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ACCUMULATION OF HEAVY METALS BY SMALL MAMMALS THE BACKGROUND AND POLLUTED TERRITORIES OF THE URALS

L. A. Kovalchuk[1*], N. V. Mikshevich[2], L.V. Chernaya[1]

[1]*Ural Branch of the Russian Academy of Sciences, Institute of Plant and Animal Ecology, 8 Marta st., 202, Yekaterinburg, 620144 Russia*
[2] *Ural State Pedagogical University, Kosmonavtov ave, 26, Yekaterinburg, Russia*
**Corresponding author*
E-mail: kovalchuk@ipae.uran.ru; KLA@isnet.ru

Accumulation of Heavy Metals by Small Mammals in the Background and Polluted Territories of the Urals. Kovalchuk, L. A., Mikshevich, N. V., Chernaya, L. V. — Accumulation of heavy metals (Cu, Zn, Cd) in hemopoietic-competent organs of ecologically contrast species of small mammals (*Clethrionomys glareolus, Sorex araneus, Apodemus uralensis*) from natural populations of the Middle and South Urals were considered. The content of exogenous and essential trace elements in animal tissues (a liver, kidney, a spleen) was determined by atomic absorption spectroscopy. It has been shown that bioaccumulation of heavy metals in organs of insectivores significantly differs from it of bank voles and wood mice. The smallest total content of heavy metals is shown in wood mice in technogenic territories of the Middle Urals. The submitted data demonstrate the competitive mechanism of the Cu, Zn, Cd. The increased concentrations of endogenous trace elements (copper, zinc) in relation to a toxicant (cadmium), other things being equal, reduce cadmium accumulation level in the tissues *Sorex araneus*.
Key words: small mammals, background and impact zones, copper (Cu), cadmium Cd, zinc (Zn).

Introduction

The Ural region owing to its resource potential and the historical reasons became a zone of environmental risk long ago. Formation of technogenic territories in the Urals is connected with the development of metallurgy which began 300 years ago. The most powerful factor of technogenic impact on the nature of the region is the enterprises of nonferrous metallurgy — the main supplier of heavy non-ferrous metals (HM) to the environment. Despite abundance of the actual material illustrating the multifunctional nature of influence of exogenous chemical factors on an organism, many aspects of their physiological influence still remain disputable or insufficiently investigated. Publications on studying of a bio-element profile in animals from natural populations are often contradictory, and the ones on a research of fluctuations of levels of the contents of bio-elements in animals from background and technogenic territories in comparative aspect are practically absent.

An assessment of possible ecological damage is of quite certain theoretical and practical interest. In this context, the numerous groups of the small mammals living in the polluted territories among generations can serve as the biological indicator of disturbances in ecosystem, and the high speed of their reproduction and quick succession of generations allow to study the remote negative effects and the developing adaptation mechanisms in these animals. Use of wild rodents allows to assess possible ecological damage of the territory and to predict genetic danger of technogenic pollution to local human population (Zakharov, 2000; Kudyasheva et al., 2004; Prokopyev, 2008; Kovalchuk et al., 2011).

Material and methods

This study is based on the field and laboratory researches. The natural populations of typical representatives of small mammals in the fauna of the Urals were used as an object (Sokolov, 1990). A bank vole, *Clethrionomys glareolus* (Schreber, 1780) is the most numerous, ecologically plastic species among rodents of mountain areas of the Urals. The wide area allows to consider a bank vole as a background species in the considerable territory of Eurasia. Borders of its area from 38° N are extended to the North to 65°30´ N, and some individuals reach 67° N. It is a herbivorous species of the voles, with single and family way of life.

The Eurasian common shrew, *Sorex araneus* (Linnaeus, 1758), a plastic and eurytopic species, is widespread in the Urals. The way of its life is settled, but individuals can make considerable movements (up to

2.5 km). The shrews consume mainly animal food: insects and their larvae, earthworms, mollusks, and from the vertebrates — frogs, lizards, small mammals. This food variety puts them in the more favorable conditions in a comparison with other small mammals (Scanlon, 1987).

