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THE CONTAMINATION OF INTERNAL TISSUES OF SMALL MAMMALS AT THE BANSKÁ ŠTIAVNICA MINING AREA

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Abstract

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The article presents the results of 142 small mammal tissues biomonitoring at mining dumps of various ages at the locality of Lúky pod Tanádom (Banská Štiavnica, Central Slovak Neovolcanites). The investigation was realized in summer and in autumn to document the differences between the seasons. It was focused on livers, kidney and spleens of three dominant rodents: *Apodemus flavicollis, Micotus arvalis* and *Clethrinomys glareolus*. The contents of Fe, Mn, Cu, Zn, Pb, Cd and Bi were determined by atomic absorption flame spectrometry (AAS).

Key words: dumps, tailing impoundments, heavy metals, toxic elements, small mammals, tissues

Introduction

The locality Štiavnické Bane - Lúky nad Tonádom is situated in the area of north-source-spring of the stream Štiavnica. It is the land markedly changed by historical exploitation of Au-Ag-polymetallic ores from the 14^{th} to the 19^{th} century. The phases of mining activities are well documented (Sombathy, 1993). They finished in 1903. The following liquidation and reconstruction works lasted till 1910 and the part of them was also the forestation of the greatest dumps (Fig. 1).

The characterization of the studied subjects

At the reference surface (position I) the soil is developed directly at the mechanically mouldered pyroxenic andesite of the Tanadian complex. At the surface of dump of the shaft

