odnawialne… 2014). After 1989 a number of pro-ecological alterations were applied in the plant, its size and the structure of production changed markedly, as well as its ownership (Historia…2016). The Steelworks obtained a number of certificates for its innovations, friendliness for the environment and clean production (Technologie…2016). However, the pollutants generated in the environment for the decades of the steelworks' previous operation remained and under specific conditions they may be released posing a secondary source of pollution.

The second region of research, the Rożniatów district, is an ecologically clean area, with low severity of anthropopressure, situated in the Podkarpackie province, Przeworsk county and Zarzecze commune. The areas were selected and compared due to their similarities, the same soil types and very good agricultural condition.

The studied sheep and goats were of the same gender (females), the same age (1year old), the same breed, fed with equal feeds, and bred in the same conditions. The only differentiating factor was intersubject (genetic) and behavioural variability between individual animals. Kidneys, livers and hair/wool were collected *post mortem* from 40 animals from the investigated regions. Samples of collected tissues were washed and homogenized before the analysis. Contents of investigated metals in kidneys, livers, and goat hair and sheep wool were assessed after wet mineralization in a mixture of nitrogenous (V) and perchloric acids (3:1) by FASA method on SOLAR M6 apparatus (Ostrowska et al., 1991). The heavy metals were determined using background correction by means of deuterium discharge lamp. Samples of the analysed materials were dissolved and determined in three replications. Differences in cadmium and lead concentrations in the analysed tissues were calculated by means of Tukey test at the significance level $\alpha = 0.05$.

RESULTS

The investigations demonstrated that the sheep tissues contained on average 40% higher cadmium concentrations than tissues collected from goats, irrespective of the investigated region. The region of research did not influence to any significant extent diversification of cadmium concentrations in the analysed goat tissues, whereas the diversification was apparent in sheep tissues (Tab.1). On the other hand, the assessment of cadmium amount according to the kind of biological material, showed significantly the highest cadmium concentrations assessed in the kidneys and livers of both animal species, lower in the livers and the lowest in their hair/wool. Over twice higher concentration of this metal was determined in goat kidneys than in their livers and over 5 to 8-fold higher than in their hair. On the other hand, sheep kidneys contained from over 2 to 3-fold more cadmium than their livers and from over 7 to over 11-fold bigger quantities than their wool.

Table 1. Cadmium content in goat and sheep organs in areas with different anthropogenic stress [mg · kg^{-1} f.m.], n=40.

Species	Parameter	Rożniatów district			Nowa Huta district		
		Kidneys	Livers	Hair/wool	Kidneys	Livers	Hair/wool
Goats	Mean	0.27abc	0.12ab	0.03a	0.3abc	0.14ab	0,05a
	SD	0.05	0.01	0.01	0.1	0.05	0,01
	Median	0.25	0.12	0.03	0.29	0.13	0.04
	minimum	0.21	0.11	0.01	0.17	0.1	0.03
	maximum	0.35	0.14	0.04	0.46	0.22	0.08
	V%	21	8	51	39	34	31
Sheep	Mean	0.5c	0.15ab	0.04a	0.88d	0.38bc	0.12ab
	SD	0.14	0.03	0.03	0.63	0.25	0.01
	Median	0.43	0.13	0.03	0.59	0.30	0.12
	Minimum	0.33	0.09	0.01	0.54	0.21	0.11
	Maximum	0.72	0.20	0.14	2.10	0.89	0.14
	V%	32	26	92	23	75	12

$NIR_{0.05}$ for animal species=0.01. $NIR_{0.05}$ for region of research=0.06; $NIR_{0.05}$ for biological material=0.02
(Means not significantly different at 0.05 level share the same superscript letter; Tukey test.)

Cadmium concentrations in kidneys and liver are to great extent determined by the animal species and its habitat. The concentration of this element in wild animal livers as a rule are higher than in farm animals, as demonstrated by the research of Anke et al. (1980, 1993). The authors determined the following cadmium contents in kidneys collected from farm and wild animals from unpolluted areas: horse 111mg Cd ·kg^{-1}d.m., heifer 0.60 mg Cd ·kg^{-1}d.m., young bulls 0.91 mg Cd ·kg^{-1}d.m., cows 3.0 mg Cd ·kg^{-1}d.m., deer 14 mg Cd ·kg^{-1}d.m., stags 3.2 mg Cd ·kg^{-1}d.m., sheep 5.1 mg Cd ·kg^{-1}d.m. On the other hand, in polluted regions cadmium concentrations in the kidneys were as follows: horse 982mg Cd ·kg^{-1}d.m., heifer 3.5 mg Cd ·kg^{-1}d.m., young bulls 4.9 mg Cd ·kg^{-1}d.m., cows 10 mg Cd ·kg^{-1}d.m., deer 39 mg Cd ·kg^{-1}d.m., stags 8.2 mg Cd ·kg^{-1}d.m., sheep 9.3 mg Cd ·kg^{-1}d.m. The same metal concentrations in livers were as follows: stags 0.58 mg Cd ·kg^{-1}d.m., deer 1.30 mg Cd ·kg^{-1}d.m., sheep 0.54 mg Cd ·kg^{-1}d.m., cows 0.78 mg Cd ·kg^{-1}d.m. In the investigations discussed in this paper, cadmium content in sheep kidneys was much higher in conversion to dry mass, on average 2.20 mg Cd ·kg^{-1}d.m. (Rożniatów district) and 3.56 mg