The Eurasian wood mouse, *Apodemus uralensis* Sylvaemus (Pallas, 1811), is a numerous species, which is known to have a certain ecological and epizootic importance. According to G. N. Chelomina's opinion (2005), *Sylvaemus uralensis* is characterized as a species with the highest adaptive opportunities: it has a bigger area, living in zones of contrast climatic and ecological conditions. The main its food is seeds of various trees which it collects on the earth, then — berries and animal forages (generally, insects), and on the last place — green parts of plants.

Small mammals were captured in August–September by means of the live-traps, which were checked out daily, in the morning. Animals for an experiment, without symptoms of diseases, were chosen and reared in laboratory conditions, according to the rules accepted by the European Convention (1986) on protection of the vertebrate animals used for the experimental and scientific purposes (European…, 1986; Yarri, 2005).

As background territories there were chosen: in the Middle Urals — the National Park "Pripyshminskye Pine Forests" (Sverdlovsk Region, 56°59´01″ N, 63°47´05″ E); in the South Urals — the Ilmensky Reserve, at the Ishkul Lake (Chelyabinsk Region, 55°00´55″ N, 60°09´30″ E).

The National Park "Pripyshminskye Pine Forests" is situated on the western outskirts of the West Siberian Plain (www.zoopoved.ru/catalog). The most part of its territory is covered with the woods (about 90 % of the area). Its other territory is occupied by water reservoirs, and quite insignificant part — by hay-makings, arable lands and pastures. Climate of the area is moderately continental, with vegetation being mainly taiga.

The Ilmensky Reserve is the typical mountain and lake area, located on a border of the wood and the forest-steppe. The average heights of ridges (Ilmensky and Ishkulsky) are of 400–750 m above sea level [http://igz.ilmeny.ac.ru]. The most part of the reserve is covered with the pine and birch woods (78 % of total area), 15.1 % is occupied by lakes, and other territory is comprised by bogs and steppe sites. The climate is moderately continental.

The areas of technogenic landscapes and various categories of the disturbed phytocenosis in the Middle and South Urals reach hundreds of thousands of hectares, where a process of degradation of biogeocenoses actively proceeds under the influence of the atmospheric pollutants containing highly toxic sour gases, heavy metals and arsenic (Peredery, Mikshevich, 1991; Bolshakov et al., 1998).

The Middle Ural Copper Smelter (MUCS) is the largest in the Urals enterprise for smelting of draft copper from primary raw materials, and for a production of sulfuric acid from the emitted metallurgical gases, and, in a period of researches, for production of mineral fertilizers and butyl xanthogenate of potassium. The enterprise is located in Sverdlovsk Region (56°50´59″ N, 59°53´57″ E), in 6 kilometers to the north of the town Revda. It is actually the only large source of emissions around the area of our researches in the Middle Urals. Vegetation in a zone of its location belongs to the Chusovskoy foothill district in a southern taiga sub-band of a boreal forest zone, with the fir-tree woods, green mosses, and some places with underbrush of a linden.

The Mednogorsk Copper-Sulphuric Plant (MCSP) producing also draft copper and sulfuric acid from the emitted gases of metallurgical production, is located in the South Urals, in the Orenburg Region (51°40´43″ N, 57°58´34″ E), in the valley of the Blyava River, in 3,5 kilometers from the Mednogorsk town, in typically steppe area (Ogurtsov, Kolesnikov, 2016). This is a hilly area with a prevalence of rich in herbs and wormwood vegetation, the feather-grass and fescue steppe, as well as with technogenic heathlands with single plants or deprived of them at all.

The range of the pollutants emitted by the enterprises into an aboveground layer of air includes both gases (SO_2, H_2S, NO), and aerosols (oxides and sulfides Cu, Zn, Pb, As, Fe, and also H_2SO_4). The real spectrum of pollutants of an atmospheric air is much wider since initial raw materials (mainly, sulfidic) contain also Sb, Cd, Te, Se and other elements.

