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Chemical Elements in the System of Trophic Levels of Terraneous Ecosystems

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Abstract

Concentrations of vitally important (S, K, Ca, Fe) and highly toxic elements (Pb, Cd), heavy metals possessing moderate toxicity (Zn, Cu, Co, Mo, Ni, Cr, Mn), and low-toxic elements (Ti, Ba, Sr, Zr) in the model animal species belonging to different trophic levels of terraneous biocenoses were investigated. Background areas and the regions chemically polluted with metals were considered. We studied invertebrate phytophages (larvae of sawfly *Arge* sp.) and carnivores (terraneous beetles *Pterostichus oblongopunctatus* L.), as well as two small mammal species belonging to different taxonomic and trophic groups: phytophagous bank vole (*Clethrionomys glareolus* Shreber) and insectivorous common shrew (*Sorex caecutiens* Laxmann). It was demonstrated that the distribution of the concentrations of chemical elements in living organisms is determined by their position in the trophic structure of natural biocenoses; thus the groups of primary producers, phytophages and carnivorous species are distinguished. Under environmental pollution, the character of distribution of the concentrations of chemical elements is determined by the specificity of mineral metabolism in animals as well as by their belonging to different taxonomic groups.

Key words: environmental heterogeneity, biogeochemical food chains, trophic levels, invertebrates, mammals, phytophages, carnivores

INTRODUCTION

According to modern concepts, spatial chemical heterogeneity of biosphere is reflected in the variability of biogeochemical food chains [1–3]. Data concerning the concentration of chemical elements in the populations of the living organisms of different trophic belonging should be considered not only as the parameters of local flows of chemical elements, but also as a powerful factor of environmental homeostasis [4]. Being labile, the system of trophic connections between naturally occurring ecosystems exhibits a reaction both with respect to the variability of elemental chemical composition of inert and bioinert bases of biocenosis, and with respect to the variability of the abundance and species composition of living organisms. In this case, a complex multilevel geochemical picture of complete biogeocenosis is observed. It is determined by different biological availability of chemical elements, their chemical species in soils, the specificity of zonal flora types, the selectivity of the processes of their absorption and deposition by the organisms belonging to different trophic groups, as well as by a possible deformation in the course of man-caused activity [5–7].

Under these conditions, V. V. Kowalski's thesis [3] concerning biogeochemical food connections possesses a special value and can be considered as a priority approach to monitoring the condition of the natural environment, which is determined by the ability of conserved bio-

ta's components for performing biocenotic functions and, first of all, for support a necessary level of biogenic exchange. More often, a similar biogeochemical monitoring is limited by determining the concentration of chemical elements, including toxic ones, in soil and plants. Meanwhile, stable functioning of natural systems is determined by a complete trophic structure of the biocenosis, since its highest levels acting as the factor of the intensification and stabilization of biogenic cycles, are often suffer from a maximal toxic impact. A small number of organisms on these levels, their mobility and limited biomass available for analysis complicate to a considerable extent the procedure of such monitoring, demanding the application of modern high-sensitivity analytical methods.

The present communication is devoted to considering the data concerning the concentration of chemical elements in model species of living organisms of various trophic levels inherent in terraneous biocenoses, both under background conditions, and under chemical pollution of the environment.

RESEARCH OBJECTS AND METHODS

The work is based on data obtained within 2004–2008 in studying the chemical composition of model widespread animal species those represent different trophic levels of terraneous biogeocenoses within the zone of aerogenic impact resulting from a large-scale copper-smelting industrial complex (Central Ural, the southern taiga zone). The copper-smelting industrial complex is functioning since 1940, and the damage zones around of it are distinctly pronounced. As a criterion for choosing the trial areas within the range of each zone we used the levels of soil chemical pollution, corresponding to background conditions and maximum pollution levels (buffer and impact zones, respectively). Earlier we presented a detailed description of the research range [8, 9].

Data concerning the concentration of some elements are considered, which elements could be united into four groups: 1) vital elements (S, K, Ca, Fe); 2) highly toxic heavy metals (Pb, Cd); 3) heavy metals with a moderate toxicity (Zn, Cu, Co, Mo, Ni, Cr, Mn); 4) low-toxic elements (Ti, Ba, Sr, Zr, *etc.*). In total, the content of 29 chemical elements was investigated in biological objects.