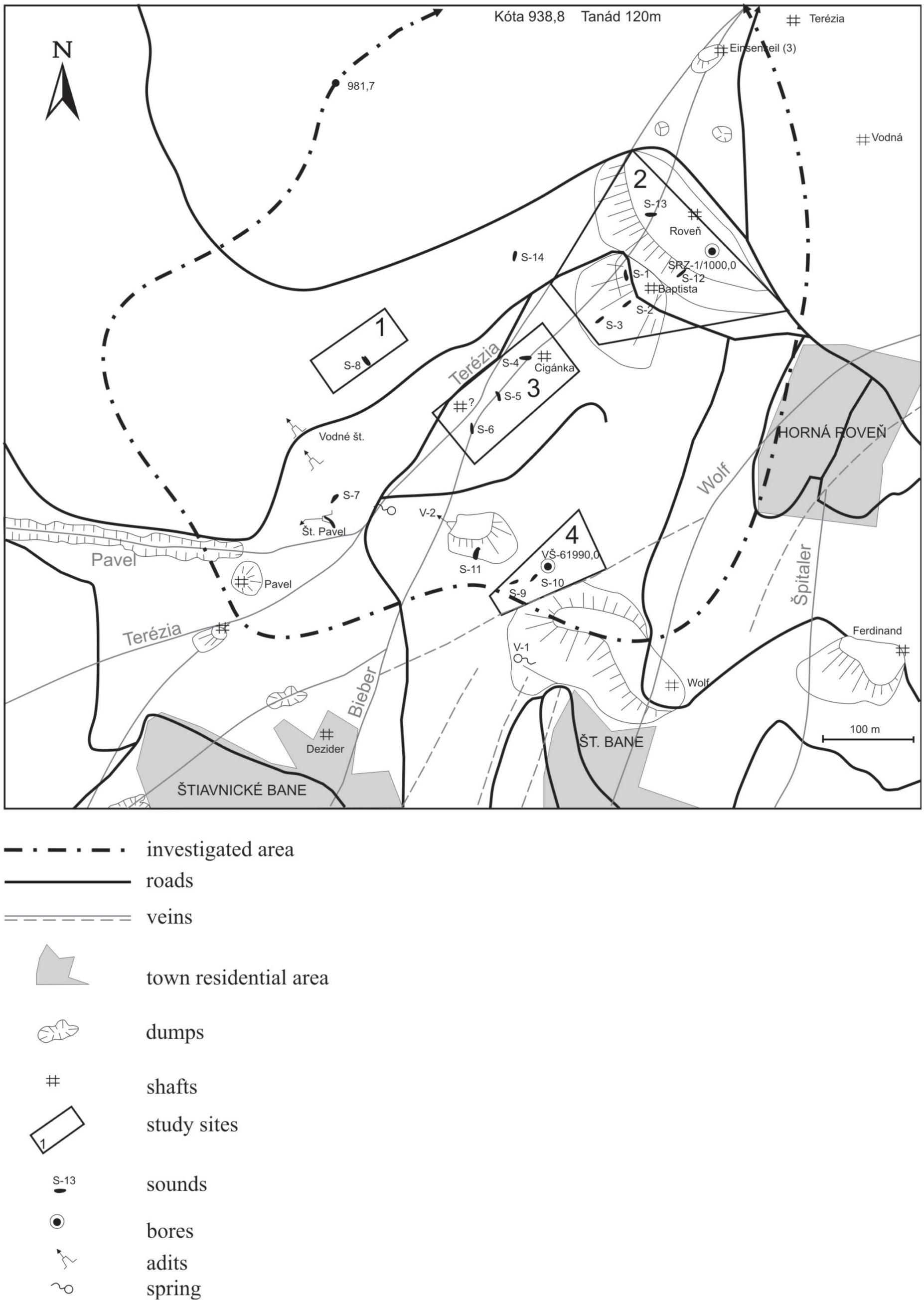

Fig. 1. Štiavnické Bane - Lúky pod Tanádom, dumps from 17th – 19th centuries; dump Babčo, in the background grassy dump of the Kamenná and Wolf shafts (in the background on the right, grassy).

Roveň (position II) the main component is the silicious-diorite porphyry from the shaft Roveň. The building and communal waste presents the foreign material. At the surface of the dump is the layer of limnic sediment. The representative of old dumps from the 17th and 18th centuries is the dump Babčo (position III) created by various rocks, materials of gangues with the dominant abundance of timazite with the considerable proportion of vein-quartz cuts and oxidized cuts of ore-filling.

The oldest dumps from the 14th and 17th centuries (position III) have the various material compositions. The crystalline vein-quartz or around-veins argillites are dominating in some of them. In the drainage endorheic area of depression under the root of dump of the shaft Wolf (position IV) the cultural layer is thick 1–5 m and there can be differentiated 3 technogenous horizons. Each of them contains the cuts of the technical ceramics and the wood-coals. It is assumed that in this area was probably the historical test-room of metals. Additional was studied the settling pit Lintich (position V).

The soils developed on the heaps (Danáková, Vlčková, 1996) containing the substratum mixture consists of the vein-quartz with the addition of hydrothermal altered andesite and sulphide ores cuts. Typical soil of dumps ANm^b with good developed horizon Bv, where the processes of darkening and the creating of the soil KMm occur, reaches the depth of 6 cm. The soil under this layer is nigger-brown, humid, and fine-lumpy, to the depth 5–10 cm, and contains 20% of skeleton. Bv horizon reaches the depth 25–30 cm and is rachel, humid, with the inexpressive polyedric structure and approximately 40% content of skeleton. Horizon C consists of mixture of quartz and illite.

The studied vegetation at the heaps tends to the association *Arrhenatheretum elatioris* (Braun–Blanquet, 1991). The portion of synantrophic species does not change in later stages of development of vegetation but the portion of meadow species of the class *Molinio Arhenatheretea* (Tüxen, 1937) increases. Out-washing of metals released from the dumps of mining-processing wastes in the form of colloids, ion solutions and organo-complexes causes their availability to vegetation. The change of plants' specific spectrum occurs in consequence of soil-loading by heavy metals whereby the composition and the covering by vegetation at the dumps and soils not affecting by mining activity are markedly different. Dump-positions are inhabited mainly by competitive weak plant species. These are able to adapt to hindered conditions ate the positions.

Materials and methods

The research was realized at 4 positions representing:

- by mining activities not affecting soil at the non-altered pyroxenic andesite in steeper slope of Tanád, covered with grass, bushes and trees utilized only for fleshing up (position I),
- greater dump from the 17th and 18th centuries (Babčo) and adjacent dump of the shaft Roveň from the end of 20th century (position II),
- the belt of small dumps from the 14th till 17th centuries (position III),
- terrain-depression created by damping the valley up with the dump of the shafts Kamenná and Wolf 1–3 (position IV).

The catching of small mammals was realized at the areas demarked near the probes excavated in the area of positions. The additional catching was realized at the settling pit Lintich (position V) in autumn.

