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Domestic cat (*Felis catus*) as a bioindicator of environmental lead contamination

Kot domowy (*Felis catus*) jako bioindykator zanieczyszczenia środowiska ołowiem

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Abstract

The investigations aimed at determining the lead content in domestic cat hair as an indicator of environmental lead contamination. The investigation material comprised hair samples collected from 20 cats from the region of Warsaw. The first group of 10 cats (five males and five females) were kept at home as the accompanying animals. Another group (five males and five females) were the so-called feral urban cats whose nutritional base comprised human food wastes. Hair samples were collected from the middle abdominal region prior to routine surgical treatments. The lead content was determined with the help of the inductively coupled plasma optical emission spectrometry method.

A significant effect of the conditions of animal life on the lead content in their hair was observed. The mean content of metal in hair of all the investigated cats amounted to 1.95 mg•kg^{-1}. The highest lead concentration in free living animals was 2.89 mg•kg^{-1} (females: 3.58; males: 2.20 mg•kg^{-1}). In cats kept as accompanying animals, the mean lead value was nearly three times lower (1 mg•kg^{-1}) (females: 0.98; males: 1.02 mg•kg^{-1}).

In the coat of animals living as urban feral cats, a significantly higher mean lead concentration was observed than in cats kept at home. The values are similar to those obtained in the analysis of the lead content in carnivorous animals originating from the non-urbanised areas.

Streszczenie

Celem badań było określenie zawartości ołowiu w sierści kota domowego będącego indykatorem zanieczyszczenia środowiska ołowiem. Materiał stanowiły próby sierści pobrane od 20 kotów z terenu Warszawy. Pierwszą grupę liczącą10 osobników (5 samców i 5 samic) reprezentowały koty utrzymywane w domach jako zwierzęta towarzyszące. Drugą grupę (5 samców i 5 samic) stanowiły tzw. zdziczałe koty miejskie, których bazą pokarmową były odpadki pokonsumpcyjne człowieka. Próby sierści pobierano z okolicy śródbrzusza przed rutynowymi zabiegami chirurgicznymi. Zawartość ołowiu oznaczono metodą ICP-OES.

Stwierdzono istotny wpływ warunków bytowania zwierząt na zawartość ołowiu w ich okrywie włosowej. Średnia zawartość tego metalu w sierści wszystkich badanych kotów wynosiła 1,95 mg•kg^{-1}. Najwyższe stężenia ołowiu odnotowano u zwierząt żyjących w stanie wolnym 2,89 mg•kg^{-1} (samice: 3,58; samce: 2,20 mg•kg^{-1}). U osobników utrzymywanych jako zwierzęta towarzyszące średnia zawartość ołowiu była niemal trzykrotnie niższa 1 mg•kg^{-1} (samice: 0,98; samce 1,02 mg•kg^{-1}).

W sierści zwierząt bytujących jako zdziczałe koty miejskie odnotowano istotnie wyższą średnią zawartość ołowiu w porównaniu do kotów domowych. Uzyskane wartości są zbliżone do wyników analizy okrywy włosowej innych gatunków zwierząt mięsożernych pochodzących z terenów niezurbanizowanych.

1. INTRODUCTION

Lead belongs to the list of the most toxic heavy metals. For many years now, it has been rated among elements with embryotoxic, teratogenic, mutagenic and carcinogenic characteristics [Kośla 1999]. It enters the animal and human organisms mainly through the alimentary tract and respiratory system [Jakubowski et al. 1997, Krzywy et al. 2010, Curi et al. 2012]. Introduced into the system, it nearly totally passes into the blood binding with plasma protein. Its toxic action causes the disturbances in the functioning of liver, kidneys, bone marrow and the central nervous system. Metabolic disturbances caused by lead poisoning result in the restriction of the enzyme functioning, abnormality in protein structure and changes in the mineral balance of the organism [Kośla 1999]. In the case of lead and other heavy metals, knowledge about their concentrations in the organism is acquired from ananalysis of blood, milk, bones and hair. It is assumed that the products of the common integument, particularly hair, show the ability for metal bioaccumulation thus comprising a proper material for the analyses of their content [Kośla et al. 2004, Kośla et al. 2011a,b, Skibniewska et al. 2011, Curi et al. 2012, Rashed, Soltan 2005]. It was revealed that the content of toxic heavy metals in animal hair is positively correlated with their level in the parenchymal organs such as liver, kidneys and skeletal muscles [Rashed, Soltan 2005, McLean et al. 2009, Curi et al. 2012].

