Vitally Important Microelements in Transbaikalian Herbs

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Abstract

The content of vitally important microelements (Fe, Mn, Zn, Cu, Mo, Co, Cr) has been studied for some herbs growing within the arid-steppe, the underhumidity meadow, the normal humidity meadow and the lowland swamp meadow landscapes in various soil types of the Western Transbaikalia. Specific and ecological specificity of the accumulation of microelements in plants has been determined. Various levels of microelemental content in herbs have been established, as well as plants the concentrators of Fe, Mn, Zn, Cr have been distinguished. Molybdenum, copper and zinc are attributed to the group of elements exhibiting intense absorption from soil; manganese and cobalt are related to the group moderate absorption, whereas iron and chromium are considered to be the elements of weak absorption.

Key words: iron, manganese, zinc, copper, molybdenum, cobalt, chromium, herbs, landscapes

INTRODUCTION

For the last decades it has been established that the pharmacological activity of herbs depends not only on the presence of specific naturally occurring compounds therein, but also on their ability to accumulate separately essential microelements and even their complexes. This fact is caused by genetic interrelation between biologically active substances and microelements in herbs, since the microelements being a part of enzymes participate in the biosynthesis of the latter [1]. Such data have been obtained by the example of a great number of herbs synthesizing alkaloids of numerous types, triterpene and steroid saponines, phenolic compounds [2]. Researchers succeeded in revealing the specificity of elemental composition inherent in herbs and in establishing correlations between the content of physiologically active substances and that of microelements [3]. In this connection revealing and quantitative estimating the content of microelements represent an important criterion of herbal quality in their practical use. At the same time data concerning phytogenous pharmaceutical preparations, their undesirable effects and medicinal interactions are often limited [4].

Under the conditions of Transbaikalia there were no studies carried out concerning microelemental composition of herbs. At the same time this region represents the territory of polyelemental biogeochemical endemic disorders of caused by the disturbance in natural biogeochemical cycles for a whole series of vitally important microelements (deficiency, excess or disbalance), which could be negatively affect the functioning stability and the efficiency of ecosystems, as well as the human health. The aim of the present work included the studies on the content level and the accumulation features for vitally important microelements (Fe, Mn, Zn, Cu, Co, Mo, Cr) in the aerial mass of some herbs under different ecophytocoenotic conditions in the Western Transbaikalia.

EXPERIMENTAL

The present research was carried out within 12 the most populated central and southern areas of Buryatia (Western Transbaikalia) in the forest-steppe, steppe and arid steppe native zones. The subjects of inquiry were presented by the herbs of steppe, meadow and marsh phytocenoses, growing respectively under the conditions of deficient, normal, normal and excess humidifying in chestnut, greywood, chernozem, alluvial meadow and alluvial marsh soils. The sampling of aerial mass of plants for biogeochemical studies was carried out during the period of the greatest productivity (a the stage of flowering, since for the majority of plants just this development stage is connected with the maximum producing of biologically active compounds) on trial platforms 100 × 100 m in size those were typical for these plots, in accordance with methodical recommendations [5].

The mineralization procedure for grinded plant samples was carried out *via* dry ashing technique in a muffle furnace at the temperature of 480 °C. The plant nomenclature is presented according to Cherepanov [6]. The content of microelements was determined via atomic absorption technique employing a Perkin Elmer spectrophotometer with flame atomization in acetylene-air mixture (for Fe, Mn, Cu, Zn, Cr, Co) and with graphite furnace atomization (for Mo). The systematic error for the determination of microelements varies within the range of 7–15 %. Simultaneously with sampling plants, we took soil samples from the same key platforms [7, 8]. The biological absorption coefficient (BAC) for microelements, by plants from soil was calculated as a ratio between the content of an element in plant ashes and its content in soil. The mathematical treatment of the results was carried out according to standard methods.

RESULTS AND DISCUSSION

Iron

The content of iron in the herbs under investigation varied within the range of 59–1140 mg/kg with respect to dry solid matter (Tables 1, 2), *i. e.* the maximal content was 19.3 times higher than the minimal value. The values obtained correspond to the literature data concerning the content of iron in 52 herbal species of the European part of Russia [2, 9] and seven species of plants growing in territory of the Southern Pribaikalia (20–1700 mg/kg) [10]. The minimal content of iron has been revealed for the nosebleed (*Achillea millefolium*) within the normal humidity meadow landscape and for the garden (green) sorrel (*Rumex acetosa*) within the underhumidity meadow landscape, whereas the maximal value (more than 1000 mg/kg) was found out for the British inula (*Inula Britannica*) within the normal humidity meadow landscape of and for the *Panzerina lanata* (Sojak L.) within the arid steppe landscape (1140 and 1095 mg/kg, respectively). These plant species could be considered to be powerful iron concentrators.

The analysis of data presented in Table 1 has demonstrated that for 29 % of determinations performed for the Transbaikalian herbs under investigation is characterized by an increased content of iron as compared to the average (clarke) content in plants, equal to 190 mg/kg [11] (1.5- to 6.0-fold excess).