Small mammals were caught in summer and autumn terms (June and October). The catching was realized by bascule-trap with the wick and there was placed the mixture of edible oil and nuts. The catching of small mammals, their specific and sexual determination, internal organs taking, and also their preparing for analysis were realized at the Zoological Institute of the Slovak Academy of Sciences in Košice. For analysis of small mammals tissues were prepared cumulative charges, i.e. organs from the several specimens of concrete species and genders were connected into samples with minimum 3g of tissue.

These samples of internal tissues (liver, kidney and spleen) were after mineralization analyzed for content of Fe, Mn, Cu, Zn, Pb, Cd, and Bi in the laboratory of the Geological Institute of the Slovak Academy of Sciences in Banská Bystrica.

Results and discussion

The possibility of higher animals utilization as the indicator of loading depends on their stressor sensibility and on extent of their reaction in time and area. The group of small mammals is the suitable modeling group for monitoring of environment toxicity (Talmage, Walton, 1991). The comparative study on value of pollutants' concentrations in tissues of various body organs is an often used method. The small mammals present very suitable group for monitoring from the view of their short-age (several months till year). Their living space is small (maximum 1–2 ha), so they enable to monitor the particular position.

At all positions the dominant species are *Apodemus flavicollis* (53.9%, thereinafter *AFLA*), *Microtus arvalis* (24.5%, thereinafter *MARV*) and *Clethrionomys glareolus* (18.2%, thereinafter *CGLA*). Species *Microtus (Pytymys) subterraneus* (*PSUB*) and the only representative of insectivorous animals *Crocidura suaveolens* have in populations the minor abundance.

Determined specific spectrum and dominance of listed rodents are typical in environment of Banská Štiavnica (Štollmann, Dudich, 1988). Dumps' biotopes differ in dominant species of small mammals depending up their demand on vegetation cover. The plant-part predominates in food of studied species; the seeds create the significant part of food of *AFLA* and the vegetation parts of plants predominate in food of common vole and *CGLA*. It is known, the reproducing organs of plants (seeds) show the considerable degree of resistance towards the contamination by heavy metals and other pollutants.

The specific composition of plant cover underlies the different species dominance of small mammals inhabited the positions. Concentrations of heavy metals in tissues of studied species show considerable differences (Tables 1 and 2). Accumulation trends of monitored metals in organs' tissues of the same species differ according to season (summer – autumn) and body organs (liver, kidney, spleen).

Total 84 samples of livers, kidney and spleens were prepared for analysis from the population of above-mentioned species. 34 of them were from the summer sampling and 50 of them from the autumn sampling. The average contents of selected elements in summer set of tissues of species *AFLA, MARV* and *CGLA* from the positions I–IV are listed in Table 1 and from the autumn set from the positions I–V in Table 2.

The graphic representation in differences of tissues' contamination of livers, kidney and spleens of *AFLA* species at positions between the summer and autumn set of analyzed

T a b l e 1. Average contents of selected elements (mg.kg^{-1}) in little mammals tissues from summer sample set from localities I–IV.

Element	Position	*AFLA*			*MARV*			*CGLA*		
		Liver	Kidneys	Spleen	Liver	Kidneys	Spleen	Liver	Kidneys	Spleen
Fe	I	639.0	2.0	1.0				4.5	118.0	1.0
	II	53.0	146.0	1.0	1248.0	163.0	22.0			
	III	720.0	3028.0	1.0	1.0	1.0	8.0			
	IV	458.0	1.0	1.0				1837.0	240.0	952.0
Mn	I	9.5	1.0	0.1				13.0	0.1	11.0
	II	6.7	0.1	1.0	9.0	0.1	0.1			
	III	17.3	26.0	3.0	3.0	0.1	0.1			
	IV	11.3	1.0	1.0				47.0	0.1	0.1
Cu	I	5.9	1.0	0.1				12.0	4.0	0.1
	II	10.8	1.0	0.1	11.0	20.0			4.0	0.1
	III	9.4	21.3	0.1	4.0	2.0	0.1			
	IV	12.0	3.0	1.0				14.0	3.0	1371.0
Zn	I	25.5	2.0	21.0				34.0	24.0	30.0
	II	26.0	15.0	21.0	21.0	28.0	15.0			
	III	34.3	33.0	20.0	27.0	17.0	24.0			
	IV	35.0	1.0	19.0				24.0	29.0	61.0
Pb	I	15.0	0.1	0.1				4.0	7.0	3.0
	II	20.4	6.0	0.1	9.0	39.0	0.1			
	III	40.0	30.0	0.1	0.1	0.1	0.1			
	IV	5.4	0.1	0.1				26.0	87.0	122.0
Cd	I	1.8	1.0	2.0				1.5	1.0	0.1
	II	1.0	1.0	0.1	1.0	2.0	0.1			
	III	2.3	2.0	0.1	0.1	0.1	0.1			
	IV	1.0	0.1	0.1				1.0	2.0	5.0
Bi	I	0.1	0.1	0.1				0.1	0.1	0.1
	II	0.1	0.1	0.1	0.1	0.1	0.1			
	III	0.1	0.1	0.1	0.1	0.1	0.1			
	IV	0.1	0.1	0.1				0.1	0.1	0.1

