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Ecological and Biogeochemical Evaluation of Elements Content in Soils and Fodder Grasses of the Agricultural Lands of Siberia

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Abstract

The data about the content of macro - and microelements in main types of soils and types of forage herbs on the agricultural lands of agricultural and industrial districts of the southern Siberia have been presented by ecological and bio- and geochemical criteria. The work is aimed at analyzing the results of the study and assessing the content of macro - and micro-elements in main types of soils and types of forage herbs on farmland of agricultural and industrial areas of the southern Siberia and their influence on animal health by ecological and bio- and geochemical criteria. Total (gross) content of macro- and microelements (As, B, Ba, Be, Ce, Co, Cr, Cu, Fe, Ga, La, Mn, Mo, Nb, Ni, P, Pb, Se, Sn, Sr, Ti, V, Y, Yb, Zn, Zr) in samples of soil was determined by the method of optical atomic emission spectrometry with the use of a double-jet argon plasmatron. In nitric-acid solutions of plants ash, K, Na, P, Ca, Mg, Li, Fe, Mn, Zn, Co, Cu, Pb and Cd were determined by flame atomic absorption spectrometry (FAAS) on an AAnalyst400 (Perkin Elmer) spectrometer. The result of the studies has shown that in soils and fodder herbs of agricultural districts of Siberia, the content of heavy metals - Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Zn, Sr - does not exceed the environmentally acceptable levels. In herbs, the concentration of Co, Cu, Mo and Zn was less than the values of the biogeochemical norm required for farm animals. It does not correspond to the Ca/Sr ratios in gramineous grasses and especially in legumes on the saline soils of the forest-steppe and steppe, as well as the Ca/P ratios in perennial and annual gramineous grasses, which may result in poor animal health, the quantity and the quality of their products. In industrial districts of Kuzbass, the dependence of heavy metals concentration in forage herbs of farmland on the level of gas-and-dust pollution of the environment by a metallurgical company has been determined. In the territory of the Republic of Tuva, in the areas of extraction of non-ferrous metal ores with local areas of technogeneous contamination of soils, plants and waters with heavy metals, pathologies in development and higher perinatal death of yaks were detected, as compared to the environmentally safe locations of their breeding.

Keywords: trace elements, heavy metals, soils, forage grass, animals, environmental safety, mineral usefulness.

INTRODUCTION

There is a widely-known sophism, which has long been used as a household joke – "we are what we eat". However, scientific achievements of the last two or three decades have shown the important role of food quality as a factor of humans and domestic animals' health and longevity. The problem of balanced and high-quality food has become especially urgent due to the results of the epigenetic research, which showed that the most genes are not autonomous, as the classical theory of heredity used to state, but have a dynamically regulated expression with highly complex and multilevel organization of regulation. However, correct functioning of the latter largely depends on the quantitative and qualitative composition of available metabolites at various stages of individual development. With that, nutrients may change gene expression and result in serious diseases in both direct descendants and subsequent generations [2; 13].

Therefore, high-quality and balanced in the elemental and biochemical composition food is rightly considered to be a key to human health. Ensuring it is the basis of the food supply and ecological safety of the country that requires production of high-quality environmentally clean agricultural products of livestock and crop breeding. Most part of the latter is used for fodder production, associating crop breeding, agriculture, farming, ecology, environmental management and environmental protection into a single system [16]. The most important condition for normal functioning components of this system is providing vital macro- and microelements (biofriendly, essential) for plants and animals, and eventually to humans, in sufficient and balanced amounts [7; 15]. Besides, it is necessary to stop excessive inflow of pollutants, primarily derived from heavy metals and poisons of organic origin, into the soil, plant and animal products [9].

Siberia has a huge potential for developing ecological animal breeding and fodder production [16; 18; 21; 22]. However, its use is restricted by the regional natural soil-and-agrochemical and ekological-and-bio-geochemical peculiarities of its territory [10-12; 25], as well as by the developing agrogeneous and technogeneous degradation of the soil and the vegetation cover of soils in farmland, including due to their contamination with heavy metals and radionuclides [12; 24].

