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Elemental chemical composition of some meadow plants in the Middle Ob basin

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Abstract. The data on the quantitative content of macro- and microelements in dry plant samples of meadow plants (*Vicia cracca, Lathyrus pratensis, Cirsium setosum, Tanacetum vulgare, Inula salicina, Elytrigia repens, Carex cespitosa*) in the Middle Ob basin within Tomsk region were obtained. We stated that these plant species differ in their ability to accumulate various elements. We showed the quantitative difference in the chemical composition of leaves and stems of three species. We made the conclusion about the dependence of absorption of elements on the plant species and element specificity.

1. Introduction

Rivers' floodplains are an important link in the system of the global cycle of matter. The role of the floodplain as J. Viers et al. [1] showed a geochemical reservoir based on the wetlands of the central Amazon.

The Ob is one of the world's largest rivers, whose vast adjoining territories are inundated during flood period. The Ob is the main carrier of chemical elements from land to the Arctic Ocean. Vegetation is an important participant in floodplain biogeochemical processes. However, the contribution of floodplain plants to natural cycles has not been studied sufficiently.

Occasionl geoecological studies on the territory of the Ob River floodplain in the Tomsk region allowed establishing the average characteristics of the geochemical background of the upper horizon of soils [2, 3]. However, river floodplains of the taiga zone of Western Siberia have been studied insignificantly from the point of view of accumulation of elements in plants. There are only isolated studies on the content of trace elements and heavy metals in the plants of the Upper Ob River floodplain [4, 5, 6] and the latitudinal segment of the Middle Ob [7, 8]. Meanwhile, floodplain meadows are used as fodder land and their geochemical study is an important applied task. Therefore, studies of the accumulation of micro- and macroelements in the plants of the Ob River floodplain are topical for the region

The aim of the research is to assess the level of the accumulation of micro- and macroelements in floodplain meadow plant species. The research is intended to reveal the regularities of accumulating elements in the stems and leaves of plants and the specificity of plants' accumulating them.

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2. Objects and methods of research

Sampling was conducted in the summer of 2016. The research site was located in the Tomsk region near the village of Kaybasovo within the flood plain of the Middle Ob. The Kaibasovo site is characterized by a significant expansion of the floodplain due to the confluence of the river Tom. The regulation of the flow of the Ob in this territory is weak and its high levels are flooded with hollow waters. The floodplain segment under study is characterized by a forested ridge-shaped near-river part and a marshy near-terrace part. The ridge-shaped and ancient levelled central floodplains, occupied mainly by meadow vegetation, are well-marked. The massifs of the near-terrace bogs are separated by channels and do not have a noticeable effect on the moistening of the meadow communities of the central floodplain, where the samples of grass stand were taken for analysis. To study the biosphere processes [9], the territory is used as a reference, and characterizes floodplain lands.

Figure 1. Sampling location (http://yandex.ru/maps/)

a ● sampling location

Sampling was carried out in a grass-mixed herbage phytocenosis, developed on the high ridge of the central floodplain. The site is well humidified, the soils are alluvial, turfy, thick argillaceous. *Cirsium setosum* (Willd.) Bess. (30-40%), *Vicia cracca* L. (15-20%), and *Tanacetum vulgare* L.(1-15%) dominate in the composition of mixed herbs phytocenosis. A significant part (2-5%) comprises the mixed herbs species *Filipendula ulmaria* (L.) Maxim, *Urtica dioica* L., *Geranium pratense* L., *Galium boreale* L. The proportion of grass is small, there are *Elytrigia repens* (L.) Nevski (2-3%) and *Alopecurus pratensis* L. (2-5%).

The research focuses on the following plant species: mixed herbs (*Cirsium setosum*, *Tanacetum vulgare, Inula salicina),* grasses (*Elytrigia repens),* legumes (*Vicia cracca*, *Lathyrus pratensis* L.). From the sedge-reedy phytocenosis, developed down the slope, the samples of the aerial part of *Carex cespitosa* L. were taken. To analyze the elemental composition of the leaves and stems we sampled the following species of meadow plants: *Inula salicina* L., *Vicia cracca*, *Lathyrus pratensis*. The standard methods were used to prepare the samples.