samples (Fig. 2) shows, that between the contamination degree of studied organs from the position I–IV is obvious similarity. Positions at younger (II) and older (III) dumps differ by proportional contamination of analyzed organs. The contents of individual elements at younger dumps from the summer and autumn set intersect and at the older dumps there is a differentiation between the summer and autumn set (III). It is similar to differentiation at the positions I and IV (Fig. 2).

T a b l e 2. Average contents of selected elements (mg.kg^{-1}) in little mammals tissues from autumn sample set from positions I–V.

Element	Position	*AFLA*			*MARV*			*CGLA*		
		Liver	Kidneys	Spleen	Liver	Kidneys	Spleen	Liver	Kidneys	Spleen
Fe	I	302.0	80.0	559.0				334.0	118.0	241.0
	II	207.0	108.0	281.0	225.0	123.0	208.0			
	III	165.0	195.0	377.0	228.0	124.0	1.0			
	IV	203.0	101.0	672.0	297.0	1.0	454.0			
	V				282.0	75.0	216.0			
Mn	I	7.3	2.6	4.0				6.0	4.0	0.1
	II	4.3	6.5	3.0	3.7	6.0	0.1			
	III	2.0	6.0	18.0	7.0	9.0	26.0			
	IV	4.4	5.0	21.0	12.0	0.1	0.1			
	V				3.4	6.0	115.0			
Cu	I	10.3	13.0	0.1				8.0	9.0	6.0
	II	8.2	18.0	0.1	1.4	25.0	0.1			
	III	9.0	0.1	0.1	1.4	10.0	75.0			
	IV	9.0	188.0	37.0	8.0	0.1	30.0			
	V				7.4	4.0	41.0			
Zn	I	271.0	305.0	477.0				281.0	284.0	275.0
	II	389.0	123.0	39.0	155.0	641.0	248.0			
	III	365.0	35.0	357.0	187.0	528.0	0.1			
	IV	266.0	309.0	570.0	750.0	575.0	0.1			
	V				177.0	12.0	42.0			
Pb	I	0.1	11.1	0.1				0.1	0.1	0.1
	II	0.1	0.1	0.1	0.1	3.0	0.1			
	III	0.1	0.1	0.1	0.1	40.0	89.0			
	IV	0.1	27.0	0.1	0.1	0.1	0.1			
	V				0.1	0.1	229.0			
Cd	I	3.0	1.1	1.0				3.0	1.5	1.0
	II	2.7	0.1	2.1	9.3	2.0	1.0			
	III	0.1	6.0	20.0	3.7	0.1	4.0			
	IV	7.7	0.1	2.0	8.0	6.0	36.0			
	V				4.3	1.0	8.0			
Bi	I	87.6	110.0	0.1				5.5	73.0	45.0
	II	51.0	119.0	15.0	0.1	164.0	35.0			
	III	50.0	18.0	177.0	9.1	203.0	44.0			
	IV	7.4	134.0	0.1	0.1	256.0	0.1			
	V				18.4	87.0	41.0			