The work is aimed at analyzing the results of the study and assessing the content of macro - and microelements in main types of soils and types of forage herbs on farmland of agricultural and industrial areas of the southern Siberia and their influence on animal health by ecological and bio- and geochemical criteria.

OBJECT AND METHODS

The macro- and microelement content in soils and plants in natural and man-made hayfields and pastures, arable land in various climatic zones and sub-zones of the southern Siberia was studied by periodic inspection (monitoring) in the period between 2008 and 2016. The research covered agricultural and industrial regions, from the southern taiga to the steppe, from the South-West of Western Siberia - Northern Urals (the Tobol-Ishim interfluve area in the Tyumen region) to the South of Central Siberia (Tuva). In the studied territories, most agricultural lands feature pollution close to the background, with the exception of the Kuznetsk basin (Kuzbass), where they are often under the influence of strong anthropogenic gas-and-dust pollution.

The botanical composition of the studied forage herbs was diverse, and was represented by species of plants belonging to the *Poaceae*, *Fabaceae*, *Rosaceae*, *Rubiaceae*, and Asteraceae families. In the hayfields and pastures, the plants were divided by dominant species into cereals and legumes of families (*Poaceae Fabaceae*), which are significantly different in their need for nutrition elements, the ability to absorb from the soil, and, consequently, by the elemental chemical composition of plant products. The composition of the analysed types of fodder grasses was dominated by: in the Tobol-Ishim interfluve area, of the Poaceae family – *Bromopsisinermis* (Leys.) Holub, *Phleum pratese* L., *Elytrigia repens* (L.) Nevski, *Festuca pratensis* Huds., *Calamagrostis arundinacea* (L.) Roth; of the *Fabaceae* family – *Trifolium medium* L., *Trifolium gybridum* L., *Lathyrus pratensis* L., *Vicia amoena* Fisch.; in the Northern forest-steppe of the Barabinskaya lowland, of the Poaceae family – *Bromopsis inermis* (Leys.) Holub, *Phleum pratese* L., *Elytrigia repens* (L.) Nevski; of the family *Fabaceae* - *Trifolium medium* L., *Lathyrus pratensis* L.; *Rubiaceae* in the southern forest-steppe of the Barabinskaya lowland and the Kulundinskaya steppe with kolkis of the *Poaceae* family – *Bromopsis inermis* (Leys.) Holub, *Poa pratensis* L., *Elytrigia repens* (L.) Nevski, *Cleistogenes by* (Trin.) Keng family *Fabaceae* - *Medicago falcate* L.*, Astragalus sulcatus* L.

In the absence of clear predominance of legumes or gramineous grasses in the hayfields and pastures, hay composition was classified as mixed herbs, and the mowing was analyzed and assessed as a whole, without dividing it into separate species. In Ulug-Chemsk basin of the Republic of Tuva, samples of mixed-herbs hay were represented by a mixture of species *Bromopsis inermis* (Leys.) Holub, *Stipasibirica* L. (Lam.), *Artemisiascoparia* Waldst. Et Kit., *Carexobtusata* Liljebl., *Medicagofalcate* L.a,d and in the Kuznetsk basin (Kuzbass) - mainly by *Viciacracca* L., *Dactylisglomerata* L. Mixtures of annual herbs grown for silage were mainly represented by *Avenasativa* L. and *Triticumaestivum.* For the purpose of comparable assessment of soils and forage plants from various regions, their samples were taken in the period when plants accumulate the highest values of aboveground biomass and concentration of macro- and microelements - during the phase of flowering or milk ripeness of grain, at the beginning of harvesting. The influence of technogeneous pollution on the elemental chemical composition (ECC) of plants was studied in the Novokuznetsk district of the Kemerovo region.

In the hayfields and pastures, the vegetation cover, the botanical composition of plants, and the productivity were studied by the method of sample plots with the size of 100x100 cm. The plots were laid in the most typical areas of vegetation cover in the studied area in the number of at least 5. In each plot, plants were cut at the height of 5 cm from the ground, sorted by species, and weighed separately. Next, the plants were packed into paper for subsequent analysis of their chemical composition. Individual soil samples were taken at 5 points in the area, from the 0-20 cm deep layer, and after mixing, a combined sample was made.

