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Heavy metals in the silvery mole-rat, *Heliophobius argenteocinereus* (Bathyergidae, Rodentia) from Malawi

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A b s t r a c t . Concentrations of lead (Pb), cadmium (Cd), copper (Cu) and zinc (Zn) were assessed in body tissues of a solitary subterranean rodent, the silvery mole-rat (*Heliophobius argenteocinereus*) from the African endemic family Bathyergidae. The mean concentrations of cooper and zinc in animals captured in Malawi were higher in liver compared to muscle (18.3 $mg.kg^{-1}$ vs. 8.8 $mg.kg^{-1}$ of dry weight for copper; 170.3 $mg.kg^{-1}$ vs. 101.2 $mg.kg^{-1}$ for zinc). No important differences were found in concentration of heavy metals between animals captured in different habitats (grassland vs. cultivated crops) or between sexes. Very low concentrations of lead (0.41 $mg.kg^{-1}$ in liver, 0.25 $mg.kg^{-1}$ in muscle) and cadmium (0.09 $mg.kg^{-1}$ in liver, 0.07 $mg.kg^{-1}$ in muscle) indicate no health risk connected with local consumption of silvery mole-rats in the area under study.

Key words: heavy metals, subterranean rodent, *Heliophobius*, bioaccumulation

Introduction

Many studies have dealt with bioaccumulation and concentration of heavy metals in organs and tissues of domestic and free-living animals (e.g. V e n o g o p a l & L u c k e y 1978, M a r t i n & C o u g h t r e y 1982, W r e n 1986, S t o e p p l e r 1992). Concentrations of heavy metals in natural rodent populations were regularly correlated with environmental pollution (C h m i e l & H a r r i s o n 1981, A n d r e w et al. 1984, B e y e r et al. 1985, C o o k e et al. 1990, M a et al. 1991, I e r a d i et al. 2002).

Generally, lack of information about the heavy metals content in small mammals is typical for sub-Saharan Africa. In spite of the rich literature about African mole-rats (Bathyergidae, Rodentia), there is no available study concerning of bioaccumulation potential of heavy metals in bathyergids. Considering the specialised subterranean way of life, feeding below ground and longevity in African mole-rats (N o w a k 1991), we decided to determine concentrations of four heavy metals (Pb, Cd, Cu, Zn) in a solitary bathyergid, the silvery mole-rat, *Heliophobius argenteocinereus* (Peters, 1846) from Malawi. We focused on this species also because it is often used as a source of animal proteins by local people as well as other large bathyergids (c.f. De G r a f f 1981, N o w a k 1991).

Material and Methods

Altogether, 12 adult specimens of both sexes captured in different habitats were studied. The collecting site, Blantyre-Limbe (15°47' S, 35°04' E, altitude 1,120 m) was situated close to the centre of the most industrial town in Malawi. Six mole-rats (5 M / 1 F) were collected in grassland characterised by clay loam soil and six mole-rats (2 M / 4 F) were taken in the fields of local crops as cassava and sweet potato on loam soil.

The samples of femoral muscles without skin and liver (5–10 grams each) were taken in animals preserved in 70% ethanol and rinsed in double distilled water for 1 min. After dry mineralization and dissolution of samples, atomic absorption spectrometry (AAS) was performed using a GBC – 932 AA (USA) apparatus in the 1M HNO_3 flame environment (B a r u š et al. 1999) at wavelength 228.8 nm for Cd, 283.3 nm for Pb, 324.8 for Cu, and 213.9 for Zn. There were three replicates in each determination. The difference between parallel estimates was lower than 11 relative per cent. The results on reference material (feed mixtures for poultry used in interlaboratory tests of the Central Institute for Supervising and Testing in Agriculture) were in agreement with certified values (Regulation No. 222/1996 of the Ministry of Agriculture of the Czech Republic). The recovery was 95.2 ± 2.95 % for Cd, 96.1 ± 3.16 % for Pb, 93.2 ± 1.86 % for Cu, and 92.0 ± 3.21 % for Zn (mean ± SE, 10 determinations for each component). The content of heavy metals was evaluated in $mg.kg^{-1}$ of 100 % dry matter.

Nonparametric statistical methods, Wilcoxon matched paired test, Mann Whitney U-test and Spearman correlation test were used for analyses of data.