The content of chemical elements in different environmental objects varies to a considerable extent, therefore this value is usually described by probability density functions $p(x_i)$ for the logarithmically normal distribution of a random variable x_i. This fact allows one to operate with geometrical mean concentration rather than arithmetic mean value. The standard root-mean-square deviation (σ_{gi}) is determined in this case for ln (x_i) value. In this case, the elements whose content in a sample under analysis cannot be determined with the help of the method used with the accuracy required are excluded. Analysts ascribe them zero concentration values, which excludes the calculation of logarithms.

As model species of living organisms we have chosen invertebrate phytophages (sawfly larvae *Arge* sp.) and carnivorous (carabus *Pterostichus oblongopunctatus* L.), as well as two small mammal species belonging to different taxonomic or trophic groups: phytophagous European bank vole (*Clethrionomys glareolus* Shreber) and insectivorous common shrew (*Sorex caecutiens* Laxmann). The choice of research objects was determined by position of these species in the structure of invertebrate and mammal communities, their occurrence in all the zones of pollution, which provides gathering a necessary amount of material for chemical analysis.

The elemental composition of the initial producers was considered by the example of leaves of the dogrose (*Rosa canina* L.), the fodder basis for the model invertebrate phytophage species (*Arge* sp. larvae).

Sawfly larvae were gathered manually, carabus were gathered into soil traps without a fixing agent with the subsequent killing by ethyl acetate vapour. Catching mammals was carried out simultaneously on all the sites during the snowless period using different gears in the linear variant. For each area under investigation we selected took from two to six samples of insects and from three to five samples of mammals (carcasses without a gastrointestinal tract). As many as 85 samples including 15 samples of plants, 30 of insects, and 40 samples of mammals were analysed.

TABLE 1

Content of chemical elements in initial producers (dogrose leaves) and phytophagous animals, μg/g of dry mass