The content of iron in the same plant species growing under different ecological conditions differs from each other to a considerable extent. So, under the conditions of arid-steppe landscapes the content of iron varied within the range of 171–290 mg/kg for the thoroughwax sp. (*Bupleurum scorzoneraefolium* L.) (1.7-fold difference), 168 to 462 mg/kg for the wormwood sage (*Artemisia frigida*) corresponding to 2.7-fold difference. Within the underhumidity meadow landscapes the content of iron for the *Galium verum* L. varies within the range of 68–225 mg/kg (3.3 times), ranging for the *Sanguisorba officinalis* L. from 59 to 325 mg/kg (5.5 times). Under the conditions of normal humidity meadow landscapes the content of iron for the field horsetail (*Equisetum arvense* L.) ranges within 87–207 mg/kg (2.4-fold difference). Ecological features of the accumulation of either chemical element by the same plant species under the conditions of different biotopes could be connected with a different level of bioavailability of the elements, which is caused by soil-and-geochemical factors. For different plant species sampled from the same plot the difference in the content of iron is also rather considerable. So, under the conditions of the underhumidity meadow landscape the content of iron in the *Galium verum* L. is 3.8

TABLE 1

Content of microelements in Transbaikalian herbs, mg/kg as calculated for dry solid matter

Plant species	Sampling place, village	Fe	Mn	Zn	Cu	Co	Mo	Cr	Ashes content, %
	Arid steppe landscape (chestnut soil)								
Thoroughwax sp. (*Bupleurum scorzonerifolium* Willd.)	the Belozersk	184	37	27.6	4.6	n. d.	0.92	0.92	4.9
	the Petropavlovka	290	58	5.8	2.9	n. d.	1.74	1.16	5.8
	the Unegetey	171	34	5.7	2.3	n. d.	0.86	1.14	5.7
Panzerina lanata (L.) Sojak	the Yagodnoye	1095	73	14.6	7.3	0.73	2.19	4.38	7.3
Wormwood sage (*Artemisia frigida* Willd.)	the Belozersk	204	51	25.5	7.7	0.26	0.51	1.53	5.1
	the Petropavlovka	168	56	56.0	8.4	0.45	2.24	2.24	4.8
	the Ust-Kyakhta	462	62	62.0	23.1	0.77	2.30	н. о.	7.7
	the Udinsk	390	65	9.8	6.5	n. d.	1.95	1.95	6.5
Thyme (*Thymus dauricus* Serg)	the Yagodnoye	196	78	39.2	9.8	n. d.	1.96	1.96	9.8
	Underhumidity meadow landscape (alluvial turfen soil)								
Pink sp. (*Dianthus versicolor* Fisch. *ex*. Link)	the Ust-Kyakhta	183	61	6.1	6.1	0.61	0.61	1.83	6.1
Gentianopsis barbata L.	the Kizhinga	156	21	5.2	2.4	0.42	1.56	1.04	5.2
Greater burnet (*Sanguisorba officinalis* L.)	the V. Taltsy	300	180	12.0	2.4	n. d.	1.20	1.80	8.1
	the Kizhinga	325	52	6.5	2.6	0.52	2.00	1.95	6.4
	the Petropavlovka	98	62	19.5	5.2	n. d.	1.95.	1.30	6.5
	the Tugnuy	144	216	36	14.4	0.72	2.88	3.60	7.2
	the Ust-Kyakhta	59	59	23.0	17.7	0.59	1.80	2.96	5.9
Fleawort (*Galium verum* L.)	the M. Kunalej	68	68	20.4	6.8	0.54	3.40	6.80	6.8
	the Sharalday	225	60	45.0	22.0	0.62	3.70	2.25	7.5
	the Tugnuy	158	61	45.0	7.6	0.76	3.80	1.68	7.6
	the Nadeeno	201	134	13.4	20.1	0.54	2.03	2.14	6.7
	the Ust-Kyakhta	224	34	5.6	5.6	0.56	1.74	1.72	5.6
Estragon (*Artemisia dracunculus*)	the Il'inka	243	122	40.5	8.1	0.65	0.41	2.43	8.1
	the Talovka	201	67	33.5	5.4	n. d.	0.67	2.01	6.7
Caraway (*Carum carvi*)	the Nadeeno	138	69	41.0	13.8	0.55	2.12	2.07	6.9
Sharp doc (*Rumex acetosa*)	the Nadeeno	67	53	13.4	5.4	0.54	2.00	13.40	6.7
	Normal humidity meadow landscape (alluvial meadow soil)								
British inula (*Inula britannica*)	the Kizhinga	1140	46	11.4	4.6	n. d.	0.57	2.28	11.4
Melilot sp. (*Melilotus suaveolens* Led.)	the M. Kunaley	152	23	15.2	4.6	0.76	1.52	1.53	6.7
	the V. Taltsy	105	28	7.0	2.8	0.56	7.00	0.70	7.0
	the Unegetey	620	12	6.2	2.6	n. d.	2.48	1.24	6.2
Meadow clover (*Trifolium pratense*)	the Nadeeno	128	64	13.0	9.6	0.51	1.90	19.20	6.4
	the Tugnuy	535	64	21.0	21.0	1.07	–	1.10	7.7
Day-lily sp. (*Hemerocallis minor*) Miller	the Tarbagatay	88	44	26.0	13.2	0.35	0.43	1.32	4.4
Silverweed cinquefoil (*Potentilla anserina*)	the Unegetey	712	178	8.9	1.8	n. d.	2.67	0.89	8.9
Common plantain (*Plantago major*)	the Yagodnoye	399	106	13.0	3.4	1.06	1.06	7.98	13.3
	the Tugnuy	89	134	26.7	5.3	n. d.	4.45	17.8	8.9
Nosebleed (*Achillea millefolium*)	the Yagodnoye	59	37	44.0	3.7	0.59	0.30	0.74	6.6
Field horsetail (*Equisetum arvense*)	the Il'iinka	207	14	6.9	1.4	0.55	0.55	0.69	6.9
	the M. Kunalej	87	26	52.0	2.6	0.70	2.60	3.50	8.7
	the Tarbagatay	108	11	32.0	6.5	0.86	5.40	6.50	10.8
	Lowland swamp meadow landscape (alluvial marsh soil)								
Water shamrock (*Menyanthes trifoliata*)	the Posolsk	213	355	21.3	2.4	n. d.	0.36	n. d.	12.1
Cowberry (*Comarum palustre*)	the Posolsk	350	420	56.0	1.5	n. d.	0.21	n. d.	7.8