The primary form of finding of metals in the aerosols emitted into the atmosphere is slightly soluble sulfides and oxides. It is necessary to consider that there is vitriolic production at the enterprises. All this creates conditions for increase in „loading" heavy metals on organisms of the animals in an impact area of the enterprise. The main way of intake of pollutants into an organism of animals appears to be mainly with forage, in which they are presented at least in two forms — soluble and insoluble. Studying of influence of technogenic factors on small mammals was carried out on the trans-sects located on an equal removal from the sources of technogenic loading. Taking into account the fact that in a zone of the maximum emission of aerosols (1.0–1.5 km from an emission source) the technogenic factor includes an effect of aerosol and gaseous pollution, for catching of animals the site of the area at a distance of 2.0 km from a source was chosen. This allowed to consider a group of heavy metals: Cu, Zn, Cd (HM) as the major affecting factor.

Level of the contents of exogenous and essential trace elements: Cu, Zn, Cd — in biological tissues of experimental animals was determined by the method of an atomic absorbtion spectrophotometry with a use of Perkin Elmer Analyst 1000 (USA) and AAS-3 (Germany) devices. The *hematopoietic-competent* organs (the liver, kidneys and spleen) were extracted from the animals, decapitated after an etherification. The raw weight of each analyzed organ was determined. The sample (1 g of raw weight), previously dried up at the room temperature, was placed in Kjeldal's flask, added 10 cm^3 of nitric acid (HNO_3) and in 10–20 minutes added 3 cm^3 of chloric acid ($HClO_4$). A flask was slowly heated until a completion of reaction, then, a temperature was increased up to 200 °C. Solution was evaporated up to the volume of 2–3 cm^3, cooled, added 10–15 cm^3 of a re-distillate. Then it was filtered via the large-porous glass filter, which was previously washed out by acid, in a measured flask on 10–25 cm^3 (Havezov, Tsalev, 1983; Frank, 1986; Subramanian K, 1986; Vasilyeva, Mikshevich, 1990). The received results were expressed in μg/g of raw mass of an organ.

Parameters of the basal metabolism of animals were determined on the basis of the assessment of oxygen consumption by means of a gas analyzer of MN-5130 (Russia). The sizes of respiration chambers allowed to make an experiment with an animal being in the condition of rest. Consumption of oxygen was expressed in milliliters on a gram of body mass of an animal within one hour (O_2 cm^3/g hour).

Statistical processing of experimental data is performed with a use of the Statistica v.6.0. and MS Exel license programs. Results are presented as an average ± a standard error (SE). For assessment of statistically significant differences between two groups in quantitative characters at normal distribution and equality of dispersions, Student's *t*-test is used. Cumulative ability of tissues of animals from the background and impact territories is estimated by the UPGMA method of the cluster analysis (Byukol, Tsefel, 2001). For all the kinds of the analysis differences at $p < 0.05$ are considered as statistically significant.

Results and discussion

It is known that the biological sense of adaptive reaction to a stress consists in mobilization of the mechanisms of emergency regulation of an organism for prevention of pathological consequences (Selye, 1960; Slonim, 1979; Meerson, 1973; Selye, 1974; Hochachka, Somero, 1977; Pathological…, 1980; Meerson, Pshennikova, 1988). At the same time, an increase in intensity of the basal metabolism is a necessary condition for maintaining activity of an organism under the changed environmental conditions that was accurately shown in our researches. In bank voles of the Talitsky District (the background territory of the Middle Urals) statistically significant differences on the basal metabolism between males (4.2 ± 0.6 cm^3/g hour) and females (3.4 ± 0.2 cm^3/g hour) are observed at $p < 0.05$. In the voles captured in a zone of technogenic loading (Revda District) the level of the basal metabolism significantly increases. In spite of this, in the voles in the conditions of technogenic pollution statistically significant differences on the basal metabolism are absent: pO_2 = 5.5 ± 0.1 cm^3/g hour ($T = 0.92 <_{Tst0,95} = 2.04$). The basal metabolism in males (4.5 ± 0.1 cm^3/g hour) and females (3.9 ± 0.6 cm^3/g hour) of bank voles in technogenic territories of the South Urals considerably increases to 5.9 ± 0.12 cm^3/g hour ($p < 0.05$). The process of elimination of excess amount of toxic metals belongs to energy-dependent ones, what shows an increase in the basal metabolism, and the forming new morphological-functional state provides to an animal the adaptive status in the conditions of permanent effect of the damaging environmental factors (Stepanova, 1990; Kovalchuk, Mikshevich, 1988; Bolshakov et al., 2005).