Elements	Content (according to Ivanov, 1994)	Initial producers and phytophages								
		Dogrose leaves ($n_i = 5$)			Saw-fly larvae ($n_i = 5$)		Bank vole			
		Background	Buffer	Impact	Background	Impact	Background		Impact	
		$<x_i>$ (σ_{gi})	$<x_i>$ (σ_{gi})	$<x_i>$ (σ_{gi})	$<x_i>$ (σ_{gi})	$<x_i>$ (σ_{gi})	$<x_i>$ (σ_{gi})	n_i	$<x_i>$ (σ_{gi})	n_i
Content in the clarke more than 1000 μg/g										
Fe	53 300	148.29 (1.17)	85 (1.1)	219 (1.2)	116 (1.2)	185 (1.1)	362 (1.3)	5	298.0 (1.1)	5
Ca	38 100	19 433.8(1.04)	19 433.85(1.0)	19 556 (1.1)	1814 (1.2)	867.1 (1.1)	24 886 (1.2)	5	32 246 (1.2)	5
K	21 300	15 104.6(1.25)	14 574.2 (1)	13 187 (1.2)	16 562.2(1.1)	17 377 (1.1)	9698 (1.1)	5	9928 (1.1)	5
Ti	5300	13.14(1.17)	8.1 (2)	12.0 (1.2)	4.6 (1.4)	4.7 (1.4)	3.5 (1.5)	5	2.4 (1.5)	5
Content in the clarke from 100 to 1000 μg/g										
Mn	900	344.86(1.5)	422 (1.3)	286.0 (1.9)	42.0 (1.2)	16 (1.2)	8.1 (1.3)	10	8.0 (1.4)	10
Ba	470	60.9 (1.2)	43 (1.5)	61.1 (1.3)	–	–	29.0 (1.2)	9	32.0 (1.2)	9
Sr	370	103.34(1.1)	108 (1.1)	122.0(1.2)	12.0 (1.3)	1.1 (1.2)	35.0 (1.2)	8	40.0 (1.2)	8
S	330	–	–	–	3763 (1.2)	5112 (1.1)	23 181 (2.1)	10	23 420 (1.2)	10
Cl	180	–	–	–	361 (1.1)	644 (1.2)	3391 (1.9)	10	2825 (1.1)	10
Zr	160	0.77 (1.97)	0.22 (1.2)	1.80 (1.5)	1.4 (1.7)	1.1 (2.0)	0.8 (1.8)	10	1.8 (1.6)	10
Rb	110	5.14 (1.16)	3.4 (1.2)	10.0 (1.3)	7.0 (1.7)	15.0 (1.5)	18.0 (1.2)	10	21.0 (1.1)	10
Content in the clarke from 10 to 100 μg/g										
Cr	92	0.99 (1.6)	2.3 (1.6)	2.0 (1.3)	0.83 (2.7)	2.5 (1.8)	0.8 (1.4)	10	1.5 (1.3)	5
Ni	70	11.38 (1.3)	2.3 (1.2)	15.0 (1.5)	1.2 (1.2)	1.1 (1.1)	1.8 (1.4)	10	2.4 (1.1)	5
Zn	68	25.5 (1.8)	33.0 (1.3)	46.0 (1.2)	72.0 (1.1)	156.1 (1.1)	94.0 (1.1)	10	95.0 (1.1)	5
Cu	53	5.71 (1.8)	4.7 (1.1)	11.0 (1.3)	6.8 (1.1)	13.0 (1.1)	6.0 (1.1)	10	7.0 (1.1)	5
Y	32	–	–	–	0.42 (1.1)	0.9 (1.3)	–	–		
Co	23	–	–	–	–	–	0.09 (1.2)	10	0.08 (1.4)	5
Nb	21	–	–	–	–	–	–	10	–	5
Pb	13	4.24 (1.33)	2.3 (1.2)	37.0 (1.3)	1.6 (1.4)	13.4 (1.2)	1.7 (1.5)	10	8.0 (1.4)	5
V	12	0.57 (1.3)	0.43 (14.5)	0.41 (1.4)	–	–	0.09 (1.4)	10	0.07 (2.4)	5
Content in the clarke from 1.0 to 10 μg/g										
Cs	4.3	–	–	–	–	–	–	9	–	10
Br	2.4	1.74 (1.6)	1.4 (1.5)	1.2 (2.1)	4.3 (1.8)	4.2 (1.1)	18.0 (1.3)	10	16.0 (1.2)	10
Sn	2.3	0.30 (1.5)	0.3 (1.5)	1.3 (1.2)	0.22 (1.2)	0.37 (1.2)	0.21 (2.0)	9	0.73 (1.6)	9
As	1.8	–	–	–	–	–	1.4 (2.2)	7	0.49 (1.8)	7
Mo	1.2	–	–	–	0.27 (1.2)	0.15 (1.1)	–	5	–	7
Content in the clarke less than 1.0 μg/g										
I	0.47	0.57 (1.6)	0.24 (1.4)	0.47 (1.2)	–	–	0.18 (1.6)	9	0.91 (3.1)	4
Cd	0.17	0.53 (1.2)	0.41 (1.3)	2.6 (1.3)	1.5 (1.2)	11.8 (1.1)	0.46 (1.4)	9	2.2 (1.4)	4

Notes. Here and in Table 2: $<x_i>$ is the geometrical mean value of the content of an element; σ_{gi} is the standard deviation of $<x_i>$; n_i is the number of the registered values of the content on which averaging is lead (carried out); a dash means, that the element was not revealed

TABLE 2

Content of chemical elements in the organisms of secondary consumers, μg/g of dry mass