Note. n. d. – not determined.

TABLE 2

Average variational statistic parameters for the content of microelements and the intensity of their entering into the herbs of Transbaikalian landscapes

Parameter	Fe	Mn	Zn	Cu	Co	Mo	Cr
			Arid steppe landscape (n = 9)				
Range, mg/kg	168–1095	34–78	5.7–62.0	2.3–23.1	0.26–0.77	0.51–2.30	0.92–4.38
$M\pm m$, mg/kg	351±99	57.1±4.9	27.4±7.0	8.1±2.1	0.59±0.16	1.63±0.23	1.91±0.39
V, %	85	26	77	76	48	42	58
r	0.62	0.87	0.23	0.11	–	0.56	−0.10
BAC	0.09±0.009	1.19±0.05	3.92±1.31	3.22±0.72	–	9.50±1.70	0.48±0.09
			Underhumidity meadow landscape (n = 16)				
Range, mg/kg	59–325	21–210	5.2–45.0	2.4–22.0	0.42–0.76	0.41–3.80	1.04–13.40
$M\pm m$, mg/kg	174±20	82.4±13.3	22.9±3.8	9.6±1.6	0.59±0.03	1.99±0.26	3.06±0.77
V, %	46	65	66	67	15	52	100
r	−0.06	0.05	0.35	−0.12	–	−0.18	−0.07
BAC	0.06±0.009	1.49±0.28	3.41±0.52	5.14±0.94	0.87±0.08	8.41±1.03	0.82±0.21
			Normal humidity meadow landscape (n = 14)				
Range, mg/kg	59–1140	11–178	6.2–52.0	1.4–21.0	0.35–1.07	0.30–7.00	0.69–19.2
$M\pm m$, mg/kg	316±87	56.2±13.4	20.2±3.8	5.9±1.4	0.70±0.08	2.38±0.58	4.68±1.68
V, %	103	89	71	91	34	88	134
r	−0.38	−0.03	0.44	−0.11	–	0.33	0.31
BAC	0.09±0.02	1.05±0.30	3.26±0.57	4.37±1.08	0.78±0.05	14.77±2.29	0.61±0.13
			Lowland swamp meadow landscape (n = 2)				
Range, mg/kg	213–350	355–420	21.3–56.0	1.5–2.4	–	0.21–0.36	–
$M\pm m$, mg/kg	282±68	388±33	38.7±17.4	2.0±0.5	–	0.29±0.08	–
V, %	34	12	63	33	–	37	–
BAC	0.07±0.02	6.80±0.59	7.40±3.70	5.25±0.25	–	0.40±0.10	–

Notes. 1. The fluctuation range, $M\pm m$, the variation coefficient V are presented as calculated for dry solid matter; the correlation coefficient r is specified for the plant (ashes)–soil system. 2. BAC is the biological absorption coefficient.

times higher than the iron content in the greater burnet (*Sanguisorba officinalis* L.). Under the conditions of the normal humidity meadow landscape the content of iron in the British inula (*Inula britannica* L.) is 7.3 times higher than that observed for the *Gentianopsis barbata* L. Under the conditions of the lowland swamp meadow landscape the mentioned parameter value for the cowberry (*Comarum palustre* L.) is 1.6 times is higher comparing to those for the water shamrock (*Menyanthes trifoliata* L.). The biological specificity of the accumulation of an element by different plant species under identical conditions indicates the selectivity of their absorption by root systems and transportation to the aerial parts of plants, which is determined by physiological and biochemical mechanisms.