Pet carnivorous animals, sharing living conditions with humans, and in many cases also food, became a research object informing about the quality of environmental conditions in the human close surroundings [Kośla et al. 2011b, Skibniewska et al. 2012, 2013, Tomza-Marciniak et al. 2012]. For this reason, a domestic cat (*Felis catus*), the top predator of the trophic chain, became the object of interest of many research teams investigating the problem of the state of environment in the urban agglomeration. In order to assess various land ecosystems, numerous species of wild and domestic animals were used. The biomonitoring of the forest environment was carried out on the basis of analysis of the tissues of species representing the *Cervidae* family as well as European bisons, foxes and wild boars [Skibniewski et al. 2010, Pilarczyk et al. 2010, 2011, Kośla et al. 2012; Tomza-Marciniak et al. 2012]. In relation to the rural environment, farm animals were used [Tomza-Marciniak et al. 2011]. Monitoring of urban environment and the regions of large agglomerations needs an analysis of tissues obtained from animals living in close proximity to humans [Kośla, Skibniewska 2010, Skibniewska et al. 2011]. The contents of biogenic and heavy metals were investigated by examining the synanthropic species of non-domesticated mammals such as, fox, mole, domestic mouse and bat [Ieradi et al. 1996, Komarnicki 2000, Luftl et al. 2003]. In the accessible literature, only few publications can be found which are devoted to the problem of bioaccumulation of metals in the tissue of carnivore animals which accompany humans. Most of them deal with the analysis of the heavy metal content in the blood serum.

The aim of the investigations was the determination of the lead content in the hair of cats originating from the Warsaw agglomeration.

2. MATERIAL AND METHOD

Research material included hair samples collected from cats originating from the region of Warsaw. Ten animals were cats kept as the accompanying animals (five males and five females). The remaining animals (five males and five females) were the feral urban cats. Hair was collected at the time of the routine surgical procedures. Material was obtained during the preparation for surgery after the earlier premedication. The stray animals were subjected to orchidectomy or ovariohysterectomy within the programme of limiting the population of stray cats in Warsaw. It assumes capturing stray cats with the help of special cage-traps, their sterilisation, vaccination and deworming. Then the animals are released at the sites where they were captured. The investigations included only mature cats without any pathological symptoms. Material was collected from the middle abdominal region (*mesogastrium*) and then placed in disposable polyethylene bags in which it was transported to the laboratory. Prior to the investigations, hair was subjected to washing and degreasing and then drying. Mineralisation was performed in a microwave apparatus under pressure in the presence of concentrated nitric acid. The content of lead was determined using the method of atomic emission spectrometry with inductively coupled plasma optical emission spectrometry in the presence of the reference material (CRM 397 Community Bureau of Reference). Statistical analysis was performed in Statistica 10.0™ Statsoft Poland, Kraków. The data distribution was assessed using the Shapiro–Wilk *W* test. Due to the fact that the values obtained during the investigation did not present the normal distribution, the significance of differences between the investigated groups was assessed using the Mann–Whitney *U* non-parametric test. The significance of differences was tested at $P \leq 0.05$ and $P \leq 0.01$.

3. RESULTS AND DISCUSSION

The presence of heavy metals in the environment mainly results from human activity connected with the industrial production, transport and agricultural activities. In relation to the urban agglomeration, the main role is played by the first and second of the above-mentioned activities which include burning of mineral fuels, metallurgical processes and production of accumulators [Sanna et al. 2008].

Hair belongs to materials that are easy to obtain in a non-invasive method and does not need any special conditions of storage prior to laboratory analyses. Despite this, it is still not valued enough as a research material providing information concerning a long-time exposition to some toxic metals [Dunnett, Lees 2003]. Hair origin and growth is regulated by physiology thus allowing the response to changing environmental conditions. It was observed that animals may eliminate pollutants from their organisms by their sequestration in skin appendages by such structures as hair, claws and feathers. The seasonal loss of hair during moulting is one of the methods of eliminating, among others, heavy metals from the organism [Dunnett, Lees 2003, Rashed, Soltan 2005]. Hair is not treated as a main excretory organ in relation to the endo- and exogenous substances because the amount of substances excreted by it reflecting the per cent of the taken dose is extremely small. However, in comparison with other tissues and organs of the organism, it can be noticed that it is very stable and heavy metals and other substances which it contains remain there for a long time. The analysis of chemical composition of hair may be the source of knowledge about the organism exposure not only for a period of a few months or even years but also for the time directly preceding the examination which can provide the information about a strong poisoning [Dunnett, Lees 2003]. Hair is mainly built of keratin which is a protein rich in sulfhydryl groups that are able to bind heavy metals [Beernaert et al. 2007, McLean et al. 2009]. They get into the hair through blood vessels supplying hair follicles and also with secretion of the sebaceous and sweat glands. There are no sweat glands in the hairy skin of the carnivorous animals and thus an important role is played only by the secretory activity of sebaceous glands [Dunnett, Lees 2003, McLean et al. 2009]. In relation to the numerous species of mammals, a positive correlation was observed between the lead content in the appendages of the skin and its concentration in the liver and kidneys. Among the species whose hair was used as an indicator of environmental