Elements	Content (according to Ivanov, 1994)	Secondary consumers					
		Carabus			Common shrew		
		Background (n_i = 11)	Buffer (n_i = 6)	Impact (n_i = 11)	Background (n_i = 6)	Buffer (n_i = 6)	Impact (n_i = 4)
		$<x_i>$ (σ_{gi})	$<x_i>$ (σ_{gi})	$<x_i>$ (σ_{gi})	$<x_i>$ (σ_{gi})	$<x_i>$ (σ_{gi})	$<x_i>$ (σ_{gi})
		Content in the clarke more than 1000 μg/g					
Fe	53 300	96.1 (1.6)	186.1 (1.8)	194.0 (2.0)	115.3 (1.42)	120.0 (1.02)	128.0 (1.1)
Ca	38 100	854.1 (1.6)	1062.0 (1.1)	754.0 (1.5)	16 957.5 (1.3)	15 067.1 (1.1)	18 236 (1.3)
K	21 300	6984 (1.1)	8043 (1.1)	7042.1 (1.2)	6068.84 (1.2)	7661.0 (1.06)	5955 (21.2)
Ti	5300	4.2 (1.8)	4.6 (1.7)	4.9 (1.5)	1.51 (2.3)	1.4 (1.1)	1.9 (1.7)
		Content in the clarke from 100 to 1000 μg/g					
Mn	900	64.0 (1.3)	110.0 (1.4)	64.0 (1.7)	8.35 (1.6)	12.0 (1.0)	10.1 (1.4)
Ba	470	5.9 (2.7)	–	2.4 (1.1)	3.92 (2.8)	5.6 (1.0)	8.0 (1.4)
Sr	370	3.9 (1.2)	4.9 (1.5)	4.1 (1.3)	28.9 (1.3)	20.0 (1.1)	25.0 (1.4)
S	330	6354 (1.2)	–	7122 (1.4)	39 939.3 (1.4)	33 581.3 (1.1)	33 399 (1.1)
Cl	180	1315.0 (1.4)	–	1279.0 (1.5)	3074.2 (1.2)	3503.0 (1.1)	2625.0 (1.2)
Zr	160	0.59 (4.4)	0.80 (1.8)	0.23 (2.0)	0.1 (1.8)	0.06 (1.1)	0.07 (2.2)
Rb	110	2.2 (1.6)	1.5 (1.1)	2.1 (1.5)	9.8 (1.3)	5.5 (1.1)	5.7 (1.2)
		Content in the clarke from 10 to 100 μg/g					
Cr	92	0.11 (3.4)	1.5 (1.2)	2.6 (3.0)	0.64 (1.3)	1.2 (1.9)	1.4 (1.6)
Ni	70	1.5 (1.4)	2.8 (1.6)	1.2 (1.4)	0.87 (1.4)	0.62 (1.0)	0.73 (1.3)
Zn	68	146.0 (1.1)	209.0 (1.1)	183.0 (1.3)	262.4 (1.4)	191.0 (1.5)	126.0 (1.2)
Cu	53	16.0 (1.7)	24.0 (1.2)	26.0 (1.6)	6.21 (1.1)	7.9 (1.2)	9.0 (1.1)
Y	32	0.1 (1.6)	–	0.17 (1.3)	0.45 (1.2)	0.35 (1.1)	0.25 (2.6)
Co	23	0.02 (1.4)	–	0.05 (1.8)	0.05 (1.3)	0.05 (1.0)	0.05 (1.1)
Nb	21	0.64 (1.8)	0.87 (1.8)	0.48 (1.6)			
Pb	13	1.4 (1.6)	4.7 (1.7)	8.8 (2.1)	5.41 (1.3)	76.0 (1.9)	66.0 (1.9)
V	12	0.95 (8.3)	–	0.22 (1.9)	0.19 (1.8)	0.08 (4.6)	0.21 (1.4)
		Content in the clarke from 1.0 to 10 μg/g					
Cs	4.3	0.06 (1.89)	–	0.09 (1.1)	0.06 (1.1)	0.087 (1.1)	0.08 (1.2)
Br	2.4	17.0 (3.6)	5.0 (1.1)	14.0 (63.4)	11.4 (1.2)	17.0 (1.3)	12.0 (1.2)
Sn	2.3	0.17 (2.3)	–	0.19 (1.6)	0.65 (2.8)	0.170 (1.4)	1.1 (1.3)
As	1.8	–	–	1.1 (4.0)	–	–	–
Mo	1.2	0.46 (1.5)	0.28 (1.2)	0.48 (1.6)	0.24 (1.1)	0.3 (1.3)	0.31 (1.2)
		Content in the clarke less than 1.0 μg/g					
I	0.47	0.33 (1.6)	–	0.62 (2.0)	0.33 (1.7)	0.9 (1.0)	0.49 (1.2)
Cd	0.17	3.7 (3.2)	12.0 (1.4)	6.6 (2.3)	0.31 (1.3)	0.61 (1.4)	0.63 (1.4)
Ag	0.07	0.11 (1.3)	–	0.11 (1.3)	0.07 (1.1)	0.08 (1.2)	0.08 (1.1)

Note. For notations see Table 1.