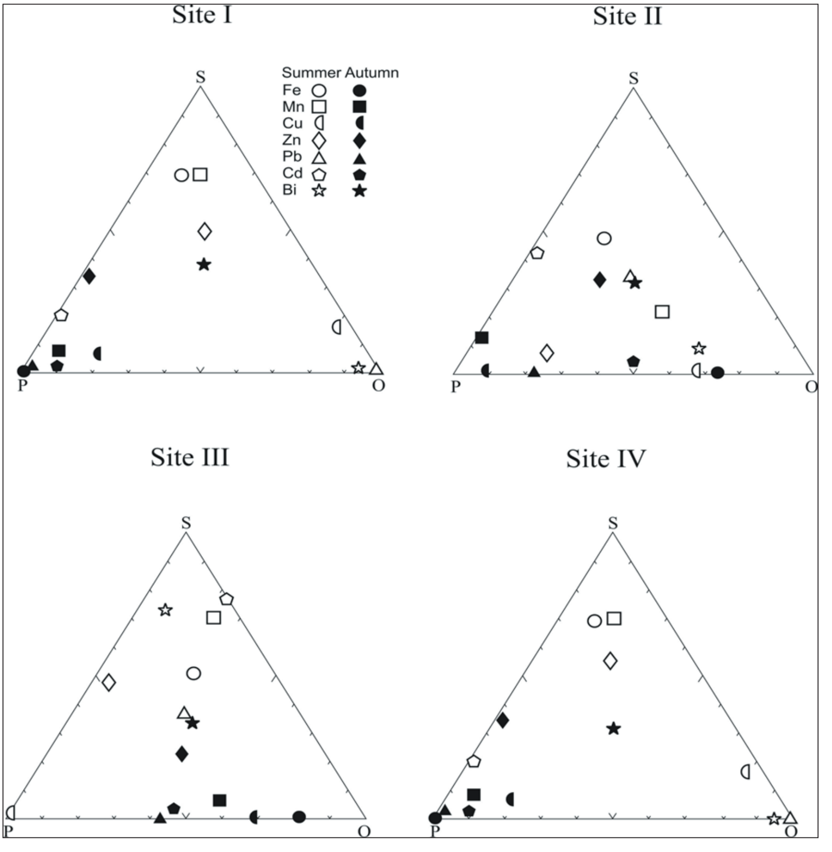

Fig. 2. Triangular plots of rate concentrations of selected elements in tissues of livers (P), kidneys (O) and spleens (S) of *Apodemus flavicolis* species from positions I–IV.

The evident insufficiency of bioaccumulation study is the fact, that the presence of chemical agents in tissues does not document the toxic effect. Opinions on effects of pollutants in higher concentrations on physiological or genetic changes are not united. The important role has the exposure time – the period while the animal is exposed to the activity of stressors. If the organs of short-living organisms are markedly contaminated, then it is very probable, that at animals with longer lifetime will the contamination of internal organs proportionally rise.

Cation Fe^{3+} predominates only in markedly acid environment (e.g. in acid mine drainage). In surface waters Fe migrates usually in following forms: $[Fe(OH)]^{2+}$, $Fe(OH)_2^+$, $Fe(OH)_3$(aq) a $Fe(OH)_4^-$. Hydrated Fe_2O_3 settles and in anaerobic conditions is reduced to Fe^{2+}, secondary sulphides are creating and Fe^{2+} releases into solutions and the cycle is repeating (Pitter, 1990). In sediments of studied settling pits were determined hexa-hydrides of Fe and Mn crystallizing from the porous solutions at the end of capillaries. Knowledge about the toxic effects of Mn and Fe is not sufficient.

Mn in waters is present in various oxidation state, in soluble and insoluble form. When in water is the lack of oxidizing agents the most stabile form is Mn^{2+}. In neutral until acid environment the simple hydrated cation $[Mn(H_2O)_6]^{2+}$ predominates from the soluble species. Depending up water composition there can be present also the complexes $[Mn(OH)]^+$, $[MnHCO_3]^+$, $[Mn(OH)_3]^-$ a $[MnSO_4(aq)]^0$ and at higher concentrations of chlorides the various chloro-complexes (Pitter, 1990).