In arable lands 5 100x50 cm sample plots were laid in each area. The crops sown for silage, mainly wheat and oats, were cut at the height of 5-10 cm from the ground. Of 15-25 plants taken in various parts of the plot, mixed plant samples were made. The mixed soil samples were taken in the same way as in the natural hayfields - from the 0-20 cm deep layer.

The air-dried plant samples were crushed with steel scissors and cindered in a muffle at the temperature of 450^{o}C. The air-dried soil samples were ground in a porcelain mortar and sieved through a 1 mm sieve. The samples of ash of plants and soils weighing 100 mg, were previously processed in an agate mortar to powder (> 0.01 mm). The total (gross) content of macro- and micro-elements (As, B, Ba, Be, Ce, Co, Cr, Cu, Fe, Ga, La, Mn, Mo, Nb, Ni, P, Pb, Se, Sn, Sr, Ti, V, Y, Yb, Zn, Zr) in such samples was determined by the method of optical atomic emission spectrometry with the use of a double-jet argon plasmatron [4]. In nitric-acid solutions of plants ash, K, Na, P, Ca, Mg, Li, Fe, Mn, Zn, Co, Cu, Pb and Cd were determined by flame atomic absorption spectrometry (FAAS) on an AAnalyst400 (Perkin Elmer) spectrometer.

Calibration of instruments and accuracy of quantitative determination in the samples of plants and soils of the studied chemical elements were checked according to the certified values of their mass fraction in the standard samples. These include: SSS No. 1485-78 "Ash of gramineous herb mixture" SBMT-1; SSS No. 3170-85 "Ash of gramineous herb mixture" SBMT-2; SSS No. 184-78 "Ash of wheat grain" SBMP-1; SSS No. 3171-85; "Ash of wheat grain" SBMP-2; SSS Sod-podzolic sandy loam soil – SPDS-1 No. 2498-83; SPDS-2 No. 2599-83; SPDS-3 No. 2500-83.3; SSS Typical chernozem – SCT-1 No. 2507-83; SCT-2 No. 2508-83; SCT-3 No. 2509-83; SSS carbonate gray soil – SSK-1 No. 2504-83; SSK-2 No. 2505-83; SSK-3 No. 2506-83. The relative error for the quantitative determination of elements in samples of soils and plants was within 10%.

The results of determining element content in plant and soil samples were calculated for absolutely dry substance (a.d.s.). For each set of samples taken from the studied agricultural lands (meadows, hayfields and pastures, arable land) of Siberia, the arithmetic mean values of the total element content and its standard deviation have been calculated.

RESULTS OF THE RESEARCH

The obtained results clearly confirmed the presence of boric salinization or boric biogeochemical province with the excess of boron in soils, waters and plants in the region of the South of Western Siberian plain [12], therefore, boric enteritis is observed in herbivores observed in salinized pastures. Here, on the Vasyugan plateau, the Barabinskaya lowland and the Kulunda plains (Table 1), the total content of boron in the soil exceeds its average concentration in the sediment [8] and in soils of the world [14], and the upper limits of agro-chemical and biogeochemical norm – 33 and 30 mg/kg, respectively [7; 12; 17]. In the territory of the Tobol-Ishim interfluve area and in the Republic of Tyva, soils turned out to be less rich in boron and other in micro-elements, mainly due to the light loamy granulometric composition of the soil (Table. 1).

Table 1. Total content of iron (in %) and micro-elements (in mg/kg) in the soils of agricultural lands in various regions of Siberia