Samples were dried using a drying oven at the temperature of 70 °C to obtain air dry mass. The further sample preparation process is described in detail in [10]. The samples of plants and animal tissues were analyzed in the form of tablets 1 cm in diameter with the mass of 30 mg. The elemental composition of biological substrates was investigated by means of the method of X-ray fluorescence analysis with the use of synchrotron radiation (SR XFA) at the elemental analysis station VEPP-3 of the Budker Institute of Nuclear Physics, SB RAS (Novosibirsk) [11]. The spectra of samples were registered at the excitation energy of 21 keV. The quantitative elemental composition was determined using the external standard method (as the reference sample, we used the Russian standard of cereal grass mixture SORM 1 GSO 8242–2003 as the closest to the samples under investigation).

Software packages Microsoft Excel and Statistica 6.0 were used.

Not all the elements under investigation are presented in the samples; therefore the cluster analysis of the samples from the background territory involves only 15 elements contained in biological samples for all the groups of organisms (Fe, Ca, K, Ti, Mn, Sr, Zr, Rb, Cr, Ni, Zn, Cu, Pb, Br, Cd). For the subsequent analysis, we considered as priority pollutants the chemical elements whose content over polluted territories exceed their background values. As far as these elements (Cr, Zn, Cu, Pb, Br, Cd, Rb) are concerned, we performed a comparative cluster analysis of trophic structure for background and polluted conditions.

RESULTS AND DISCUSSION

Accumulation of elements in living organisms within the background area

Table 1, 2 demonstrate data the concentration of chemical elements under investigation in naturally occurring objects of different trophic levels under background conditions and under chemical pollution of the environment, as well as the clarke concentrations of elements in soil according to V. V. Ivanov [12].

The specificity of active interaction between living organisms with the geochemical environment is demonstrated by their ability of accumulating chemical elements to a greater or lesser extent as compared to inert and bioinert biogeocenosis components. Irrespective of a trophic belonging of model species under investigation, the concentration function expressed in greater values as compared to clarkes, is noticed for

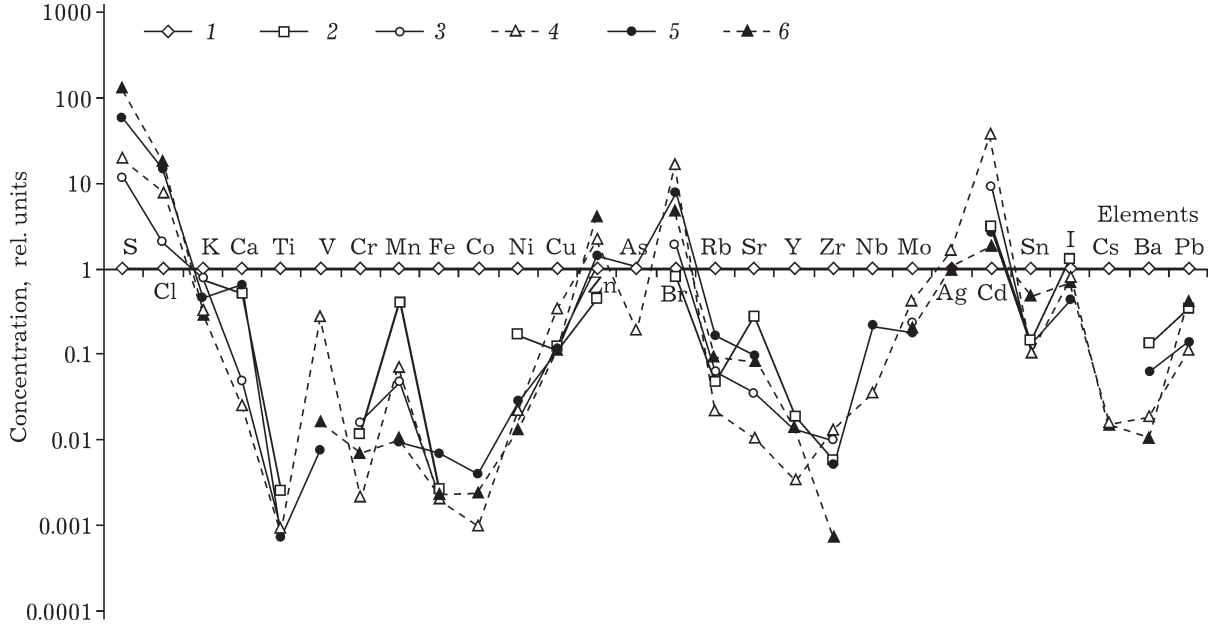

Fig. 1. Concentration relationship for chemical elements in the organisms with different trophic belonging with respect to clarke data: *1* – clarke, *2* – dogrose (leaves), *3* – sawfly (larvae), *4* – carabus (imago), *5* – bank vole, *6* – common shrew.