The total content of iron in Transbaikalian soils is high amounting to 30 280–60 990 mg/kg (the average iron content in soils all over the world is equal to 40 000 mg/kg). According to the content in soil, iron could be classified as a macroelement, however the intensity of iron absorption by plants is very low: BAC = 0.02–0.25 (0.07 on average) (see Tables 2, 3). The content of iron in plants as calculated for ashes is equal to 1000–10 000 mg/kg. From the data presented in Tables 2, 3 one can see that on the average the intensity parameters for the absorption of iron by plants from soils belonging to different landscapes are comparable: for the plants sampled within the arid steppe landscapes BAC = 0.09, for the underhumidity meadow landscapes BAC = 0.06, for the normal humidity meadow landscapes BAC = 0.09, for the lowland swamp meadow landscapes BAC = 0.07. As far as the relationship between the content of iron in plants and total iron content in soils is concerned, it has been established that an average positive correlation is inherent in the arid steppe landscapes for the plant–soil system (r = 0.62), whereas a negative correlation is characteristic of meadow landscapes (r = –0.06, –0.38).

Manganese

The content of manganese in herbs varies within a considerable range from 11 to 420 mg/kg (see Table 1); the maximal content is 38 times higher than the minimal value. The herbs of the European part of Russia are noteworthy for a much wider range of manganese content values (5.3–1346 mg/kg) [2]. The minimal content of manganese is revealed in the field horsetail (*Equisetum arvense* L.) under different growth conditions amounting to 11–26 mg/kg (for the European part of Russia a low content of manganese in this plant is also registered to amount to 27.8 mg/kg [2]). To all appearance, this fact could be caused by a high level silicon accumulation observed for the field horsetail (according to our data, this value amounts to 7590–10 800 mg/kg for the field horsetail, whereas for the majority of other plants this value ranges within 1000–2500 mg/kg).

There are data in the literature concerning the antagonistic silicon influence upon manganese accumulation in plants [12]. The maximal content of manganese (355–420 mg/kg) is registered in plants of the lowland swamp meadow landscape such as the water shamrock (*Menyanthes trifoliata* L.) and the *Comarum palustre* L. The increased manganese accumulation level for the plants growing on alluvial lowland swamp meadow soils under the conditions of excess humidifying could be connected, first of all, with geochemical features of its behaviour in these soils. Under the conditions of the reducing mode of such soils the mobility level of manganese abruptly grows [12], which promotes active absorbing manganese by plants. In the herbs of the arid steppe landscapes there is a rather close (with respect to the aforementioned) manganese content observed ranging within 34–78 mg/kg (2.2-fold difference), which, to all appearance, is determined by much more uniform ecological conditions including the content of manganese in soils amounting to 600–1000 mg/kg (1.7-fold difference). For plants of meadow landscapes the difference in the content of manganese observed is equal to 10.8–16.2 times, which could be connected with the contrast conditions of humidifying, with manganese content in soils (330–1005 mg/kg) as well as the difference in manganese availability. Under different conditions the content of manganese observed for the same plant species exhibits 1.3-fold difference for the wormwood sage (*Artemisia frigida*), 2.4-fold difference for the field horsetail (*Equisetum arvense*), 3.9-fold difference for the *Galium verum* L. and 4.2-fold difference for the greater burnet (*Sanguisorba officinalis* L.).

On the average the herbs of the arid steppe landscape (57.1 mg/kg), underhumidity meadow landscape (84.2 mg/kg) and normal humidity meadow landscape (56.2 mg/kg) contain in 4.6–6.9 times less manganese, than plants growing within the lowland swamp meadow landscapes (388 mg/kg).

According to the classification proposed by Perelman [13] manganese can be attributed to chemical elements exhibiting a moderate intensity of accumulation by herbs growing within the arid steppe landscapes (on the average, BAC = 1.15), within the underhumidity meadow landscapes (1.60) and normal humidity meadow landscapes (1.02), and exhibiting a high intensity of accumulation by plants growing within the lowland swamp meadow landscape (6.2–7.4).

For the arid steppe landscapes the correlation between the content of manganese in plants and that in soils is strong (r = 0.87), whereas for meadow such a correlation is weak (r = 0.05, –0.03).