Zone Indicator	1	2	3	4	5	6
Meadows						
n	12	16	12	12	15	5
B	26±2	56±3	62±8	86±21	91±24	19±2
Cd	0.3±0.1	0.3±0.1	0.3±0.1	0.3±0.1	0.2±0.1	0.3±0.1
Co	10±3	16±2	16±4	12±3	8±2	9±2
Cr	87±27	89±11	96±17	72±5	52±17	43±5
Cu	36±2	45±3	36±8	30±8	26±9	15±2
Fe,%	0.90±0.20	1.90±0.40	2.90±0.40	2.50±0.70	2.20±0.50	1.88±0.41
Mn	1508±966	851±162	851±163	974±188	593±93	290±42
Mo	1.9±0.7	3.7±0.4	3.1±0.6	2.5±0.6	1.6±0.3	1.9±0.3
Ni	24±5	44±10	50±7	41±7	30±8	17±7
Pb	15±3	22±3	15±3	16±3	13±4	9±3
Zn	46±9	74±11	74±12	67±12	59±18	34±14
Sr	102±35	175±33	286±71	344±130	254±96	267±46
Arable lands						
n	7	7	6	10	7	2
B	28±4	54±4	58±6	55±10	44±6	22±4
Cd	0.2±0.1	0.2±0.1	0.2±0.1	0.2±0.1	0.2±0.1	0.4±0.2
Co	9±3	14±1	15±2	11±3	8±3	13±2
Cr	77±14	100±14	99±15	58±11	48±13	54±7
Cu	32±13	38±5	35±4	30±10	22±8	27±2
Fe,%	0.88±0.10	1.82±0.20	3.30±0.80	2.00±0.50	2.00±0.40	3.42±0.27
Mn	1056±579	743±140	774±179	570±193	510±58	457±134
Mo	2.5±0.6	2.8±0.3	3.0±0.5	2.3±0.2	1.3±0.2	1.8±0.2
Ni	21±4	40±7	46±5	36±11	28±6	27±12
Pb	12±6	18±3	19±2	15±4	11±4	14±2
Zn	48±19	70±10	58±7	59±17	48±14	46±9
Sr	127±47	160±14	186±33	168±45	204±45	188±23

Note:
Zone 1 – Western Siberia, Trans-Urals - the Tobol-Ishim interfluve area, sub-taiga, gray forest and sod-podzolic light loamy soils
Zone 2 – Western Siberia, the Vasyugan plateau, southern taiga, sod-podzol heavy-loamy soils
Zone 3 – The Barabinskaya lowland, northern forest-steppe, meadows in the chernozem-meadow saline soils and alkaline soils, arable lands in leached and ordinary chernozems
Area 4 – Western Siberia, the Barabinskaya lowland, southern forest-steppe, hay from saline soils, silage from ordinary chernozems
Area 5 – Western Siberia, the Kulundinskaya plain, steppe with kolkis, hay from saline soils, hay from southern chernozems
Zone 6 – The Ulug-Khemskaya basin of the Tuva Republic, southern chernozems and light loamy chestnut soils

Table 2. Content (in mg/kg of absolutely dry substance (a.d.s.)) of chemical elements in coarse forage in various zones of Western Siberia