Results

Concentration of heavy metals varied widely among analysed samples (Table 1). Accumulated levels of heavy metals were the highest for Zn. The Pb and Cd concentrations were low. Concentrations of heavy metals were generally higher in liver, with significant differences in concentration of Cu (Wilcoxon test, Z = 2.75, P = 0.006) and Zn (Wilcoxon

Table 1. Sex, habitat and weight (g) of twelve silvery mole-rats and concentration ($mg.kg^{-1}$) of four heavy metals in liver and muscle tissue samples.

			Pb		Cd		Cu		Zn	
Habitat	Sex	Weight	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle
Crops	f	177	0.04	0.18	0.12	0.05	13.22	11.28	115.69	118.62
"	f	147	0.62	0.37	0.01	0.16	26.23	8.30	132.11	98.60
"	f	268	1.03	0.07	0.11	0.26	42.50	4.12	125.38	44.43
"	f	168	0.73	0.28	0.27	0.03	17.37	7.57	124.22	71.34
"	m	150	0.19	0.28	0.07	0.02	31.44	11.17	171.96	110.88
"	m	174	0.25	0.28	0.04	0.02	14.93	9.98	121.75	125.78
Grassland	f	137	0.23	0.48	0.03	0.03	11.26	5.64	162.23	79.27
"	m	276	0.45	0.12	0.12	0.02	12.22	5.05	169.66	87.48
"	m	182	0.39	0.21	0.11	0.21	9.03	11.70	534.22	146.99
"	m	170	0.02	0.16	0.04	0.03	11.35	12.94	113.03	125.03
"	m	177	0.64	0.28	0.06	0.02	14.05	9.71	112.73	103.58
"	m	248	0.27	0.26	0.07	0.03	15.43	8.12	160.86	102.81
Mean		189.5	0.41	0.25	0.09	0.07	18.25	8.80	170.32	101.23
SD		47.33	0.3	0.11	0.07	0.09	10.03	2.82	116.82	27.74

Explanations: SD, standard deviation.

test, Z = 2.51, P = 0.012). The ratio of compared concentrations R (R = mean value of heavy metals in muscle / liver) indicates the bioaccumulation potential of different tissues. Found R showed that mean concentrations of heavy metals is almost double in liver (with exception of Cd) compared with muscle: $R_{Cd} = 0.86$, $R_{Zn} = 0.59$, $R_{Pb} = 0.58$, $R_{Cu} = 0.48$.

A correlation was found between the body mass and concentration in some heavy metals. Concentration of Cd in liver was higher in larger animals (Spearman test, R = 0.56, P = 0.058). Concentration of Pb in muscle was inversely correlated with body mass (Spearman test, R = -0.816, P < 0.001). Concentration of Cu in liver differed between animals captured in grassland (12.22 ± 2.26 $mg.kg^{-1}$) and in cultivated crops (24.28 ± 11.35 $mg.kg^{-1}$) (Mann-Whitney test, U = 3, P = 0.016). Mean concentration of Zn in muscle differed between sexes (82.45 ± 28.06 $mg.kg^{-1}$ in females, 114.65 ± 19.55 $mg.kg^{-1}$ in males; Mann-Whitney test, U = 5, P = 0.042).

There was also correlation of concentrations among some heavy metals. Concentrations of Cu in muscle and Zn in muscle were highly intercorrelated (Spearman test, R = 0.91, P < 0.0001). Both metals in muscle were negatively correlated with concentration of Pb in liver (Spearman test, R = -0.65, P = 0.022 for Cu and R = -0.61, P = 0.035 for Zn, respectively).

Discussion

It is generally accepted that the main route of exposure of wild mammals to heavy metals in their habitats is through the consumption of food (M a et al. 1991). In subterranean rodents accumulation and concentration of heavy metals can also be influenced by their subterranean way of life. The bathyergids consume mainly below-ground storage organs of plants (N o w a k 1991) and because some consumed plants are perennials, we should expect long-term accumulation of heavy metals also in these parts of plants.

Our findings correspond with published information on concentration of heavy metals in rodents and with their concentrations in sequence Zn > Cu > Pb > Cd in nonloaded or in extremely loaded environment, or in experiments (C a m e r o n 1973, H u n t e r et al. 1989, C o o k e et al. 1990a,b, H a l l et al. 1990, M a et al. 1991, K o r o l j e v a et al. 1992, T u l l - S i n g l e t o n et al. 1994).