Researches show that insectivores are characterized by the most intensive energy metabolism among warm-blooded animals (Kalabukhov, 1946, 1954; Ivanter et al., 1985). The basal metabolism in the males of a common shrew is 2.7 times, of Laxmann's shrew — 3.1 times and of a Eurasian water shrew — 2.0 times higher, than in the males of a bank vole living in the floodplain of the Pyshma River, in National Park "Pripyshminskye Pine Forests"; (Kovalchuk, 2007). It is known, that an increase in intensity of the basal metabolism under the influence of technogenic pollutants confirms a high reactivity of functional systems of an organism in the conditions of a long action of extreme factors (Kovalchuk, Yastrebov, 2003).

However, in a common shrew from a zone of pollution in the South and Middle Urals a maintenance of a homeostasis is not followed by statistically significant increase in the basal metabolism (11.0 ± 0.26 cm^3/g hour at $_{T1-2} = 1,06 <_{Tst0,95} = 2,04$). Undoubtedly, the shrews have physiological and biochemical mechanisms allowing them to withstand technogenic loading, especially as the population number of these animals in impact zones of capturing was not considerably reduced in comparison with background territories (Kovalchuk, 1995). Population stability of shrews in technogenic territories, apparently, is reached owing to not so much intensification of energy processes how many due to metabolic reorganizations at the cell level (Kovalchuk, Mikshevich, 1992; Kovalchuk, 1995).

The data obtained by us earlier when studying the levels of content of copper, zinc, lead and cadmium in the "soil-plant-animal" system showed that the ratio between metals changes in a process of their advance on a food chain, and accumulation of metals in its separate links depends on a species of a plant, a species of an animal and their physiological status (Mikshevich, Kovalchuk, 1990).

So, assessment of the maximum daily doses of intake of cadmium, zinc, lead and copper with a food into an organism of the animals living in the Revda and Mednogorsk Districts has shown that they considerably (to 1–2 orders) exceed those indicators for animals from the background territory of National Park "Pripyshminskye Pine Porests" (table 1) (Abaturov, 1983; Moskalyov, 1985; Kovalchuk et al., 2002).

At the same time, it turned out that the differences in the contents of these metals in critical organs of animals, from the territories which are exposed to technogenic effects and from background territories appear to be significantly less, taking into account the estimates of daily intake of metals into an organism with vegetable food (Gmielnika et al., 1988; Mudry, 1997; Lind, Wicklund, 1998). It should be noted, however, that at the same time (as well as at the transition of metals from the "soil" level to the "plant" level) a many-fold surplus of essential elements — copper and zinc over toxicants — cadmium and lead remains. We consider this circumstance important as it allows to assume a participation of competitive processes in distribution of such toxicants like lead and cadmium along separate links of a chain "soil-plant-animal" and, finally, to explain the lower level of their contents in critical organs of animals. This circumstance brings us to existence of the microelement physiological system of a homeostasis which is a part of the general regulatory system of an organism (Avtsyn et al., 1991; Kudrin, Gromova, 2007; Kovalchuk, 2008; Agadzhanyan, Notova, 2009).

In a zone of the maximum impact of aerosol pollution from the copper-smelting enterprises the contents of HM in the liver and kidneys did not show the high values though they significantly exceeded background ones (soils, plants). Apparently, at assessment of the contents of copper, zinc and cadmium in critical organs of rodents, along with the homeostatic mechanism, it is necessary to consider also a kind-specificity of the plants eaten by animals. This allows to explain rather low contents of copper, zinc and cadmium in the liver and kidneys of bank voles in relation to the contents of these elements in the soil and plants on experimental plots of capturing in a zone of technogenic pollution, and also low contents of copper and zinc in critical organs of the voles from an impact zone in comparison with the voles from the background zone (table 2).