Zone Indicator	1	2	3	4	5	6
Hay of gramineous herbs						
n	11	16	11	12	16	–
B	5±1	4±1	11±3	7±1	12±4	–
Cd	0.2±0.1	0.2±0.1	0.1±0.0	0.1±0.0	0.1±0.0	–
Co	0.1±0.0	0.1±0.0	0.2±0.1	0.2±0.0	0.3±0.1	–
Cr	0.1±0.0	0.1±0.0	0.4±0.1	1.0±0.2	0.6±0.2	–
Cu	3±1	3±1	8±1	4±1	5±1	–
Fe	55±17	38±11	49±5	87±18	86±16	–
Mn	70±15	46±10	20±5	44±9	39±7	–
Mo	0.1±0.0	0.4±0.1	0.6±0.1	0.9±0.2	0.9±0.1	–
Ni	1.5±0.6	0.9±0.2	1.0±0.2	0.7±0.2	1.4±0.3	–
Pb	0.2±0.0	0.1±0.0	0.8±0.2	0.4±0.2	1.1±0.2	–
Zn	8±1	10±2	17±3	14±4	19±3	–
Ca/Sr	102±15	133±21	34±7	52±3	65±15	–
Ca/P	0.2±0.1	0.2±0.1	0.6±0.2	0.5±0.1	0.3±0.1	–
Hay of leguminous herbs						
n	12	15	8	11	15	–
B	19±5	18±5	26±5	18±3	31±7	–
Cd	0.2±0.1	0.2±0.1	0.1±0.0	0.1±0.0	0.1±0.0	–
Co	0.3±0.1	0.2±0.0	0.3±0.1	0.3±0.0	0.4±0.1	–
Cr	0.4±0.1	0.4±0.1	0.5±0.2	1.5±0.2	1.1±0.4	–
Cu	8±1	6±1	9±2	6±2	12±1	–
Fe	54±4	57±11	84±15	84±13	123±25	–
Mn	78±10	38±8	25±8	26±6	27±7	–
Mo	0.7±0.1	0.8±0.2	2.0±0.4	1.2±0.4	1.2±0.4	–
Ni	1.5±0.6	2.3±0.7	1.4±0.5	1.0±0.3	2.1±0.6	–
Pb	0.9±0.1	0.5±0.1	1.5±0.3	0.7±0.2	1.8±0.7	–
Zn	9±2	16±3	27±4	17±3	23±4	–
Ca/Sr	78±10	118±12	19±5	33±6	39±14	–
Ca/P	0.2±0.1	2.5±0.5	1.6±0.3	1.6±0.2	1.5±0.4	–
Wheat-and-oats haylage						
n	–	7	6	10	7	3
B	–	2±1	4±1	2±1	14±2	5±2
Cd	–	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0
Co	–	0.1±0.0	0.2±0.1	0.1±0.0	0.3±0.1	0.1±0.01
Cr	–	0.3±0.1	0.3±0.1	1.2±0.2	0.6±0.2	0.3±0.1
Cu	–	4±1	4±1	3±1	7±1	3±1
Fe	–	58±12	86±12	36±6	53±3	53±3
Mn	–	61±10	54±11	30±7	23±3	27±3
Mo	–	0.3±0.1	0.4±0.1	0.7±0.1	0.5±0.1	0.3±0.1
Ni	–	2.0±0.1	1.8±0.2	1.2±0.3	1.4±0.2	0.5±0.1
Pb	–	0.6±0.1	0.8±0.1	0.2±0.1	0.8±0.2	0.6±0.2
Zn	–	23±6	24±6	18±5	31±6	18±1
Ca/Sr	–	148±12	104±12	88±10	70±4	-
Ca/P	–	0.2±0.1	0.4±0.1	0.3±0.1	0.1±0.0	-

The results of studying the content and the ratio of chemicals in fodder herbs in the hayfields and arable lands showed unfavorable situation with their mineral usefulness and safety as forage (Table 2).

The reasons are the following. First, in most forage herbs, concentration of cobalt, copper, molybdenum, and zinc was less than the lower critical value (threshold) of the biogeochemical concentration level [1; 7; 17; 20]. Such lack of micronutrients in the diet of animals will, with a high degree of probability, result in diseases. Second, in some fodder grasses, an adverse (less than the biogeochemical norm) calcium to strontium (Ca/Sr) and calcium to phosphorus (Ca/P) rate is observed, which can also cause diseases in animals. In the agricultural areas of Siberia, no significant excess of the maximum permissible level (MPL) of heavy metals has been detected in forage herbs according to the Russian criteria, as well as the maximum permissible concentration (MPC), by foreign criteria (Table 2). We associate some increase in the chromium MPL in forage herbs of the forest-steppe of the Barabinskaya lowland and the steppe of the Kulundinskaya plains with contamination of grass forages with soil dust, rather than with the technogeneous pollution of plants with chromium or its increased absorption by the plants, though the mobility of chromium in saline soils contributes to their slightly alkaline reaction of the environment.

Studies have shown a significant difference between gramineous plants (*Poaceae*) from leguminous plants (*Fabaceae*) by the ECC (Table 2). Leguminous plants accumulate B, Co, Cr, Cu, Mo, Ni, P more than gramineous ones, and have lower values (closer to the negative) of the Ca/Sr ratio and high values of Ca/P ratio [7; 12]. The latter is due to a considerable accumulation of calcium by leguminous plants. The unfavorable Ca/P ratio in cereals may be caused by lack of calcium, rather than by excess of phosphorus in plants; lack of the former, along with the lack of magnesium, is observed not only in Siberia, but in other regions of Russia and the world as well.