The lithogeochemical studies of the samples were carried out using ICP-mass-spectrometric analysis by the specialists from the Tomsk Regional Center for the Collective Use of Scientific Equipment**.**

The elemental composition of the plants was determined by inductively coupled plasma mass spectrometry (ICP-MS) which combines the use of an inductively coupled plasma as an ion source with a quadrupole mass spectrometer acting as a mass analyzer and a discrete dynode detector that is used to record individual ions and their flows [10].

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On the analytical balance we took a weighed quantity of the ground sample with a weight of 0.10 g, placed it into a fluoroplastic cylinder, added 1.0 ml of concentrated nitric acid, covered with a protective laboratory film and placed in a fuser, heated to 115 ^{0}C, for an hour until the sample was completely dissolved. A dissolved sample was transferred to a measuring polypropylene tube, washed three times from the walls of the cylinder, and adjusted to 10 ml with deionized water. Then we sealed hermetically with a protective laboratory film and mixed. Mass-spectral determination of the content of elements in the analyzed samples was carried out using Agilent 7500cx, AgilentTechnologies, Japan.

We used statistical packages of the programs "Statistica 6.0" and "Excel" to process the obtained results. The processing included calculating the statistical parameters (mean (M), standard error (m), variation coefficient (V)).

3. Discussion of results

The obtained materials on studying the chemical composition of plants displayed significant variability of the content and accumulation of elements (Table 1, Fig.1,2,3), which indicates the selectivity of the absorption of elements by plants, confirming the available information [5, 7, 11].

To find out plant parts to be used to study the absorption of micro- and macroelements we divided the tops of three species from different habitats (*Inula salicina*, *Lathyrus pratensis, Vicia cracca*) into the fractions – leaves and stems. The results of studying the elemental composition of these plants are given in Table 1.

It was established that in most cases the higher content of the studied elements was in plant leaves. However, plant stems accumulate such elements as Si, Mo to a higher degree. Accumulation of Na in plants depend on the species. Thus, in *I. salicina* concentration of this element occurs in plant stems mainly, it is 6 times more than in leaves. In *L. pratensis* the difference between leaves and stems is comparatively small, and in *V. cracca* the concentration of Na is higher in leaves. Leguminous *(V. cracca* and *L. pratensis*) accumulate Zn in leaves, while *Inula salicina* – in stems (Table 1). These species have the highest concentration of Mg, which is established for *V. cracca* in [12].

Table 1. Elemental composition of meadow plants in the Middle Ob floodplain (ppm, %)

Species	*Inula salicina*		*Lathyrus pratensis*		*Vicia cracca*	
Element	leaves	stems	leaves	stems	leaves	stems
Mg	13,809.39	6,063.42	9,709.96	6,000.37	13,108.73	7,189.77
K, %	3.70	1.74	2.44	2.32	1.08	0.99
Ca,%	16.00	2.21	8.40	4.53	14.83	4.60
Mn	283.2529	62.7583	218.2596	120.3435	351.1111	72.9874
Fe	269.1885	136.0099	976.1815	253.4407	410.1924	132.4341
Al	54.8174	3.7795	212.8516	8.7980	53.1961	25.2583
Cu	3.9868	2.7121	5.9105	2.8476	4.1612	2.4724
Zn	13.1580	18.7859	60.9856	32.6874	73.4540	17.8478
Na	67.99	382.64	130.11	179.57	72.96	66.29
B	7.7041	1.5120	3.6177	2.3689	3.6033	1.7460
Mo	0.3078	2.4392	0.5234	1.0127	0.4753	0.7917
Si	30.5194	55.6753	49.4079	43.1148	47.3800	53.5384
Cd	0.0300	0.0118	0.0318	0.0248	0.0205	0.0119
Pb	0.1011	0.0604	0.0005	0.1026	0.1432	0.1597
V	0.3646	0.2631	1.7934	0.3150	0.6171	0.1595
Ni	1.0557	0.4942	2.4481	1.0565	1.8716	0.8761
Ti	4.0772	5.6679	31.1694	3.8612	16.9524	1.1782

The ratio of the content of elements in stems and leaves in plants differs significantly. Often there is a difference in concentration by an order of magnitude of such elements as Mg, Ca, Mn, Na, Ti. In other cases (Si in leguminous) the concentration of the element in leaves and stems may be similar. Such information can be found in the literature [7, 8]. This is the reason why to analyze the elemental composition of plants we took the aboveground part of plants.

Macroelements (Fig. 1, 2). In the meadow plant species under study we found out the following macroelements: Ca, K, Mg, Mn, Fe, Na, Al, Si.

