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Concentration of lead, cadmium, and mercury in tissues of European beaver (*Castor fiber*) from the north-eastern Poland

Aleksandra Giżejewska, Anna Spodniewska, Dariusz Barski

Department of Pharmacology and Toxicology, Faculty of Veterinary Medicine, University of Warmia and Mazury in Olsztyn, 10-957 Olsztyn, Poland
aleksandra.gizejewska@uwm.edu.pl

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Abstract

The aim of the study was to determine the concentrations of lead (Pb), cadmium (Cd), and mercury (Hg) in the liver, kidneys, and muscles of European beavers (*Castor fiber*) and thus to evaluate the degree of heavy metals contamination in Warmia and Mazury region in Poland. The study was conducted on free-living beavers captured in region of Warmia and Mazury during autumn 2011. Concentrations of the elements were determined by atomic absorption spectrometry. The presence of the metals was detected in all individual tissue samples. Mean Pb and Hg concentrations were relatively low. However, the high mean Cd level, especially in the kidneys (7.933 mg/kg) and liver (0.880 mg/kg) was demonstrated. Despite the fact that region of Warmia and Mazury is considered to be "ecologically clean", the conducted studies indicate that systematic monitoring for the presence of heavy metals is necessary not only in industrialised but also in agricultural regions, as well as in natural ecosystems.

Key words: beaver, lead, cadmium, mercury, concentration, Poland.

Introduction

Heavy metals are widely applied in numerous industries, and the resulting risk of toxicity poses a significant environmental problem. Heavy metals have both natural and anthropogenic sources, and due to their physical and chemical properties, they can be transported over long distances after release. They are found in ambient air, soil, as well as surface and underground waters. Elevated concentrations of heavy metals are also observed in bottom sediments of lakes and rivers where they are accumulated and bound to organic matter (14). Toxic metals migrate in the environment freely and change their chemical form, becoming available for plants and animals at various levels of the food chain, which ends in human consumers. Their long half-life and ability to accumulate in tissues increase their toxicity. Lead, cadmium, and mercury poisoning have serious consequences, and long-term exposure to low metal doses leads to chronic poisoning (8). Their mutagenic, carcinogenic, embryotoxic, and teratogenic effects may be visible even after the source of exposure has been eliminated.

Wild animals, for example beaver (*Castor fiber*), roe deer (*Capreolus capreolus*), wild boar (*Sus scrofa*), and otter (*Lutra lutra*), are good bioindicators of environmental contamination with harmful substances including heavy metals (1, 6, 9, 11). The European beaver is the largest Eurasian rodent, which exerts strong pressure on the environment. It inhabits nearly all regions of Poland, excluding high mountains. The beaver colonises terrestrial and aquatic habitats. This herbivorous animal graze on around 200 plant species, including herbs, ferns, and aquatic vegetation, also plants accumulating heavy metals, for example willow (*Salix* sp.) (7).

In Poland, the beaver population is constantly growing and according to Central Statistical Office it is estimated at over 78 thousand animals (3). This large population can be attributed to several factors, among them the introduction of the Active Beaver Protection Plan, the species' ability to quickly adapt to habitat conditions, absence of natural enemies, drop in the popularity of fur goods, as well as improved quality of water resources. In Poland, the European beaver is subjected to partial protection (13) but in six European

countries (Lithuania, Latvia, Estonia, Belarus, Norway, and Sweden) it is classified as a game species.

Due to the very limited investigations on this species there is not much information concerning the level of toxic substances, including heavy metals, in beavers' tissues. Therefore, the aim of this study was to determine lead, cadmium, and mercury concentrations in the liver, kidneys, and muscles of the free-living European beaver inhabiting region of Warmia and Mazury, and to evaluate the degree of contamination in this area based on the maximum levels for heavy metals in tissues of farm animals recommended by the European Commission (4).

Material and Methods

Six beavers captured in November 2011 in the Masurian Lakeland, a typical agricultural region with extensive forests and a large number of lakes were used for this study. The animals were collected upon the approval of the Regional Nature Conservation Authority and the Local Ethics Committee and divided into 2 groups. One group of the animals consisted of two males and one female captured near human settlements (Leszkiemie, Wiżgóry), while the second group included two females and one male from wild habitats (Mauda, Burmiszki) (Table 1).

Beavers were captured during daytime with a net and transported to the place of research in cages specially adapted for this purpose. The animals were anaesthetised with xylazine and ketamine in doses appropriate to body weight. Beavers were weighed and measured, bled, and then were decapitated under full anaesthesia.

Samples of approximately 15 g of the liver, kidneys, and biceps femoris muscle were collected and stored in polyethylene bags at -25°C until analysis.