Close to industrial enterprises, their gas and dust emissions have significant impact on life and ECC of plants. This is well demonstrated by the results of studying ECC of meadow grasses of hayfields and pastures in close proximity to a ferrous metallurgy enterprise in the South of Kuzbass – in the Novokuznetsk district of the Kemerovo region (Table 3). In the territory with high level of dust pollution of environment, vegetation in the sanitary-protective zone of the metallurgical plant was too much dusted with anthropogenic particles rich in iron, the amount of which in hay exceeded the MPC 2 times (Table 3). In addition, significant excess of background concentrations of heavy metals has been identified in the hay of herbs: for iron - 40 times, for chromium and nickel - 10 to 14 times, for zinc and cobalt - 3 to 5 times. Excess of the MPL of metals in hay was for iron - 20 times, for chromium - 25 to 30 times, for nickel - 4 to 6 times, for zinc and cobalt - 2 times and more. Such hay can be dangerous to the health of animals, since many metals have cumulative synergistic action – the presence of one of them increases the toxic effect of another [7]. Outside the sanitary protection zone of the enterprise on the territory with the average level of dust pollution of the environment, the environmental conditions for growing plants and forage production were better, although excessive background levels and MPL of iron and nickel were detected in hay (Table 3). Such content is typical for forage grasses in the areas with similar (average) level of dust pollution in other industrial centers of the region, and is close to the average content of these elements in terrestrial vegetation [26].

In the unfavorable areas of the Republic of Tuva, cadmium content in the soil was 3 times higher (0.50±0.15 mg/kg) than in conditionally clean areas. In separate areas, cadmium content in the soil reached 0.89-0.95 mg/kg. In the pastures with chestnut type of soil, lead content in the polluted area reached 900 mg/kg (MPC being 32 mg/kg), and zinc content - 61 mg/kg (MPC being 55 mg/kg). In the same territory, concentration of cadmium in water was 2 times above the MCL (0.002±0.0003 mg/kg), and concentration of lead - 1.3 times (0.04±0.01). In the polluted area of the Republic of Tuva, the content of Cd in forage grain exceeded the MPC 1.3 times (0.40±0.06 mg/kg). In the polluted area, there were much less (73.0±3.0%) healthy yaks without affected cardiovascular system than in the conventionally clean zone (98.0±1.3%). In the conventionally pure areas, there were more yaks without diseases of the distal limbs (98.1±1.2) than in the polluted areas (84.4±2.7) [Chysyma et al., 2003]. Perinatal mortality in yaks in the area of anthropogenic pollution was 24.0±3.0%, whereas in the conditionally clean area, it was 6 times lower (4.0±2.0%). Pollution affected the immune status of the newborn yaks. In 45±8.0% of heads, concentration of immunoglobulins was very low (less than 5 mg/ml). In the conditionally clean area, there were no newborn yaks with such status [Chysyma et al., 2003a].

Table 3. Concentrations of micro-elements in the hay from meadow herbs with various levels of technogeneous pollution of the atmosphere by metallurgical enterprises of Kuzbass, mg/kg a.d.s.

Indicator	Background (conventionally clean) territory	Territory with average level of technogeneous gas and dust pollution	Territory with high level of technogeneous gas and dust pollution
n	12	12	12
Fe	52±12	221±110	2.024±685
Cd	0.11±0.04	0.15±0.06	0.15±0.08
Co	0.78±0.09	0.98±0.24	2.23±0.25
Cr	1.0±0.3	2.7±0.5	14.2±7.8
Cu	3.1±0.3	4.5±1.7	4.5±1.4
Mn	54±15	65±23	71±18
Ni	1.5±0.4	4.4±2.8	14.2±6.2
Pb	0.44±0.27	0.47±0.28	0.76±0.32
Zn	30.0±1.2	22.6±5.8	134.9±3.1

DISCUSSION

In the world and in Russia, two problems are becoming increasingly important - depletion of soil fertility in the agricultural lands, on the one hand, and pollution of the environment with technogeneous pollutants, on the other hand [18; 21; 22]. This, in turn, affects health and productivity of plant and animal organisms [3; 14; 20]. Especially dangerous are heavy metals with high translocation and toxicity that contaminate forage and meat and dairy food products [27; 28].

Studying the ECC of soils and plants in the agricultural lands of the southern Siberia, which is most developed in terms of industry and agriculture, confirmed the characterization of this part of the region as complicated from the ecological and biogeochemical point of view [10-12; 25].