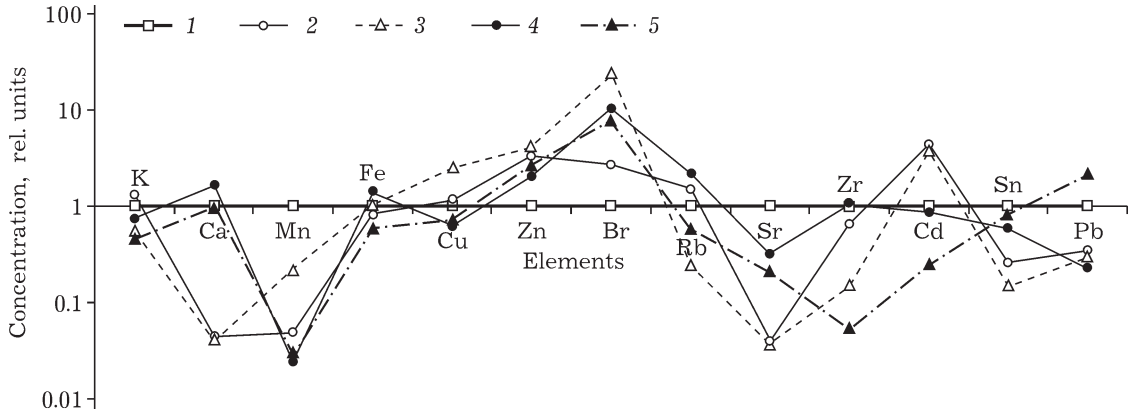

Fig. 2. Concentration of chemical elements in the organisms with different trophic belonging and in plant samples: *1* – dogrose (leaves), *2* – sawfly (larvae), *3* – carabus (imago), *4* – bank vole, *5* – common shrew.

S, K, Br and typical metals such as Zn and Cd. With respect to other elements, living organisms represent as geochemical barriers; therefore the content of the majority of chemical elements in living organisms is lower than their clarke values (Fig. 1).

A comparative analysis of data concerning the content chemical elements and their clarke level does not reflect to a complete extent the geochemical specificity of the community of the living organisms dwelling within particular territories under investigation. As the basis of biogenic exchange, we considered plants those being initial producers, directly cooperate with inert and bioinert biocenosis components, consequently, reflect the biogeochemical specificity of the particular background, and polluted areas.

Most of invertebrate and vertebrate predators represent polyphages, therefore with a complicated system of trophic relations occurring within natural systems one could not select unequivocal trophic chains. In this connection, we have to consider separate trophic levels presented by modelling species of producers, phytophages and carnivorous animals.

The role of trophic levels under investigation in the concentration or discrimination of chemical elements could be established by a comparative analysis of their concentration in various organisms and in initial producers. As compared to plants, concentrating such elements as Fe, Cu, Zn, Br, Rb, Zr, Cd is mentioned. Other elements (Ca, Mn, Sr, Pb) are discriminated and accumulated in phytophage and carnivorous animals in lower amounts (Fig. 2).

Accumulation of elements in living organisms within polluted areas

The participation of living organisms in biogenic cycles can be characterized by a set of chemical elements' concentration. In order to estimate the originality of bioaccumulation by the organisms of various trophic groups in the background territory we performed the cluster analysis of concentration for 15 chemical elements under investigation. As the result of the analysis of a sampling from non-polluted territory, invertebrate and vertebrate phytophages (sawfly larvae and bank volea) were joined together into one cluster. Carabuses and common shrews are selected into separate clusters, basing on the concentration of elements in an organism (Fig. 3).