Lead and cadmium concentrations were determined after dry mineralisation by flame atomic absorption spectrometry (Unicam Solar 939). The total mercury content was determined by the AMA 254 analyser by atomic absorption spectrometry without chemical processing of the sample. The metal concentrations in tissues, expressed as mg/kg of wet weight, are given as the mean, standard deviation (SD), and the minimum and maximum values. The results were processed by analysis of variation (ANOVA) using Ducan's test to determine significant differences between captured sites. Differences were considered significant at $P < 0.05$. The Spearman's rank correlation method was used to test the relationship between metal concentrations in each tissue as well as between each metal content in the tissues. The correlation coefficient r was considered significant when P value was below 0.005. The comparative analysis between results obtained and maximum allowable concentrations of heavy metals in the tissues of farm animals set by the European Commission was made.

Results

The concentrations of lead, cadmium, and mercury in the liver, kidneys, and biceps femoris muscle of European beavers are presented in Table 2.

Mean Pb concentration in the liver was 0.105 mg/kg. The highest Pb concentration in the liver and kidneys were observed in adult male (no. 2) weighing 18.07 kg (0.129 mg/kg and 0.137 mg/kg, respectively). The same individual had the lowest Pb content in muscle tissue. The lowest concentration of Pb in the liver was recorded in beaver no. 3 (0.085 mg/kg), and in kidneys of the individual no. 6 (0.029 mg/kg).

The average Cd concentration in the liver and kidneys reached 0.88 mg/kg and 7.933 mg/kg, respectively. The highest Cd levels in all analysed tissues were noted in adult male (no. 6) weighing 14.03 kg and the lowest in the liver and kidneys of the youngest female (no. 5) weighing 6.75 kg. These both individuals were captured in the wild habitats (Mauda, Burmiszki). The lowest Cd value in muscle tissue was found in the youngest individual no. 3 (0.011 mg/kg) and the highest in the oldest animal no. 6 (0.040 mg/kg).

The highest mean Hg concentration was noted in kidneys (0.0321 mg/kg), then in the liver (0.0239 mg/kg), and the lowest in the muscle (0.0106 mg/kg). Generally, Hg contents in all samples were low and not determined by age and body weight of animals.

Table 1. Characteristics and location of European beavers used for the study

Beaver no.	Sex	Age	Location	Weight (kg)	Body length (cm)
1	♀	adult	Leszkiemie	15.94	106.5
2	♂	adult	Wiżgóry	18.07	111.5
3	♂	young	Wiżgóry	8.91	89.0
4	♀	adult	Mauda	16.65	109.0
5	♀	young	Mauda	6.75	83.5
6	♂	adult	Burmiszki	14.03	108.5

Table 2. Concentrations of lead, cadmium, and mercury in the liver, kidneys and biceps femoris muscle of European beavers (mg/kg w.w.)

No. of beaver	Liver			Kidneys			Muscle		
	Pb	Cd	Hg	Pb	Cd	Hg	Pb	Cd	Hg
1	0.122	1.203	0.0190	0.047	12.526	0.0283	0.030	0.025	0.0112
2	0.129	0.487	0.0178	0.137	4.205	0.0301	0.011	0.019	0.0106
3	0.085	0.673	0.0204	0.048	3.069	0.0330	0.070	0.011	0.0099
4	0.099	0.455	0.0256	0.055	11.612	0.0438	0.012	0.027	0.0109
5	0.091	0.398	0.0424	0.05	2.024	0.0263	0.019	0.034	0.0108
6	0.106	2.065	0.0182	0.029	14.159	0.0312	0.027	0.040	0.0104
Mean	0.105	0.880	0.0239	0.06	7.933	0.0321	0.028	0.026	0.0106
SD	0.017	0.651	0.0095	0.038	5.401	0.0062	0.022	0.010	0.0005
Min	0.085	0.398	0.0178	0.029	2.024	0.0263	0.011	0.011	0.0099
Max	0.129	2.065	0.0424	0.137	14.159	0.0438	0.07	0.040	0.0112
Maximum levels set by the EC*	0.5	0.5	-**	0.5	1.0	-**	0.1	0.05	-**

* Commission regulation (EC) 2006
** – no regulations

The Pb levels recommended by the European Commission were exceeded in none of samples. Amounts exceeding EC regulation were determined in the liver and kidneys for Cd only. There are no regulations for maximum acceptable Hg concentration in tissues of farm animals. No correlation between metal concentrations in any of the examined beaver's tissues was found. However, the cadmium content correlated negatively with the sampling site ($r = -0.93$; $P < 0.05$). The highest content of cadmium was found in the kidneys and the lowest in the muscle.

Discussion

According to the literature, very few studies have been conducted to investigate metal concentrations in tissues of European beaver, although this research is important because of the environmental monitoring. Due to lack of standards for the levels of heavy metals in wild animals' tissues, the results obtained were compared with the admissible in European Commission levels for heavy metals in tissues of farm animals (4). The allowable EC limits are presented in Table 2.