Zinc

The content of zinc in the herbs of Transbaikalia ranges from 5.2 to 62.0 mg/kg (11.1 times), which is lower as compared to that for the European part of Russia (5.3–136 mg/kg) [2]. The minimal content of zinc is registered for the *Gentianopsis barbata* L. and the pink sp. *Dianthus versicolor* Fisch. (5.2 and 6.1 mg/kg, respectively). The maximal content of zinc was revealed in the wormwood sage (*Artemisia frigida*) under the conditions of the arid steppe landscape

TABLE 3

Data on the content of microelements in soil (1), ashes of plants (2) (in mg/kg) and the biological absorption

Plant species	Section	Fe			Mn			Zn		
		1	2	3	1	2	3	1	2	3
										Arid steppe
Thoroughwax sp.	60 D	50010	4000	0.08	806	800	1.00	78	600	7.69
(*Bupleurum scorzoneri-*	58 D	60110	5000	0.08	800	1000	1.25	98	100	1.02
folium Willd.)	55 Z	40010	3000	0.07	496	600	1.21	50	100	2.00
Wormwood sage	60 D	50010	4000	0.08	806	1000	1.24	78	500	6.41
(*Artemisia frigida*)	61 Kh	50020	6000	0.12	810	1000	1.23	60	150	2.50
										Underhumidity
Pink sp. (*Dianthus versicolor* Fisch.)	19 K	40060	3000	0.07	580	1015	1.75	56	105	1.88
Gentianopsis barbata L.	52 KZh	40025	3000	0.07	840	405	0.48	92	103	1.12
Greater burnet	19 K	40060	1020	0.03	580	1005	1.73	56	400	7.14
(*Sanguisorba officinalis*)	34 M	60100	2000	0.03	867	3000	3.46	98	485	4.95
	52 KZh	40025	5000	0.13	840	805	0.96	92	105	1.14
	59 D	50005	1500	0.03	1005	310	0.31	102	305	2.99
	62 Kh	60110	5000	0.08	806	3000	3.72	58	203	3.50
Galium verum L.	19 K	40060	4000	0.10	580	600	1.03	56	104	1.86
	24 T	49990	3000	0 06	850	2000	2.35	106	202	1.91
	30 B	40040	1000	0.03	900	1000	1.11	93	300	3.23
	34 M	60100	2000	0.03	867	800	0.92	98	600	6.12
	33 M	30280	3000	0.10	920	810	0.88	140	610	4.36
Caraway (*Carum carvi*)	24 T	49985	2000	0.04	850	1010	1.19	106	595	5.61
Sharp doc (*Rumex acetosa*)	24 T	49985	1000	0.02	850	800	0.94	106	210	1.98
								Normal humidity		
British inula (*Inula britannica*)	51 KZh	40025	10000	0.25	840	400	0.48	92	100	1.09
Melilot sp. (*Melilotus*	31 B	60990	2000	0.03	960	300	0.31	110	200	1.82
suaveolens Led.)	63 Kh	60110	1500	0.03	806	400	0.50	58	100	1.72
	56 Z	40010	10000	0.25	496	200	0.40	50	100	2.00
	36 S	40025	3000	0.08	840	1000	1.19	92	600	6.52
	40 K	50020	2000	0.04	906	300	0.33	91	310	3.41
Meadow clover	20 T	49985	2000	0.04	850	1000	1.18	106	208	1.96
(*Trifolium pratense*)	32 M	60100	5000	0.08	867	600	0.69	98	200	2.04
Day-lily sp. *Hemerocallis minor* Miller	20 T	40020	2000	0.05	468	1000	2.14	87	600	6.90
Silverweed cinquefoil (*Potentilla anserina*)	56 Z	40010	8000	0.20	490	2000	4.08	50	100	2.00
Common plantain (*Plantago major*)	32 M	60100	1000	0.02	867	1500	1.73	98	300	3.06
Field horsetail	20 T	40020	1000	0.03	465	150	0.32	87	290	3.33
(*Equisetum arvense*)	31 B	40040	1000	0.03	900	300	0.33	93	610	6.56
										Lowland swamp
Water shamrock (*Menyanthes trifoliata*)	100 KB	60018	3000	0.05	808	5000	6.20	27	300	11.10
Cowberry (*Comarum palustre*)	100 KB	60018	5000	0.08	808	6000	7.40	27	100	3.70

Note. n. d. – not determined.

coefficient BAC (3)

Cu			Mo			Cr		
1	2	3	1	2	3	1	2	3
landscape								
27	100	3.70	2	20	10.0	60	20	0.33
32	50	1.56	2	30	15.0	64	20	0.24
22	40	1.82	2	15	7.5	29	20	0.69
27	150	5.56	2	10	5.0	60	30	0.50
29	100	3.45	3	30	10.0	48	30	0.63
meadow landscape								
24	97	4.06	4	11	2.75	82	28	0.34
23	51	2.22	5	32	6.40	44	21	0.48
24	300	12.5	4	31	7.75	82	47	0.57
31	200	6.45	4	38	9.50	66	50	0.76
23	42	1.83	5	29	5.80	44	27	0.61
52	84	1.62	7	32	4.57	98	20	0.20
49	40	0.82	3	21	7.0	41	32	0.78
24	98	4.08	4	30	7.5	66	29	0.44
28	300	10.71	4	28	7.0	60	36	0.60
18	100	5.56	3	50	16.7	61	100	1.64
31	104	3.75	4	48	12.0	66	30	0.45
34	295	8.68	3	46	15.3	58	35	0.60
28	190	6.79	4	30	7.5	60	37	0.62
28	82	2.93	4	32	8.0	60	200	3.33
meadow landscape								
23	40	1.74	5	50	10.0	44	20	0.45
26	60	2.31	3	20	6.67	58	20	0.34
49	40	0.82	3	100	33.3	41	10	0.24
22	40	1.82	2	40	20.0	29	20	0.69
24	200	8.33	5	60	12.0	44	30	0.68
21	205	9.76	4	80	20.0	55	100	1.82
28	150	5.36	4	30	7.5	60	300	5.00
31	200	6.45	4	100	25.0	66	23	0.35
23	300	13.04	3	10	3.33	78	30	0.38
22	20	0.91	2	30	15.0	30	10	0.33
31	60	1.94	4	50	12.5	66	200	3.03
23	62	2.70	3	50	16.7	78	60	0.77
18	30	1.67	3	30	10.0	61	40	0.66
meadow landscape								
4	22	5.50	10	5	0.50	n. d.	n. d.	n. d.
4	20	5.00	10	3	0.30	n. d.	n. d.	n. d.