In general, soils of farmlands in the agricultural (relatively clean) regions of Siberia have the level of total content of microelements within the agrochemical and biogeochemical standards. The only exception is boron.

With that, the concentration of microelements - heavy metals - does not exceed the maximum allowable or approximate allowable values (MPC or APC, respectively). Thus, in terms of the hygienic (ecological), agro-chemical and biogeochemical criteria, the studied soils of farmlands in the agricultural areas of Siberia guarantee environmental safety of plant forage [18; 19]. However, due to the progressive exhaustion of soils, they are not always able to satisfy the needs of crops for macro- and microelements, and mineral usefulness of their products.

The obtained data about evaluation of ECC of forage herbs in the farmlands of the southern Siberia are characteristic of Russian and the entire world – lack of copper and zinc is detected everywhere, and only contamination by lead, cadmium and other heavy metals is observed locally [1; 3; 7; 9; 12; 14-17; 20].

In whole, studying the ECC of forage plants in the agricultural areas of Siberia bespeaks of its dependence on both the physiological need of plants for mineral nutrition elements and the ability to absorb them from the soil, and on the landscape-geochemical specifics of the chemical elements content in the soil, their mobility, level of soil fertility and their changing trends. The latter is negative, since degradation of soil fertility is observed everywhere due to increased deficiency of Ca, Mg, P, Cu, Zn and other essential macro- and microelements. In addition, plants' ECC is affected by synergism and antagonism of the elements manifested in soils, plants, and in the soil-plant system.

In the conditions of technogeneous environmental pollution, the monitoring of heavy metals concentrations in soils and plants plays an important role in identifying adverse changes in soil and properties of forage crops, since it affects health of animals and the environmental safety of their products, and, eventually, the quality of human life. The latter is true for the most part of farmlands in the industrially developed Kuzbass, where local catastrophic technogeneous environmental pollution is observed, as well as destruction of the soil and the vegetation covers, and for some areas in Tuva - with technogeneous geochemical anomalies in the areas of development of nonferrous metals deposit.

It should be noted that in the studied area of moderate influence of the metallurgical plant on the environment, no high concentrations of heavy metals that may be dangerous for animals have been found in hay; on the contrary, copper and zinc content in it was less than the critical limit of their content in plant forage. Deficiency and excess of copper and zinc in the forage affect their concentration in organs and tissues of animals, and may be negative for them [21, 22]. Thus, not only excess, but lack of vital metals in plants is possible in the technogeneously contaminated territories. Therefore, in Kuzbass and in other industrial centers of Siberia, where farmlands are located in the areas of strong and moderate technogeneous contamination of the environment, its influence on the environmental safety and mineral usefulness of plant forage in the farmland, and on the health of farm animals should be comprehensively studied. As our study has shown, this also applies to other types of plant products [12].

In some regions of the Republic of Tuva, soil and vegetation covers are predominantly environmentally clean. However, there are territories where the soil, plants and water are contaminated due to extraction of non-ferrous metals and uncontrollable ingress of heavy metals into the environment after closing industrial enterprises [5; 6; 23]. In such territories, diseases of animals caused by the negative influence of heavy metals have been detected.

Thus, environmental pollution results in reduced resistance of animals to diseases, increased perinatal mortality, and reduced immunity.

CONCLUSIONS

1. In most agricultural soils of the agricultural districts of Siberia, the total content of microelements, including heavy metals, is within the agrochemical and biogeochemical norms, and does not exceed their maximum or approximate permissible concentrations.
2. Fodder grass in the farmlands of the agricultural areas of Siberia are mostly not polluted by heavy metals. On the contrary, deficiency of some essential microelements in plants, and especially in animals is observed, such as Co, Cu, Mo, Zn. Since deficiency of these microelements in the forage herbs may cause diseases in animals, thus, evaluation and correction of the mineral usefulness of their diet is urgent.
3. In territory of Siberia, close to the industrial enterprises, especially of black and nonferrous metallurgy, technogeneous geochemical anomalies with dangerously high concentrations of heavy metals in soil and plants are observed. Animals that breed in the contaminated areas have increased prenatal mortality and significant health deterioration.

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