Lead concentrations in beaver tissues were low and not influenced by the animals' body weight, age, or sex. The results obtained can be attributed to the fact that Warmia and Mazury, also known as the Great Lake District or the Green Lungs of Poland, is mainly agricultural and weakly industrialised region. Nevertheless, slightly higher Pb contents were noted in animals collected near human settlements (Leszkiemie, Wiżgóry) than in beavers colonising wild habitats (Mauda, Burmiszki). This may be caused by municipal sewer systems and the use of multicompound fertilisers. Secondary release of Pb from soil and bottom deposits is also possible (14). Pb concentrations did not exceed the maximum levels set by the EC in any of the analysed samples.

Similar results were reported by Zalewski *et al.* (16) who compared heavy metals concentrations in two groups of beavers collected in the Region of Warmia and Mazury in 2003. The content of Pb in the liver, kidneys, and muscles from the "control group" of animals captured in the Srokowo Forest District was 0.14 mg/kg, 0.09 mg/kg, and 0.031 mg/kg, respectively. These values were lower than concentrations of this metal in the "exposure group" from the Beaver Refuge on the Pasłęka River near a former military airport, but more similar to our results. In obese animals, Pb levels reached average values, which provides a further evidence that concentrations in the analysed organs are not influenced by body weight, which was also observed in our study.

Cadmium concentration in the analysed tissues was significantly higher in animals from wild habitats than in beavers captured near humans settlements. Mean Cd content in the liver was nearly twice higher, in the kidneys almost eightfold higher, while in the muscle twice lower than EC limits (4). The results relating to the content of Cd in the liver and kidneys of beavers collected near human settlements were similar to those recorded by Zalewski *et al.* (16) in the animals captured near a former military airport. These authors noted that the Cd levels in the liver and kidneys of animals from "exposure group" was threefold higher than in the "control group". Fimreite *et al.* (6) reported that average concentration of Cd in the liver and kidneys of beavers in Norway was 1.03 mg/kg and 10.25 mg/kg, respectively. These values were higher than those found in our studies. Higher values were also reported by Nolet *et al.* (12) in Germany. The authors, similarly noted an increase in Cd content in the kidneys with the animals' age. That correlation was also observed in other wild animal species (5, 9, 11, 12) with similar foraging preferences to beavers. The red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), and moose (*Alces alces*), as well as beaver, may be at risk of

chronic Cd poisoning by consuming plants, which accumulate this toxic metal. For such reason, estimations of heavy metal concentrations in the tissues of wild herbivores should account for the seasonal availability of different plant species in the local habitat (2).

There are no publications discussing Hg concentrations in beaver tissues and only a few concerning free-living animals. In this study, Hg levels in beaver tissues seem to be low; however, maximum acceptable concentration of this metal is not limited by the currently applicable Commission Regulation (EC) No. 1881/2006 (4). Nonetheless, Hg was identified in every individual sample, thus confirming its presence in the natural environment. Albińska *et al.* (1) examined Hg concentration in tissues of roe deer, wild boar, and red deer captured in the region of Lodz. The reported values in the liver and muscles of roe deer and red deer were lower than these obtained in our study. The values noted in wild boars were most similar to the average Hg concentrations observed in beavers in this study. The above could attribute to the fact that beavers and wild boars have richer diets than roe deer and red deer.

Heavy metal concentrations in the tissues of wild animals are influenced not only by the diet but also by the species and its habitat. Kucharczak *et al.* (10) noted high Pb contents exceeding the allowable EU limits in the muscles of roe deer captured in industrial and urbanized regions of Poland. No such correlations were reported with respect to Cd. Above authors concluded that the analysed animals were exposed to toxic substances, which were ingested with plant food (indirect exposure), as well as inhaled with gases and dusts (direct exposure).

Szkoda *et al.* (15) in the monitoring study analysed the content of heavy metals in game (roe deer, wild boar, and red deer) and farm animals' tissues. They found that Pb concentrations in the muscle of game animals were significantly higher than in our study, but the authors attributed this fact to secondary contamination of tissue samples collected from shot wounds rather than to environmental pollution. Concentrations of Cd and Hg in the liver and muscle of wild animals were lower than in this study. It is worth noting, that over 50% of samples in which the concentrations of heavy metals were above maximum EC levels constituted samples of game animals (15). According to our results, the exceeding of EC limits was found for Cd only, and was noted in half of liver specimens and in all of kidney samples.

The study revealed the presence of all analysed toxic metals *i.e.* Pb, Cd, and Hg in all individual samples of the liver, kidneys, and muscles of beavers captured in Warmia and Mazury region. The mean concentrations of Pb and Hg were relatively low. The results indicate high level of Cd in the investigated organs, especially in the kidneys, where the concentrations of Cd were almost eightfold higher than the EC standards for this metal. It can be concluded that anthropogenic pollution is observed not only in industrialised but also in agricultural regions, as well as in natural ecosystems, which confirms that regular monitoring is necessary.

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