From the data obtained from the analysis of the spectrum of chemical elements considered above it follows, that in our case the for-

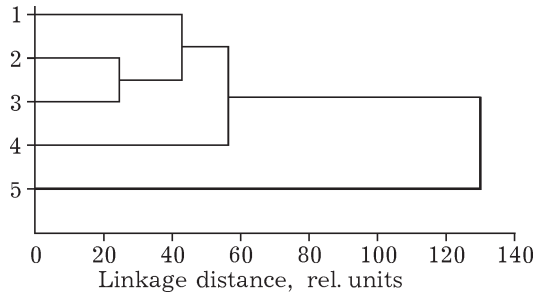

Fig. 3. Cluster analysis for the concentration of 15 chemical elements in animal organisms with different trophic belonging: *1* – dogrose (leaves), *2* – sawfly (larvae), *3* – carabus (imago), *4* – bank vole, *5* – common shrew.

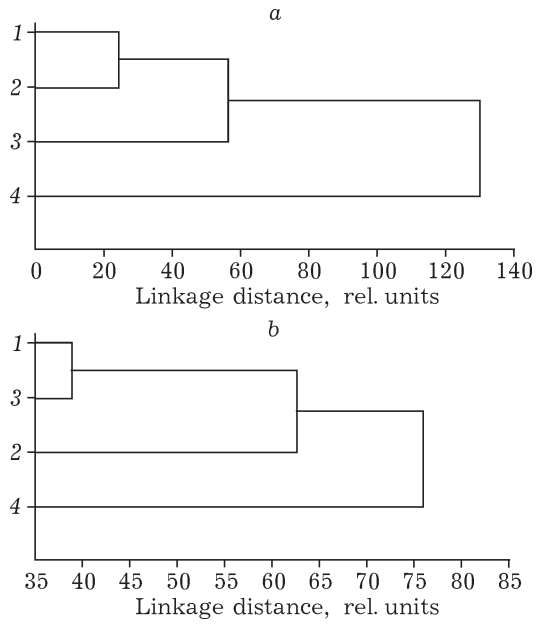

Fig. 4. Cluster analysis for the concentration of chemical elements – environmental pollutants (Cr, Cu, Zn, Rb, Zr, Cd, Pb) for background (*a*) and polluted territories (*b*): *1* – sawfly (larvae), *2* – bank vole, *3* – carabus (imago), *4* – common shrew.

mation of biogenic cycles by living organisms is determined exclusively by their belonging to different trophic groups.

Under environmental pollution caused by the aerogenic emission of metallurgical enterprises, the geochemical specificity of impact areas is expressed by an increased concentration of several elements only. Hence, the contribution of separate trophic levels to the overall biogeochemical exchange of these elements in the biocenosis should be different. In order to estimate similar changes, we performed the cluster analysis of concentrations on the background and polluted areas only for those chemical elements those could be considered in our case as priority pollutants of the environment (Cr, Cu, Zn, Rb, Zr, Cd, Pb).

Under the conditions when the concentration of these elements does not exceed background values, one could select a cluster joining together plants and phytophages irrespective of their systematic belonging (saw-fly larvae, bank vole). Independent clusters are formed by carabuses and shrews (Fig. 4, *a*), which corresponds to the aforementioned general law (see Fig. 3). Another picture takes place for the conditions of intense pollution: in this case the clusters invertebrates and mammals are selected irrespective of their trophic belonging (see Fig. 4, *b*). In this case a taxonomic belonging of animals matters from the standpoint of concentrating chemical elements.

The mentioned change of the cluster structure reflects a number of differently directed processes in the community of living organisms. The matter concerns a direct toxic action of metals whereby the most sensitive groups of organisms could disappear from the dietary intake. On the other hand, an increase in the concentration of chemical elements in the organisms of some species is quite possible. A similar change of the species and elemental composition of dietary intake under the conditions of environmental pollution was mentioned by a number of authors. Within the emission zones of the Middle-Ural Copper-Smelting Plant, there is a cardinal change in the structure of meadow vegetation observed [13, 14]. Under the same conditions, the abundance and species composition of invertebrate chortobionts exhibits a change [15]. The authors of [16–18, *etc.*] presented similar data concerning the change in the gradient of chemical pollution in the invertebrates' composition. There are data concerning the change in the species composition of dietary intake within chemical pollution gradient for hollow-nesting birds [18] and small mammals [8].