The distribution of Ca, Mg in investigated group is characterized by similar regularities (Fig. 1), which allows us to suggest their existing in the plants in the form of complexes. The phytocenosis dominants *C. setosum* and *I. salicina* accumulate these elements very intensively. In cereals and oats, the need to accumulate these biophilic elements is minimal. Legumes (*L. pratensis*) are demanding for the absorption of magnesium, which corresponds to the published data [12].

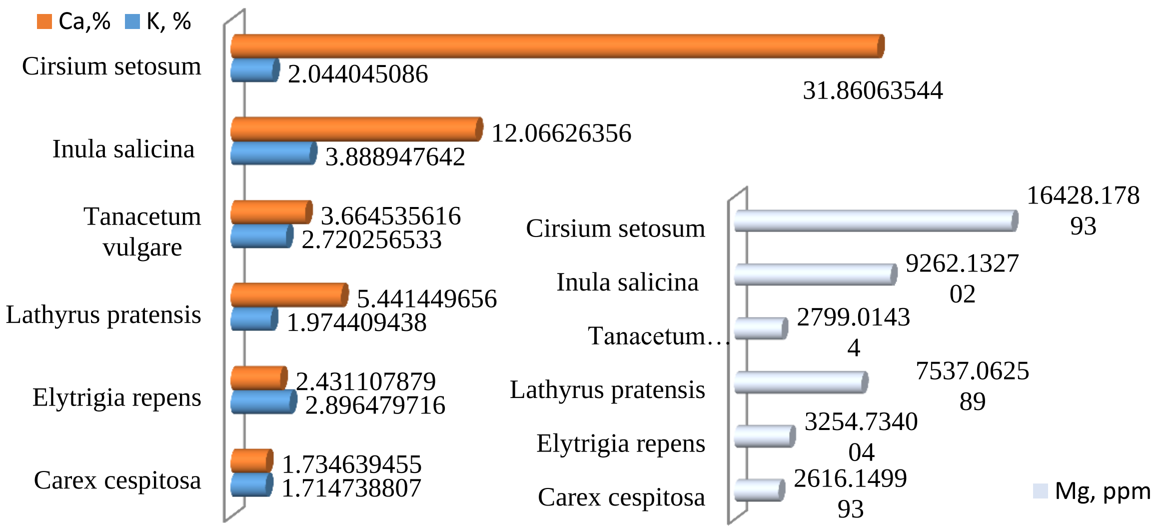


Figure 2. The content of Ca (%), K (%), Mg (ppm) in meadow plants in the Middle Ob floodplain

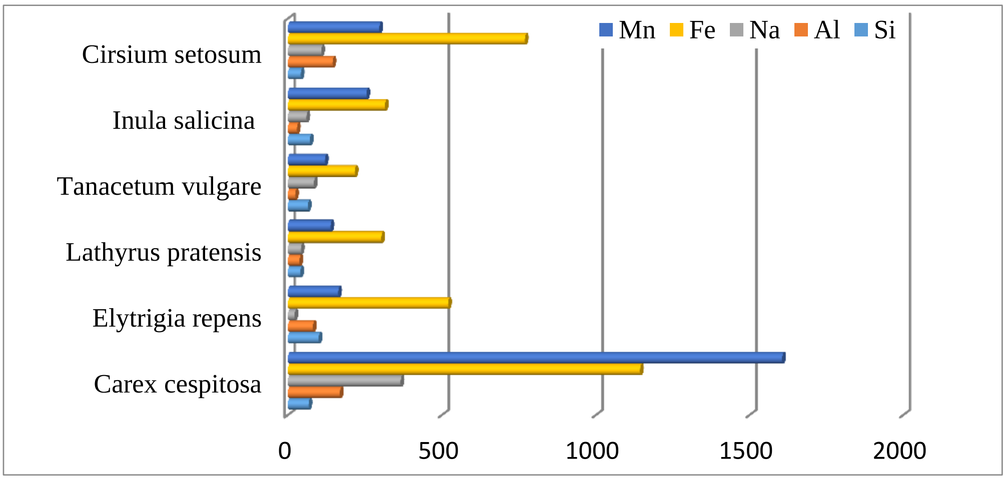


Figure 3. The content of Mn (ppm), Fe (ppm), Na (ppm), Al (ppm), Si (ppm) in meadow plants in the Middle Ob floodplain.