in the Dzhidino district (56.0–62.0 mg/kg) and in the cowberry (*Comarum palustre*) under the conditions of the lowland swamp meadow landscapes at the Selenga River delta (56.0 mg/kg), which is higher as compared to its content in the plants of the European part of Russia (30.4 mg/kg).

The content of zinc in the same plant species under different conditions exhibits the difference within the following range: 2.5 times (6.2–15.2 mg/kg) for the melilot sp. (*Melilotus suaveolens* Led.), 5.5 times (6.5–36.0 mg/kg) for the greater burnet (*Sanguisorba officinalis*), 8.0 times (5.6–45.0 mg/kg) for the fleawort (*Galium verum*).

The content of zinc in herbs is equal to, mg/kg: 5.7–62.0 (average 28.0) for the arid steppe landscapes, 5.2–45.0 (average 22.9) for the underhumidity meadow landscapes, 6.2–52.0 (average 20.0) for the normal humidity meadow landscapes, 21.3–56.0 (average of 38.7 mg/kg) for the lowland swamp meadow landscapes. In most cases one can note a low content of zinc in herbs under investigation, which, to all appearance, could be caused by zinc and iron antagonism [12].

The high iron content established for the plants promotes a decrease in the content of zinc therein.

In spite of a low level of zinc content in herbs, data concerning its BAC appeared to exhibit high value amounting on the average to: 3.92 for the arid steppe landscapes, 3.94 for the underhumidity meadow landscapes, 3.19 for the normal humidity meadow landscapes, 7.4 for the lowland swamp meadow landscapes. Thus, according to the classification proposed by Perelman, zinc can be attributed to the elements of intense accumulation.

As against other microelements under investigation, a positive correlation has been established for zinc in the plant–soil system: for the arid steppe landscapes it is weak ($r = 0.23$), whereas for the meadow landscapes it is moderate ($r = 0.35$, 0.44).

Copper

The content of copper in herbs of Transbaikalia ranges from 1.4–1.8 mg/kg in the field horsetail (*Equisetum arvense*), the cowberry (*Comarum palustre*), the silverweed cinquefoil (*Potentilla anserina)* to 20.1–23.1 mg/kg in the fleawort (*Galium verum*), the meadow clover (*Trifolium pratense*), and the wormwood sage (*Artemisia frigida*). For the herbs of the European part of Russia the content of copper ranges from 2.2 to 50 mg/kg, and the lowest content has been also registered in the field horsetail (*Equisetum arvense*) [2]. The content of copper in the same plant species from different habitats varies within 1.8 times for melilot sp. (*Melilotus suaveolens* Led.) (2.6–4.6 mg/kg), 2.0 times for the thoroughwax sp. (*Bupleurum scorzonerifolium* Willd.) (2.3–4.6 mg/kg), within 3.6 times for the wormwood sage (*Artemisia frigida*) (6.5–23.1 mg/kg), 3.9 times for the fleawort (*Galium verum*) (5.6–22.0 mg/kg), within 7.4 times for the greater burnet (*Sanguisorba officinalis*) (2.4–17.7 mg/kg). For different plantspecies growing under identical conditions the data concerning the content of copper differ from each other within the range of 3.7 times and are equal to, mg/kg: 5.4 (1.0 times) for the sharp dock (*Rumex acetosa*), 13.8 (in 2.6 times) for the caraway (*Carum carvi*), 20.2 (3.7 times) for the fleawort (*Galium verum*).

The average content of copper in herbs for the arid steppe landscapes amounts to 8.1 mg/kg, for the underhumidity meadow landscapes 9.1 mg/kg, for the normal humidity meadow landscapes 5.9 mg/kg, for the lowland swamp meadow landscapes 2.0 mg/kg.

Copper belongs to the elements those exhibit intense accumulation in plants: its concentration in the ash residue is much higher comparing to its content in soil. On the average, the BAC value for copper in the herbs of the arid steppe landscapes amounts to 4.63, for the underhumidity meadow landscapes 5.14, for the normal humidity meadow landscape it is equal to 4.37, for the lowland swamp meadow landscape BAC = 5.25.