To all appearance, the exchange processes including the supply, deposition and removal of chemical elements, proceed in invertebrate and warm-blooded animals with different intensity. One should note also the important fact that the Machalanobis distance (linkage distance), reflecting the similarity between the concentrations of chemical elements for various objects on the polluted sites is much less than the same parameter for background conditions (see Fig. 4, *a*, the linkage distance is equal to 75 and 135 rel. units, respectively). This indicates that under an intense chemical pollution of the environment the concentrations of chemical elements differ for the species of animals under consideration to a lesser degree, than in the case of non-polluted territory.

The cluster analysis results in a certain integral estimate of the similarity between the chemical compositions of different groups of

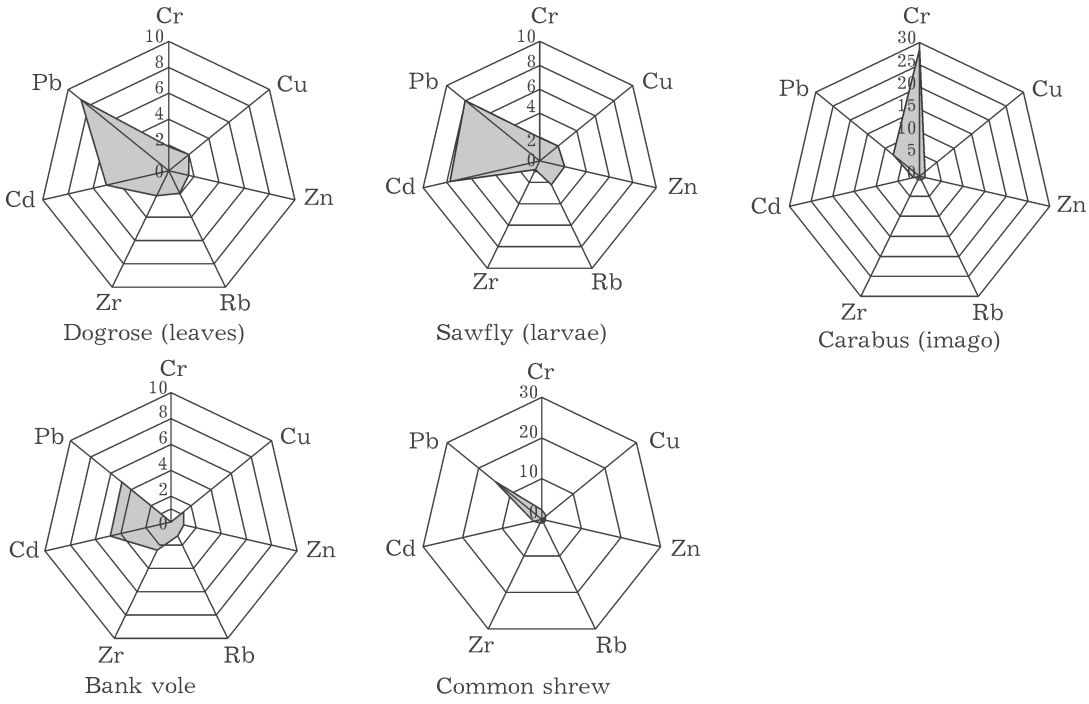

Fig. 5. Multiplicity of increase in the concentration of chemical elements within the most polluted areas as compared to the background data.

living organisms. Meanwhile, due to the specificity of mineral exchange each element can be accumulated in different amounts, which is determined as the concentration ratio for polluted and background sites (the concentration coefficient). Figure 5 demonstrates the repetition factor for the increase in concentration inherent in the priority pollutants. One can see, that for phytophagous animals (sawfly larvae, bank vole) the concentration of elements such as Pb, Cd, Zn, Cu, Rb, Zr, Cr increase almost identically (2–8 fold). For predatory species (carabus, common shrew), one can observe a 10–30-fold increase is marked only with respect to Pb and Cr.

CONCLUSION

Thus, as far as the background territories are concerned, the concentration distribution of chemical elements in living organisms is determined by their position in trophic structure in natural biocenoses, thus the groups of initial producers, phytophages and carnivorous species can be distinguished. Under environmental pollution, the distribution picture for the concentration of chemical elements is different and, to all appearance, is determined by the specificity of the mineral exchange and the belonging species to different taxonomic groups. In this case, the differences in the concentration of chemical elements in the organisms of various species over polluted territories are much less pronounced.

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