There was significantly increased accumulation of Cu and Zn in liver compared to muscles, which is in agreement with findings in other mammals. M a et al. (1991) explained the differences in concentrations between liver and muscle by more effective regulation by homeostatic mechanisms during regulation of some heavy metals. It concerns especially essential elements Cu and Zn because of their importance in metabolism and enzymatic reactions (R o b e r t s & J o h n s o n 1978).

The low accumulation rate of Pb is indicated also by negative correlation of Pb concentration in muscle with weight (thus probably with age) of captured mole-rats. The positive correlation of Cd in liver with body mass agrees with the published information that Cd is characteristically cumulated in liver and kidney, contrary to Pb, Cu and Zn (S a b b i o n i et al. 1978, H u n t e r et al. 1989, M a et al. 1991). Nevertheless, M e r t e n s et al. (2001) found little influence of weight on accumulation of Cd.

Contrary to the absence of information about concentration of heavy metals in bathyergids and other small mammals from this geographical area, there is a huge amount of information about load of heavy metals in Holarctic area, mainly in muroid rodents.

Published studies cover areas with the minimal load of heavy metals to extremely polluted areas. Mean concentrations of Pb in the liver and body tissues of rodent genera *Mus*, *Microtus*, *Clethrionomys*, *Peromyscus*, *Apodemus* ranged 0.2–13.9 mg.kg^{-1} of dry matter (G e t z et al. 1977, R o b e r t s et al. 1978, C h m i e l & H a r r i s o n 1981, H a l l et al. 1990, M a et al. 1991, K o r o l j e v a et. al. 1992). Mean concentrations of Cd ranging 0.05–9.8 mg.kg^{-1} were found in the same group and tissues of rodents (A n d r e w s et al. 1984, C o o k e et al. 1990a,b, H a l l et al. 1990, M a et al. 1991, K o r o l j e v a et al. 1992, M e r t e n s et al. 2001). Mean concentrations of Pb and Cd in liver and in muscle of silvery mole-rats were very low, near the lower limit of values known for rodents. It suggests low contamination of the areas under study with both xenobiotic metals. This fact is probably caused by low level of industry (especially coal industry) and low vehicular traffic in Malawi. In addition, their subterranean way of life may also contribute to low level of heavy metal burden in subterranean rodents. M e t c h e v a et al. (2001) found lower load with Pb in species living more in subterranean habitat (*Pitymys subterraneus*) in comparison with more surface dwellers.

Mean concentrations of Zn in liver and in total body of rodents (*Microtus*, *Clethrionomys*, *Apodemus*, *Peromyscus*) ranged from 22.1–309.0 mg.kg^{-1} (C a m e r o n 1973, R o b e r t s & J o h n s o n 1978, B e y e r et al. 1985, C o o k e et al. 1990a,b, H a l l et al. 1990, M a et al. 1991, K o r o l j e v a et al. 1992, M e r t e n s et al. 2001). Mean concentrations of Cu in liver and skinned bodies of *Microtus*, *Clethrionomys*, *Apodemus* ranged from 0.4–23.7 mg.kg^{-1} of dry matter (C a m e r o n 1973, H u n t e r & J o h n s o n 1982, B e y e r et al. 1985, H u n t e r et al. 1989, H a l l et al. 1990, K o r o l j e v a et al. 1992). Mean concentration of Zn in silvery mole-rats was thus close to mean concentrations in liver and close to the lower limit for muscle's published values. Mean concentration of Cu was close to the upper range limit for liver compared with published values on other rodents. Higher concentration of Cu in animals captured in cultivated area, correspond with high concentration of copper in some local crops, especially in sweet potatoes (P i e t s c h 2001).

We can conclude, that the concentrations of heavy metals in liver and muscle of the silvery mole-rat were, with exception of Cu, are typical for a lightly contaminated environment. We confirm that the concentration of essential heavy metals is higher in liver in comparison with muscle. From this point of view, concentrations of xenobiotic heavy metals (Pb and Cd) found and recommended maximum allowable concentrations in food stuff by WHO (http://www.who.int/fsf/), there is no important health risk for local consumption of silvery mole-rats in the area of Malawi studied.

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