As far as copper is concerned, the correlation in the soil–plant system ranges from a weak positive one for the arid steppe landscapes ($r = 0.11$) to weak negative correlation for the meadow landscapes ($r = -0.12$).

Cobalt

The content of cobalt in herbs ranges from 0.26 mg/kg for the wormwood sage (*Artemisia *frigida*) to 1.07 mg/kg for the meadow clover (*Trifolium pratense*). As far as the herbs of the European part of Russia are concerned, the content of cobalt therein ranges from 0.1 to 2.2 mg/kg [2]. The distribution of cobalt throughout the herbs under investigation is rather uniform: for the majority of species (81 %) the content of the element varies within the range of 0.42–0.77 mg/kg, *i. e.* the difference amounts to only 1.8 times. The content of cobalt in the same plant species growing under different conditions exhibits a 1.4-fold difference for the greater burnet (*Sanguisorba officinalis*) (0.52–0.72 mg/kg) and the *Galium verum* L. (0.54–0.76 mg/kg), a 1.6-fold difference for the field horsetail (*Equisetum arvense*) (0.55–0.86 mg/kg), as well as up to 3.0-fold difference for the wormwood sage (*Artemisia frigida*) (0.26–0.77 mg/kg).

The content of cobalt in herbs on the average amounts to 0.55 mg/kg for the arid steppe landscapes, 0.59 mg/kg for the underhumidity meadow landscapes, and 0.70 mg/kg for the normal humidity meadow landscapes. As far as the plants of the lowland swamp meadow landscapes are concerned, cobalt has not been found out therein, in the same manner as in peaty soil where these plants grow. Cobalt could be attributed to the elements exhibiting weak absorption: BAC < 1.0 is demonstrated for the majority of cobalt determinations.

Molybdenum

The content of molybdenum in herbs of Transbaikalia varies within the range of 0.21–7.0 mg/kg, which exceeds to a considerable extent this parameter value for the herbs of the European part of Russia (0.2–2.5 mg/kg) [2]. The minimal content of molybdenum is registered for the cowberry (*Comarum palustre*), the nosebleed (*Achillea millefolium*) and in the water shamrock (*Menyanthes trifoliata*) – 0.21, 0.30 and 0.36 mg/kg, respectively (under the conditions of the European part in the cowberry (*Comarum palustre*) molybdenum was not found out). The maximal content has been revealed in the melilot sp. (*Melilotus suaveolens* Led.), the fleawort (*Galium verum*) and in the greater burnet (*Sanguisorba officinalis*) (7.0, 3.8 and 2.88 mg/kg, respectively).

The content of molybdenum in the same species of the plants growing under different conditions, differ from each other within 2.0 times for the thoroughwax sp. (*Bupleurum scorzonerifolium* Willd.) (0.86–1.74 mg/kg), within 2.2. times for the fleawort (*Galium verum*), (1.74–3.8 mg/kg), 2.4 times for the greater burnet (*Sanguisorba officinalis*) (1.20–2.88 mg/kg), 4.5 times for the wormwood sage (*Artemisia frigida*) (0.51–2.3 mg/kg), and within 4.6 times for melilot sp. (*Melilotus suaveolens* Led.) (1.52–7.0 mg/kg). For different species of plants under the same conditions the difference in the content of molybdenum amounts up to 3.0 times: for the pink sp. (*Dianthus versicolor* Fisch.) its content is equal to 0.61 mg/kg, for the fleawort (*Galium verum*) 1.74 mg/kg, for the greater burnet (*Sanguisorba officinalis*) 1.80 mg/kg. The average content of molybdenum in the herbs of the arid steppe landscapes amounts to 1.63 mg/kg, for the underhumidity meadow landscapes 1.99 mg/kg, for the normal humidity meadow landscapes 2.38 mg/kg, and for the lowland swamp meadow landscapes this value is equal to 0.29 mg/kg. One can see that the minimal content of molybdenum is inherent in the herbs of the lowland swamp meadow landscapes being 5.6–8.2 lower in comparison with its content in the plants growing within other landscapes. Thus, the total content of molybdenum in peaty soil of this landscape is 2–5 times higher than that in mineral soils of other landscapes. This fact could be caused by a low availability of molybdenum for the plants growing under the conditions of peaty soil, which is indicated by to a low value of BAC (0.4). To all appearance, it is connected with an antagonistic influence upon molybdenum exerted by iron and manganese, whose content in peaty soil is much higher, and, moreover these elements exist in an easily accessible form therein. As far as other landscapes are concerned, under the conditions of mineral soils molybdenum belongs to the group of elements those exhibit intense absorption: for the plants growing within the arid steppe landscapes the molybdenum BAC on the average amounts to 9.5, for the plants of the underhumidity meadow landscapes BAC = 8.4, for the normal humidity meadow landscapes this value is equal to 14.8.