In natural, mine and dump drainage waters Cu is in soluble form presented in forms of simple hydrated ion Cu^{2+}, carbonated complexes $[CuCO_3(aq)]^0$, $[Cu(CO_3)_2]^{2-}$ and hydro-complexes [CuOH], $[Cu(OH)_2(aq)]^0$, $[Cu(OH)]^{3-}$ a $[Cu(OH)_4]^{2-}$. Cu forms with ammoniac the amino-complexes (Pitter, 1990). Cu is an essential element, which containing many metallo-enzymes and influencing the heamatogenesis. It is the basic element by synthesis of hemoglobin and oxidative enzymes (Talmage, Walton, 1991). The lack of Cu in organism causes the pathologic changes. It limits the transport of Fe ions and causing anemia although there is enough Fe in organism. The redundancy of Cu in organism is toxic, blocks membrane process. Cu overly secretes in urine and accumulates mainly in liver, kidney, bone marrow, cerebrum, cornea, and in hair and can cause the degenerative changes. Intoxication can cause the damage of liver and kidney and also death (Melicherčík, Melicherčíková, 1997).

Zn^{2+} is present in solutions mainly in following forms: $[Zn(OH)_2(aq)]^0$, $[Zn(OH)_3]^-$, $[Zn(OH)_4]^{2-}$, $[Zn(CO_3)_2]^{2-}$, $[ZnHCO_3]^+$. In waters with high concentration of sulphates Zn can be presented as $[ZnSO_4(aq)]^0$ (Pitter, 1990). Long-time and excessive Zn intake is toxic. Besides the reduced re-sorption of phosphates there are presented the symptoms of anemia and other gastro-intestinal symptoms (Melicherčík, Melicherčíková, 1997).

Pb^{2+} predominates among bio-available forms of Pb in hydrated compound $[PbCO_3(aq)]^0$. In alkaline area can be presented in higher concentrations also the complexes $[Pb(CO_3)_2]^{2-}$, $[Pb(OH)_2(aq)]^0$ a $[PbOH]^+$ (Pitter, 1990). Pb is in soils most commonly in solid phase as $PbCO_3$ a $PbSO_4$. Pb effects mainly on red-blood-pigment and blood corpuscles. It endangers the system nervous, musculature and blood vessels. The toxic effect it has also on digestive system, kidney and on ductless glands. Pb is in blood transported mainly on the surface of erythrocytes as colloid phosphate. Uthe et al. (1979) discovered that Pb is accumulating in liver and kidney of animals.

Cd and Bi belong to high toxic elements and have the tendency to accumulate in organisms where are binding in plasma to proteins (Virčíková, Pálfy, 1997). They accumulate mainly in kidney, spleen, genitals and liver. In contrast to Bi, which is geochemical related to Pb, Cd is related to Zn, but is more mobile than Zn mainly in acid environment. In solutions Cd is presented in forms of simple hydrated ion Cd^{2+} and inorganic complexes $[CdOH]^+$, $[Cd(OH)_2(aq)]^0$, $[Cd(OH)_3]^-$, $[CdCO_3(aq)]^0$, $[Cd(CO_3)_2]^{2-}$, $[CdSO_4]^0$ (Pitter, 1990). So it becomes bio-available to plants. Cd contents in animals' organisms decrease also in case of Ca deficit. It accumulates mainly in bones, liver and kidneys, at least in musculature and cerebrum (Kminiak, 1994). Higher contents of Cd were determined at predacious species from family *Insectivora*. This species was in our set represented only by 3 individuals. The differences of Cd contents in liver can be credit to differences in metabolism or in physiological anomalies of individuals (Kováčiková, Reichrtová, 1986). Talmage and Walton (1991) stated, the influence of contamination of main food components on overall Cd concentration in tissues of two species of rodents *Microtus agrestis* and *Apodemus silvaticus*. *Microtus agrestis* consumes mainly herbs and grasses and *Apodemus silvaticus* has the main component of food the fruges and seeds containing lower Cd concentrations as herbs and grasses. Poltárska (2003) states the data on Cd toxicity in respect to Pb and Hg. When the Cd concentration in liver reaches the threshold value it is secreted in urine connected to glutathione but mainly to stools. The bile has the important role in Cd secretion (Schenkel, Krehl, 1983).

Conclusion

The herbivorous animals predominate in specific composition of small mammals inhabited the areas of dumps positions. The insectivorous animals were represented only by one species. The herbivorous animals were represented by species whose main food component are the vegetation organs of plants and seeds. Higher contamination by heavy metals and toxic elements of analyzed tissues of internal organs was determined at animals consuming in preference vegetation organs of plants. Animals consuming mainly the seeds show lower contamination by heavy metals. The different contamination of internal tissues was shown at individual monitored elements from the summer and autumn sets of studied rodents within the individual positions and between the positions.

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