Cd ·kg^{-1}d.m. (Nowa Huta district) and for the goats, respectively, 1.20 mg Cd ·kg^{-1}d.m. and 1.30 mg Cd ·kg^{-1}d.m. Mean concentrations of this element in the liver samples collected from goats in Rożniatów area were 0.36 mg Cd ·kg^{-1}d.m. and in sheep 0.44 mg Cd ·kg^{-1}d.m. In the area of Nowa Huta district goats accumulated in their livers on average 0.42 mg Cd ·kg^{-1}d.m. and sheep 1.08 mg Cd ·kg^{-1}d.m. Thus it was demonstrated, that cadmium level in livers of sheep bred in Rożniatów district area with lesser severity of anthropopressure was similar to assessed in the research of Anke et al. (1980, 1993), whereas in Nowa Huta region sheep accumulated almost twice more of this metal in their livers.

Table 2. Lead content in goat and sheep organs in areas under different anthropogenic pressure [mg · kg^{-1} f.m.], n=40.

Species	Parameter	Rożniatów district			Nowa Huta district		
		Kidneys	Livers	Hair/wool	Kidneys	Livers	Hair/wool
Goats	Mean	1.99cd	1.09ab	1.63abc	3.5d	1.87abcd	2.94cd
	SD	0.87	0.27	0.62	0.87	0.62	0.51
	Median	2.04	1	1.59	3.29	1.66	2.78
	minimum	0.82	0.83	0.66	2.34	1.4	2.5
	maximum	3.06	1.55	2.31	4.61	3.21	3.96
	V%	48	26	41	28	38	20
Sheep	Mean	2.44cd	0.77a	3.32d	2.82cd	1.81abc	5.12e
	SD	0.83	0.25	0.94	1.07	0.26	1.36
	Median	2.74	0.69	3.53	2.28	1.79	5.4
	Minimum	0.92	0.49	2.1	1.59	1.35	2.82
	Maximum	3.15	1.12	4.49	4.26	2.19	6.9
	V%	37	36	30	52	16	29

$LSD_{0,05}$ for animal species = n.i. $LSD_{0.05}$ for region of research = 0.14; $LSD_{0.05}$ for biological material = 0.17
(Means not significantly different at 0.05 level share the same superscript letter; Tukey test.)

Comparing the obtained results with the Commission Regulation (EC) No. 1881/2006 it was observed that goats from both investigated areas and sheep from Rożniatów fulfilled the consumption standards for cadmium. The admissible content of this metal 1.00 mg ·kg^{-1}f.m. was exceeded in 20% of sheep kidneys from Nowa Huta district. For liver permissible cadmium content was 0.5mg mg ·kg^{-1} f.m. Exceeded contents were assessed in 20% of the samples collected in the region of Nowa Huta district. At the same time this element concentrations in sheep kidneys from Nowa Huta district revealed a low variability coefficient – 23% (Tab.1). The analysis of lead concentrations (tab. 2) showed that sheep tissues accumulated on average 8.5% more of this element than goat tissues, however the dependencies were not statistically significant. Moreover, significantly higher lead levels were determined in the biological material collected in Nowa Huta region than in Rożniatów. The assessment of lead concentrations regarding the kind of biological material revealed the highest concentrations in goat kidneys, lower in hair and the lowest in livers. Irrespective of the sampling site, significantly higher, between 1.7 to 1.9 fold lead quantities were found in goat kidneys than livers and from over 5 to over 8-fold higher than in their hair. In sheep the highest lead content was found in wool, lower in kidneys and the lowest in livers. Sheep wool contained from more than 1.4 to over 1.8-fold higher level of this metal than their kidneys and more than 2.9 to over 2.4-fold higher level than their livers (Tab.2).