There is a moderate positive correlation between the content of molybdenum in plants and soils for revealed the arid steppe landscape and the normal humidity meadow landscapes (r = 0.33, 0.36) and a weak negative correlation observed for the underhumidity meadow landscapes ($r = -0.18$).

Chromium

The content of chromium in the herbs of Transbaikalia varies within the range of 0.74–19.2 mg/kg, amounting to 0.16–8.4 mg/kg for the herbs of the European part of Russia [2]. According to data presented in [14], a very high content of chromium was revealed in medicinal plant raw material: 56.4 mg/kg for the trefoil (*Menyanthes trifoliata*) grass, 78.1 and 47.4 mg/kg for the briquettes of the field horsetail and nosebleed grass, respectively. The minimal content of chromium is established for the nosebleed (*Achillea millefolium*), the silverweed cinquefoil (*Potentilla anserina*) and thoroughwax sp. (*Bupleurum scorzoneraefolium* L.) being of 0.74, 0.89 and 0.98–1.16 mg/kg, respectively. The maximal content of chromium is revealed in the meadow clover (*Trifolium pratense*) (19.2 mg/kg), the common plantain (*Plantago major*) (7.98–17.8 mg/kg), sharp dock (*Rumex acetosa*) (13.4 mg/kg) and the *Panzerina lanata* L. (4.38 mg/kg). These plants could be attributed to the group of chromium concentrators.

The content of chromium in the same species of plants growing under different conditions, varies within 1.3 times for thoroughwax sp. (*Bupleurum scorzoneraefolium* L.) (0.92–1.16 mg/kg), within 1.5 times for the wormwood sage (*Artemisia frigida*) (1.53–2.24 mg/kg), within 2.2 times for the melilot sp. (*Melilotus suaveolens* Led.) (0.70–1.5 mg/kg), within 2.8 times for the greater burnet (*Sanguisorba officinalis*) (1.3–3.6 mg/kg), within 4.0 times for the *Galium verum* L. (1.68–6.8 mg/kg). Data concerning the accumulation of chromium by different species of plants growing within the same biotope exhibited a 6.6-fold difference and amounted to the following values, mg/kg: the sharp dock (*Rumex acetosa*) 13.4, the *Galium verum* L. 2.03, the caraway (*Carum carvi*) 2.07. The average content of chromium in the herbs for the arid steppe landscapes amounts to 1.91 mg/kg, for the underhumidity meadow landscapes 3.06 mg/kg, for the normal humidity meadow landscapes it is equal to 4.68 mg/kg. In the herbs of the lowland swamp meadow landscapes chromium was not revealed due to the fact that this element can form strong chemical bonds with organic substances of peaty soil. Moreover, the content of chromium in peaty soil is 2.9–9.8 times lower than in mineral soils (10 and 29–98 mg/kg, respectively).

Chromium could be attributed to the group of elements those exhibit a low intensity of absorption: for the majority of chromium determinations BAC < 1.0. On the average the BAC value of chromium for plants of the arid steppe landscapes is equal 0.48, for the underhumidity meadow landscapes 0.54, for the normal humidity meadow landscape 0.49. For five determinations with a high content of chromium in plants BAC > 1.0 (1.6–5.0).

As far as chromium is concerned, a moderate positive correlation has been revealed within the plant-soil system for the normal humidity meadow landscapes ($r = 0.31$), whereas a weak negative correlation is observed for the arid steppe landscape and the underhumidity meadow landscapes ($r = -0.10, -0.07$).

CONCLUSION

A considerable non-uniformity is revealed in accumulation of microelements by herbs, which is caused both by the physiological importance of elements, biological features of plants coupled with the selectivity of absorbing them from the nutrient medium, and by the ecogeochemical factors determining the bioavailability of these elements. The content of microelements in herbs vary mainly within the following ranges (expressed in mg/kg of dry solid matter): several tenth for Co, several units for Mo, Cr, from several units to several tens for Cu, several tens for Zn, several tens – several hundred for Mn, several hundred – several thousand for Fe. The order of biogeochemical structure of these microelements in herbs could be presented in the following form: Fe > Mn > Zn > Cu > Cr > Mo > Co.

Plants those accumulate microelements in significant amounts are revealed as it follows: British inula (*Inula britannica*), *Panzerina lanata* (L.) Sojak, silverweed cinquefoil (*Potentilla anserina*) (Fe); water shamrock (*Menyan-*

thes trifoliata), cowberry (*Comarum palustre*) (Mn); cowberry (*Comarum palustre*), wormwood sage (*Artemisia frigida*) (Zn); *Galium verum* L., meadow clover (*Trifolium pratense*) (Cu); meadow clover (*Trifolium pratense*) , common plantain (*Plantago major),* sharp dock (*Rumex acetosa*), field horsetail (*Equisetum arvense*) (Cr); melilot sp. (*Melilotus suaveolens* Led.) (Mo).

It has been established that for the same plant species growing under different ecological conditions the content of microelements varies over a wide range, whereas different plant species within the same biotope accumulate different amounts of microelements.

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