Levels of accumulation of copper, zinc, cadmium in the tissues of insectivores are significantly differed from those in the voles and wood mice what is connected with the differences caused by a character of feeding of these species. Content of essential zinc in tissues of all researched groups of small mammals in the background territories is rather high. Significant differences in accumulation of essential Zn and Cu by tissues of bank voles from technogenic and background territories are not noted ($p > 0.05$). In the contents of Cu in kidneys of the bank voles living in a zone of technogenic pollution and in the

Table 1. Daily doses of the maximum intake of heavy metals with forages in an organism of a bank vole

Zone	n	Daily dose, μg/sut Mean ± SE			
		Cd	Zn	Cu	Pb
1. Background (National park "Prepyshminskye Pine Forests")	51	< 0.01	6.0 ± 0.4	8.0 ± 0.9	< 0.01
2. Impact zone (an area adjacent to the Sredneuralsky copper smelting plant)	24	0.5 ± 0.15*	460.0 ± 2.8*	47.0 ± 2.1*	8.0 ± 0.9*
3. Impact zone on the South Ural (an area adjacent to the copper smelting plant)	24	1.3 ± 0.01*	265.0 ± 4.0*	54.0 ± 2.1*	3.2 ± 0.9*

* Statistically significant distinctions between zones 1–2; 1–3 at $p < 0.05$ (Student t-test).

background territory the significant differences also are not noted (1.6 ± 0.5 μg/g and 2.4 ± 0.1 μg/g, respectively, $p > 0.05$). Our researches have shown that contents of exogenous and essential trace elements in tissues of small mammals are the organ-specific (table 2). As it was already noted, a bank vole can feed on about 280 species of plants. As different species of plants have unequal ability to accumulation of copper, zinc and cadmium, it is possible to assume that this circumstance can provide a smaller extent of accumulation of heavy metals by the organs of a bank vole. The increased level of a content of copper in the liver and kidneys of shrews is noted in the background territory.

The organ-specificity of the spleen in accumulation of eco-toxicant Cd should be noted in all three studied species from the National Park "Pripyshminskye Pine Forests". The increased level of content of cadmium is noted in a spleen of all species, and its maximum — in a bank vole. Content of cadmium in a spleen of *C. glareolus* and *Ap. uralensis* (to 3.1 times and to 1.9 times — respectively) exceeds its content in the spleen *of S. araneus* (table 2). Earlier in an experiment we showed rather quick distribution of cadmium in a hemopoiesis — competent organs and its slow removal from an organism through kidneys (Kovalchuk, 2008). The level of cadmium accumulation in kidneys of the studied three animal species is comparable both on background (0.39–0.38–0.39 μg/g), and on technogenic territories (0.8–0.8–0.9 μg/g) ($p > 0.05$) (table 2). Without raising the questions on specificity of metabolism in different species, we will note that the levels of accumulation of cadmium in a liver and kidneys of bank voles (0.05 μg/g and 0.39 μg/g) determined by us are close to these by D. L. Boureier, R. P. Sharma and C. R. Brincehoff (1981).

It is known, that cadmium and its compounds are capable to affect many organs and provoke pathological processes in physiological systems, causing anemia, hypertensia, disturbances of functions of the liver and damage of bone tissue (Campbell, 1999; Mazzei et al., 2014). There are publications indicating that accumulation of cadmium in kidneys tissue, the pancreas and spleen practically does not depend on structure of a diet whereas its accumulation in the liver, on the contrary, is a subject to considerable changes depending

Table 2. Concentration of heavy metals in organs (liver, kidney, spleen) of small mammals from the background (1) and impact (2) territories of the Urals