Comparing the obtained results with the Commission Regulation (EC), it was demonstrated that none of the analysed kidney samples fulfilled the recommended standards, i.e. 0.5mg Pb $\cdot kg^{-1}$ f.m. The assessment of the liver suitability for consumption, for which the permissible lead content is the same as for cadmium, it was found that only 20% of samples collected in Rożniatów region fulfilled these requirements. In medicine, the analysis of undyed hair is considered a good assessment of pollution state, because unlike blood or other tissues it does not undergo such strong homeostatic mechanisms (Patkowska-Sokoła et al., 1996, Pięta and Patkowski, 2007). Bodkowski et al. (2006) reported lead concentrations of 21.5 mg$\cdot kg^{-1}$d.m. and cadmium 0.14 mg $\cdot kg^{-1}$d.m. in sheep wool in the region of Legnica and Głogów Copper District. On the other hand, in the region considered as ecologically clean in the Barycz River Valley, lead concentration in sheep wool was 2.8 mg $\cdot kg^{-1}$d.m. and cadmium 0.27 mg $\cdot kg^{-1}$d.m. Higher cadmium concentrations in sheep wool from the region considered as an unpolluted compared to a polluted one (like the Copper District) might be explained by the recent flood. In the research discussed in the paper, mean cadmium content in conversion to dry mass in goat hair and sheep wool in Rożniatów region was respectively 0.03 and 0.05mg Cd $\cdot kg^{-1}$d.m. and in Nowa Huta region was over 1.8 to over 2.7-fold higher reaching respectively 0.05 and 0.13 mg $\cdot kg^{-1}$d.m. Mean content of lead in goat hair and sheep wool was on the level of 1.49 and 3.30 mg Pb $\cdot kg^{-1}$d.m. in Rożnaitów area and by over 1 to 1.5 higher in Nowa Huta district area under a stronger anthropopressure, reaching 2.55 (goats) and 4.95 (sheep) mg Pb $\cdot kg^{-1}$d.m. Comparing the obtained results with those reported by Bodkowski et al. (2006), lower cadmium contents were assessed in sheep wool, irrespectively of the region of research. Lead level in the tested wool collected from the sheep in Rożniatów area, under low antropopressure was lower than this element content in sheep wool collected in the Barycz River Valley, whereas it was between 1 and over 1.7-fold higher in the Nowa Huta region. Many authors point to the fact that heavy metal concentrations in animal feeds depend on their content in the soil, plant species and on the severity of anthroporessure in a given area (Fotyma and Mercik, 1995, Buczek et al., 2007). As demonstrated by numerous investigations in the regions effected by large industrial plants, generally higher cadmium and lead concentrations are assessed in soils, plants and farm animal tissues, as well as in wild animals than in ecologically clean areas (Golcz and Breś, 2000, Lipiński, 2000, Bednarek et al., 2006, Zawadowski et al., 1999, 2001, Kośla et al., 2008). The results presented here confirmed this dependence with reference to both elements. Higher cadmium and lead concentrations were assessed in the analysed animal tissues in Nowa Huta region than from the area under lesser anthropopressure, i.e. Rożniatów. Higher concentrations of the studied metals in biological material from Nowa Huta region result from pollutant emission, by among others Kraków city, including the steelworks, however the time of pollutant inflow is of secondary importance. Studies on the soils and crops conducted in this region point to a negative effect of the urban and industrial agglomeration on the above mentioned elements of the natural environment (Gambuś et al., 1995, Curzydło et al., 1997, Szwalec et al., 2005, Mundała et al., 2013).

CONCLUSIONS

1. Cadmium and lead contents depended on the animal species, the kind of biological material and region of research.
2. Tissues collected from sheep had higher amounts of cadmium and lead than the tested goat tissues.
3. The highest cadmium content was found in kidneys, lower in livers and the lowest in hair of the analysed animals.
4. Lead concentrations in the analysed tissues depended on the animal species. In goats the highest lead content was in kidneys, lower in hair and the lowest in livers. In sheep the highest lead concentrations were found in wool, lower in kidneys and the lowest in livers.
5. In compliance with Commission Regulation (EC) No. 1881/200 goat kidneys from both regions of research and sheep kidneys from Rożniatów met the consumption standards for cadmium. The standards were not fulfilled by 20% of kidney samples collected from sheep in Nowa Huta district.
6. The in kidneys and livers from all goats (irrespective of the localization) and from all sheep in Nowa Huta district did not meet the standards for lead concentrations. All kidney samples and 70% of liver samples of sheep from Rożniatów did not meet the standards, either.

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