Table 1. Lead content in the hair of cats depending on their gender and living conditions ($mg \cdot kg^{-1}$)

Statistical parameters	Keeping condition		Males		Females		All animals
	Pet	Feral	Pet	Feral	Pet	Feral	
N	10	10	5	5	5	5	20
Arithmetic mean	1.0*	2.89*	1.02	2.20	0.98	3.58	1.95
Standard deviation	0.17	1.92	0.18	0.65	0.18	2.57	1.64
Min	0.90	0.90	0.90	1.60	0.90	0.90	0.90
Max	1.30	7.50	1.30	3.20	1.30	7.50	7.50
Lower quartile (Q_{25})	0.90	1.70	0.90	1.80	0.90	1.70	0.90
Median	0.90	2.20	0.90	1.90	0.90	3.50	1.30
Upper quartile (Q_{75})	1.10	3.50	1.10	2.50	0.90	4.30	2.20

*Significant differences at $P \leq 0.01$

contamination with heavy metals are wood mouse (*Apodemus sylvaticus*), field vole (*Microtus agrestis*), European hedgehog (*Erinaceus europaeus*), brown antechinus (*Antechinus stuartii*), black rat (*Rattus rattus*) and brown rat (*Rattus norvegicus*) [Hunter et al. 1989, D'Have et al. 2005, McLean et al. 2009, Rautio et al. 2010]. However, small mammals are characterised by a relatively short lifespan estimated at about 2 years which may make the observation of a long lasting exposure to heavy metals more difficult. Due to this, carnivorous animals which are the top predators of the trophic chain with a relatively longer lifespan seem to be more suitable for the research on the accumulation of metals. In the environmental research, the lead concentrations in wild dog family such as crab-eating fox (*Cerdocyon thous*), maned wolf (*Chrysocyon brachyurus*) and hoary fox (*Lycalopex vetulus*) have been studied [Curi et al. 2012].

The mean lead content in the hair of the investigated animals amounted to 1.95 $mg \cdot kg^{-1}$. Detailed data are presented in Table 1. The highest concentrations were noted in free living animals (2.89 $mg \cdot kg^{-1}$) (females: 3.58; males: 2.20 $mg \cdot kg^{-1}$). In cats kept as accompanying animals, the mean value of the lead concentration was nearly three times lower at 1 $mg \cdot kg^{-1}$ (females: 0.98; males 1.02 $mg \cdot kg^{-1}$).

As compared with the data published by other authors, the values obtained in the hair analysis of individuals kept as accompanying animals should be considered as low. In the case of stray cats living in the urban agglomeration, they are close to the data from literature. McLean et al. [2009] observed that the lead content in the hair of brown antechinus was within the limits (from 1.78 to 5.54 $\mu g \cdot g^{-1}$). In the coat of the black rat and brown rat, these values amounted to 1.49–10.6 and 2.16–20.6 $\mu g \cdot g^{-1}$, respectively. Lower values were obtained in the analysis of the lead content in the spines and hair of the European hedgehog. In the animals of this species from southern Finland, Rautio et al. [2010] obtained the values 0.54 $\mu g \cdot g^{-1}$ in the spine and 0.98 $\mu g \cdot g^{-1}$ in hair, which is close to the value obtained in the hair analysis of the Warsaw cats kept as accompanying animals. It was noted that in small omnivorous mammals and predators, the content of heavy metals mainly depends on their environmental concentration but the weight and body size do not significantly affect the disused parameter. Higher values are noted in animals living in the vicinity of foundries or other industrial plants [Beernaert et al. 2007, McLean et al. 2009]. While investigating the content of heavy metals in animals of the dog family free living in Brazil, Curi et al. [2012] observed that the mean value of lead in the coat of crab-eating fox amounted to 2.45 $mg \cdot kg^{-1}$. In maned wolf it was 2.34 $mg \cdot kg^{-1}$ and in hoary fox 2.35 $mg \cdot kg^{-1}$. These results are similar to those obtained in our own investigations. It results from the presented data that the hair of domestic cats from the Warsaw region contains the amounts of lead similar to that observed in the coats of animals originating from areas characterised by a low environmental hazard.

4. CONCLUSIONS

Domestic cat is a proper model for investigating the environmental exposure to lead. In the coat of animals living as urban feral cats fed on human feed wastes, one could observe significantly higher mean lead concentrations as compared with cats kept at home. The values are similar to those obtained in the analysis of the lead content in carnivorous animals originating from the non-urbanised areas.

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