The content of K in meadow plants varies from 1.5 % to 3.9 %. The maximal content of potassium was registered in the samples of *Inula salicina*, the second position (from 2.5 to 3.0 %) is taken by *E. repens, T. vulgare*.

The third position belongs to *C. setosum*, *C.cespitosa* and *L. pratensis* with a concentration range from 1.5 to 2.0 %. It is noteworthy that the content of K in *E. repens* slightly exceeds the amount of Ca, and the sedge has an equal ratio of these elements.

The highest concentration of Mn, exceeding in 8-10 times its content in other plants, is characteristic of *C. cespitosa* (1,606 ppm). However, in the cereal-herbage phytocoenosis *C. setosum* and *Inula salicina* dominate (more than 250 ppm). The lowest concentration of this element is found in *L. pratensis* and *T. vulgare* (Fig. 2).

The content of Fe in the plants under study is rather large, especially in *C. cespitosa* (1,144 ppm*) and C. setosum* (769.7 ppm). In contrast to sedge, in the species of the cereal-herbaceous community (*C. setosum*, *I. salicina*, *E. repens*, *L. pratensis* and *T. vulgare*), ferrum in its content exceeds the amount of Mn. The concentration of Fe in the aboveground mass of *C. setosum* and *E. repens* is 2-3 times higher than in other herbs and leguminous plants.

Relatively high content of Na (about 400 ppm) is characteristic of *C. cespitosa (*Fig.2*)*, the lowest (21.8 ppm) - *E. repens*, among the mixed herbs species *C. setosum* and *T. vulgare* stand out, with the content of Na about 100 ppm.

The content of Al in plants varies considerably – within the range 40-200 units, the high concentration of Al being characteristic of *C. cespitosa* and *C. setosum* (about 150 ppm), *I. salicina*, *L. pratensis* and *T. vulgare* have a low concentration (Fig. 2).

The content of Si in plants is generally rather low (the concentration range being 40.5 – 100.3 ppm). The most amount of it can be found in *E. repens* and then in «rough» xeromesophilic motley grass (*T. vulgare*, *I. salicina*) and sedge *C. cespitosa.*

The lowest concentration of Si is characteristic of the representative of a group of legumes – *L. pratensis*. It complies with the well-known belief about the good eatability of plants from this family. It should be noted that in the grass-and-herb phytocenosis the leguminous grasses have the smallest content of all the macroelements under study.

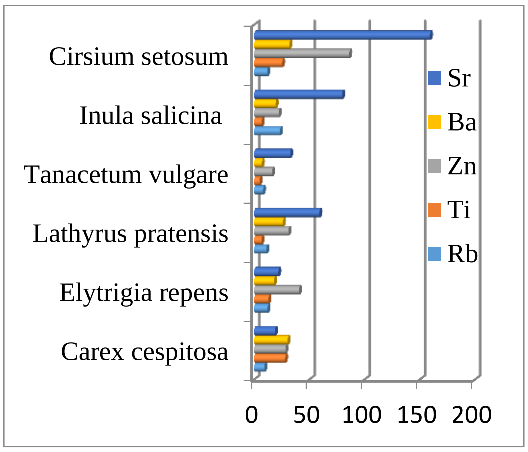
Microelements. The content of 14 microelements in meadow plants was studied (*T. vulgare*, *I. salicina*, *C. setosum*, *L. pratensis*), the plants taken from gramineous and mixed herbs (ridge top) and *C. cespitosa* – from sedge-reed grass (ridge slope) phytocenoses. Microelements, on the one hand, are physiologically necessary for the life of living organisms, on the other - a number of them belong to highly hazardous pollutants (Pb, Sr, V) [13].

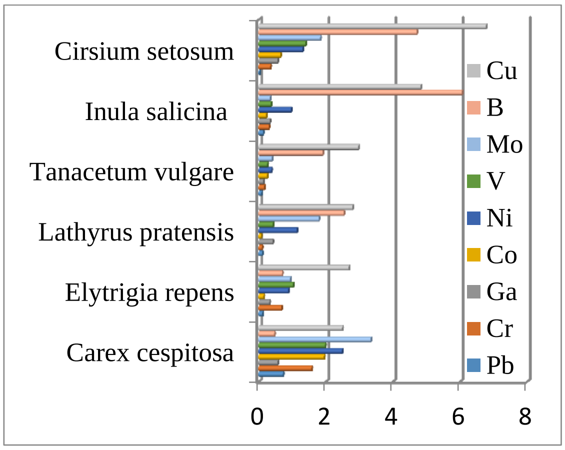
According to V.B. Ilyin [1991] the interaction between plants and soil, microelement circulation in particular, has a double character. On the one hand, plants regulate the absorption and accumulation of metals, on the other hand they can not completely neutralize the "geochemical pressure" of the medium with increasing concentrations of elements in soils above the optimum level (Ilyin, 1991), which negatively affects their development. The results obtained show that the concentrations of most microelements in plants are low - in the range from 0 to 7 ppm (Fig. 3b), only the content of Sr, Zn, Ba, Rb, Ti in plants exceeds 10 ppm. (Fig.3 a).