Species	Parameters	Areas	n	Concentration of heavy metals, μg/g Mean ± SE		
				Cu	Zn	Cd
Apodemus uralensis	liver	1	96	2.9 ± 0.2	25.5 ± 0.4	0.10 ± 0.01*
		2	62	3.2 ± 1.0	33.8±10.6	0.70 ± 0.09
	kidney	1	96	3.4 ± 0.7	13.1 ± 1.1	0.38 ± 0.01*
		2	62	2.2 ± 0.7	10.6 ± 3.3	0.80 ± 0.06
	spleen	1	96	4.9 ± 0.1	24.2±2.6*	0.95 ± 0.09*
		2	62	5.1 ± 1.6	8.40 ± 2.6	1.30 ± 0.01
Clethrionomysglareolus	liver	1	109	5.3 ± 0.1	20.2 ± 1.1	0.05 ± 0.01*
		2	78	3.5 ± 1.1	20.8 ± 6.5	0.50 ± 0.06
	kidney	1	109	2.4 ± 0.1	18.3 ± 0.2	0.39 ± 0.01*
		2	78	1.6 ± 0.01	23.5 ± 7.4	0.80 ± 0.03
	spleen	1	109	3.3 ±0.02	21.7 ± 1.9	1.57 ± 0.1*
		2	78	4.5 ± 1.4	24.5 ± 0.1	2.9 ± 0.09
Sorex araneus	liver	1	108	13.1 ±0.8	28.2 ± 2.4*	0.20 ± 0.02*
		2	54	24.2 ±7.6	69.4 ± 21.8	0.60 ± 0.04
	kidney	1	108	7.7 ± 0.9	13.7 ± 2.2*	0.39 ± 0.05*
		2	54	11.3 ±3.5	37.8 ± 11.8	0.90 ± 0.15
	spleen	1	108	5.6 ± 0.1*	14.7 ± 2.1*	0.50 ± 0.02*
		2	54	34.2 ± 10.7	48.6 ± 15.2	0.70 ± 0.02

* Statistically significant differences between values of heavy metals in background zone (1) and impact zone (2) are shown at $p < 0.05$. Values were analysed using Student's test. n = number of animals.

on a quality of food (Skalnaya, Notova, 2004). The highest content of cadmium is noted in the liver of common shrews *S. araneus* (0.2 ± 0.02 μg/g) that, apparently, reflects also the features of their food (Frank, 1986; Scanlon, 1987; Lukyanova et al., 1990; Hunter et al., 1997; Prokopyev, 2008).

It should be noted a statistically significant increase in the content of essential zinc and copper in a hematopoietic-competent organs of shrews, in a comparison with voles and wood mice ($p < 0.05$) in the territories with technogenic pollution. In bank voles the content of copper in the liver is 6.9 times less, than in shrews. The ability of the spleen of a bank vole to accumulation of copper is much lower, than in a common shrew by 7.6 times (table 2). An accumulation of essential Zn in common shrews from technogenic populations is 2.8 times higher in a comparison with animals from background territories. So, in the liver of common shrews the content of zinc increased to 2.5 times, in kidneys — to 2.8 times, in a spleen — to 3.3 times (table 2).

The content of copper in tissues of the studied organs of shrews in territories of technogenic pollution is 2.6 times higher, than in animals from the background population ($p < 0.05$). Total content of copper in the studied tissues of shrews — 69.7 μg/g, that is 7.3 times more, than in organs of bank voles (9.6 μg/g) and 6.6 times more, than in wood mice (10.5 μg/g) (fig. 1) In the tissues of common shrews (the liver, kidneys and spleen) the total content of zinc — 155.8 μg/g that is to 2.3 times more, than in voles and to 2.9 times more, than in wood mice (fig. 1). It is possible to consider that in shrews from an impact zone a total accumulation of cadmium is slowed down by the increased content of zinc (the physiological antagonist of cadmium) (Barbier et al., 2005; Jacquillet et al., 2006; Jihen et al., 2008; Messaoud et al, 2009; Sabolić et al., 2010). Numerous researches allow to conclude that this system of elimination is one of the functions of a mobile pool of zinc in an organism (Boureier et al., 1981; Prasad, 2008; Beattie, Dremner, 1998; Godwin, 2000; Liuzzi, Cousins, 2004; Levenson, 2005; Wlostowski, Slobozhanina, 2008).

The smallest total content of heavy metals is shown in wood mice in technogenic territories of the Middle Urals (fig. 1). In all species investigated in impact zones the