Of all the microelements in plants, the concentration of Sr turned out to be the highest - up to 160 ppm in *C. setosum*, somewhat less (80 ppm) in *I. salicina*. The lowest concentration of this element was found in *E. repens* and *C. cespitosa*. The distribution of Sr in the considered series of plants is similar to the distribution of Ca and Mg.

Apparently, *C. setosum* should be considered as a storage of this element. In the conditions of the soils rich in carbonates of the forest-steppe and transitional to the southern taiga the Ob floodplain Sr has a high mobility, which was noted by L.A. Izerskaya et al. [2, 3, 4].

The concentration of Zn was rather high in *C. setosum* (more than 80 ppm), the second position was taken by *E. repens* (40 ppm), the third – by *L. pratensis* and *C. cespitosa*.





a b

Figure 4. The content of microelements (ppm) in meadow plants in the Middle Ob floodplain

In other species, the concentration of Zn was less than 20 ppm. In general, the content of this element is rather low in the plant species studied. According to the literature data [6], the average content of Zn in plants of non-contaminated areas of the Irtysh and Ob rivers is 44 mg / kg. Therefore, we can say that in comparison with other species *C. setosum* also actively accumulates Zn.

C. setosum is comparatively rich in Cu (about 7 ppm) and B (4.7 ppm). In other species the concentration of Cu is about 2-3 ppm. It is rather a low concentration, nearly shortage [13, 14], and lower than the average calculated level of copper in medicinal plants in the floodplains of the Irtysh and Ob – 5.6 мг/кг [6].

I. salicina also has a comparatively high concentration of Cu, however unlike other species it accumulates B (6 ppm) more actively than Cu. *L. pratensis* and *T. vulgare* are characterized by average concnetrations (1.5-25 ppm), *E. repens* and *C. cespitosa* have the lowest concentration of B – less than 0.6 ppm – nearly shortage [13].

The concentration of Pb in the plants is low, which testifies to the absence of anthropogenic pollution of this territory [13]. The amount of V is little – less than 1 ppm in *I. salicina*, *L. pratensis* and *T. vulgare*. The higher concentration of this element – 1-2 ppm – was revealed in *E. repens*, *C. setosum*, and especially, *C. cespitosa*.

C. cespitosa demonstrated the highest content of Ti, Ba, Mo and Ni, Cr and Co. The active absorption of Ni and Cu be sedges was also showed in the work by I.V. Kravchenko et al. [2014]. It is known that the ability of plants to accumulate certain elements is influenced by habitat conditions [8, 15]. It is obvious that the features of biogeochemical properties plants determine their distribution in the conditions of the floodplain.

4. Conclusions

1. The preferred place for the accumulation of micro and macro elements in the aboveground part of most herbaceous plants are the leaves, but there are exceptions. In the legumes, the elemental composition of leaves and stems differs slightly in some elements, *Inula salicina* accumulates some elements (Na, Zn, Si, Ti) in the stem.

2. One can observe the specificity of micro- and macronutrient absorption by plants species. The active concentrator of many elements is Cirsium setosum, which develops in meadows during the years of weak flooding. Apparently, its ecological and biological demands can be met only with a weak development of cereals and sedges dominating in the flood years.

3. Leguminous plants and *Tanacetum vulgare* accumulate relatively few metals, elements of contaminants and silicon. These species can be used as good forage plants and as medicinal raw materials.
4. The elemental chemical composition of *Carex cespitosa*, growing in more humid conditions, differs significantly from the composition of plants of dry habitats in the low content of macroelements (K, Ca, Mg) and the high content of microelements (Mn, Fe, Ti, Ba, Mo and Ni, Cr and Co).

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