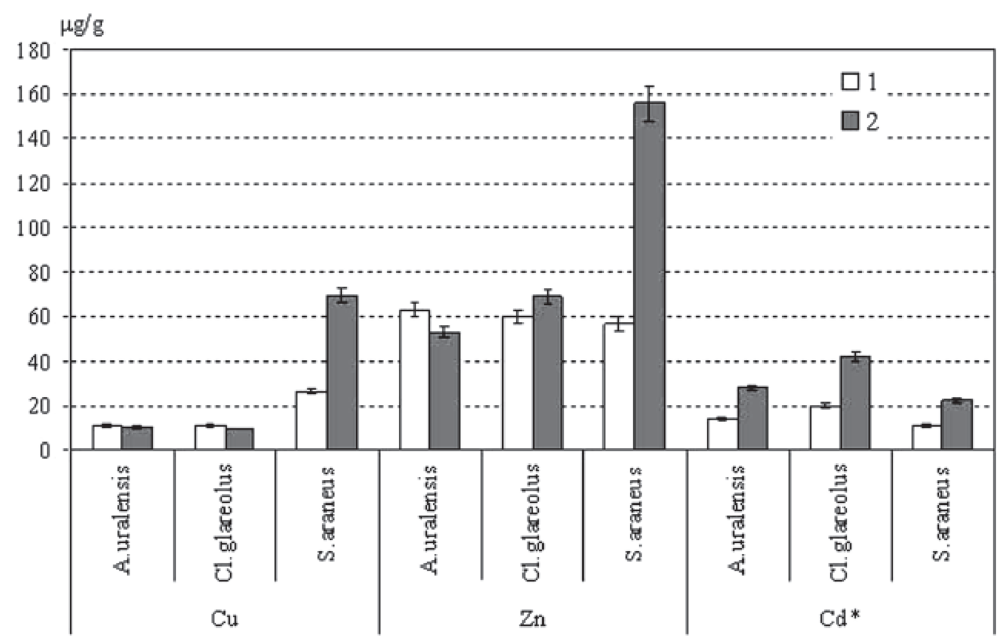

Fig. 1. Concentration of heavy metals in the tissues (liver+kidney+spleen) of small mammals: 1 — background zone; 2 — impact zone.

*Concentration of cadmium (Cd) is increased 10-fold.

increased content of cadmium in the tissues is noted. But, the total content of cadmium in hematopoietic-competent organs of shrews is much less, than in the compared species ($p < 0.05$). Statistically significant specific differences are noted in the content of Cd in tissues of all studied animals ($p < 0.05$). Total accumulation of cadmium in the tissues of a bank vole is higher, than in forest mice to 55 % and in common shrews — to 90 % (fig. 1). Also, a kind specificity to cadmium accumulation by a spleen is noted. It is known, that the cadmium entering an organism accumulates in organs and tissues, causing morphological changes of cells what leads them to a death (Gubina, 2007; Baurand et al., 2014). In the technogenic polluted territories the content of cadmium increases in the liver of a bank vole to 10 times, of a wood mouse — to 7 times and of a common shrew — to 3 times (table 2).

The smallest total content of heavy metals is shown in wood mice in technogenic territories of the Middle Urals. In the territories with technogenic pollution the contents of HM increase in tissues of a common shrew to 227.7 ± 70.8 μg/g that is 2.7 times higher in comparison with common shrews in background territories. On the total content of heavy metals in the tissues of a bank vole in background and technogenic territories significant differences are not noted (81.2 ± 3.5 μg/g and 82.6 ± 17.2 μg/g, respectively, $p > 0.05$).

Checking statistical hypotheses on specific susceptibility of total accumulation of heavy metals by the tissues of the studied animals was performed with a use of the cluster analysis. Results of the cluster analysis by UPGMA method testify bio-accumulative opportunities of hematopoietic-competent organs: a liver, a kidney and a spleen in three species of mammals from background and technogenic territories of the Urals (fig. 2). The structure of the received cluster confirms that on accumulation of heavy metals all the samples of three species of mammals are divided into three independent clusters, two of which are more similar and unite in the general one: these are the samples of *C. glareolus* and *Ap. uralensis*. he sample of *S. araneus* is isolated for 100 % that is fair for the total content of all studied heavy metals in the tissues (a liver, kidneys, a spleen) of animals from populations in the background and technogenic territories. A dendrogram reflects an existence both similarities in accumulations of heavy non-ferrous metals, and kind-specific differences in the nature of

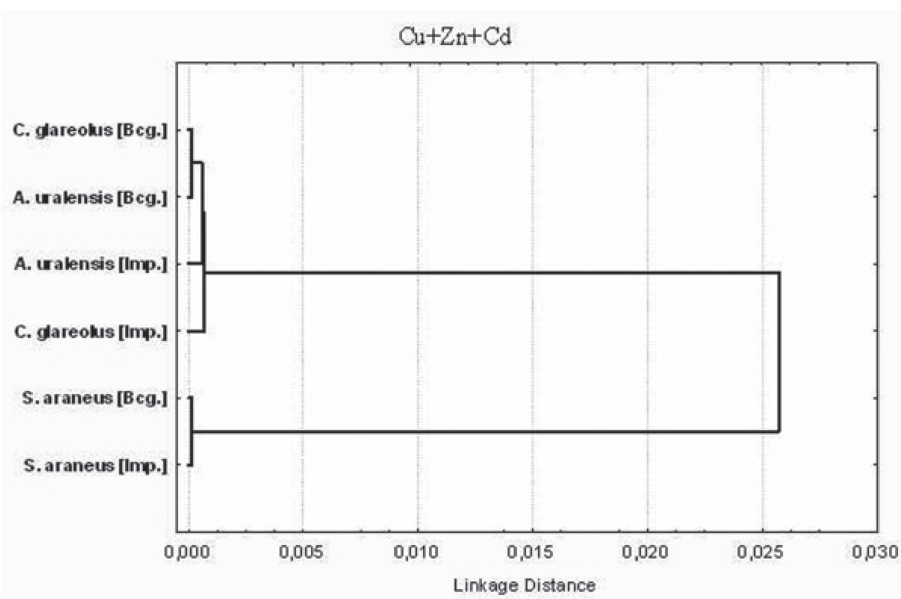

Fig. 2. The dendrogram is obtained for element analysis (Cu+Zn+Cd) in small mammals from natural populations in the background zone (Bcg) and polluted territories (Imp).

The results of cluster analysis confirmed the statistically significant differences in heavy metals total accumulation in three species of small mammals.

accumulation by tissues of ecologically contrast animal species from natural populations. It is established, that accumulative opportunities depend on a species of an animal and its physiological status that, apparently, is caused also by a structure of their food.

Conclusion

Researches showed statistically significant differences on bio-accumulation of exogenous and essential trace elements in the hematopoietic-competent organs (the liver, kidneys and spleen) in the small mammals living in the territories subjected to the impact of emissions of copper smelter. It is shown that accumulation of copper, zinc, cadmium in the tissues of insectivores (*Sorex araneus)* significantly differs from it of bank voles (*Clethrionomys glareolus)* and wood mice (*Apodemus uralensis)* that, at least, is connected with ecological and physiological distinctions of these species caused by the structure of a food. In the liver, kidneys and spleen of common shrews from "technogenic populations", in comparison with common shrews in background territories, the content of Cd is 2.0 times higher. At the same time, the content of cadmium in hematopoietic-competent organs of shrews both from natural, and technogenic territories is much less, than in a bank vole and European wood mouse ($p < 0.05$). The submitted data demonstrate the competitive mechanism of the Cu, Zn, Cd in the tissue *Sorex araneus.* That is why the increased concentrations of endogenous trace elements (copper, zinc) in relation to a toxicant (cadmium), with other things being equal, reduce cadmium accumulation level. Essential intracellular trace elements not only perform a structural function (being the cofactors of enzymes), but play also a regulatory role in metabolic processes that is difficult to overestimate in the light of the above-submitted results of our study.

This circumstance is important also because in operating conditions of the enterprises of non-ferrous metallurgy there is always an emission in the environment of a complex of pollutants, in various ratios, among which there are both essential and toxic elements. In this case, the competitive mechanism reduces a load of toxicants upon critical organs of animals. In the same time, the high level of homeostatic regulation limits an accumulation of exogenous elements in organs and tissues of animals.

This circumstance needs to be meant at ecological rationing and use of the data of toxicological researches of separate elements. Use of the wild rodents living in anthropogenically modified territories at a research of the remote consequences of influence of technogenic pollution at assessment of ecological damage of the territory promotes both extrapolation of the received results to the sphere of forecasting of genetic danger of this factor to local human population, and a search of the ways of correction of eco-physiological mechanisms of formation of adaptive strategy and population homeostasis.

Conflict of interest

All authors declare that they have no conflicts of interest regarding the content of this study.

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