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УМЕРЕННО ОПАСНЫЕ МИКРОЭЛЕМЕНТЫ В ПОЧВАХ ЗАСОЛЕННЫХ АГРОЛАНДШАФТОВ БАРАБИНСКОЙ РАВНИНЫ

(✉) **[1]Семендяева Н.В., [1,2]Морозова А.А., [2]Елизаров Н.В.**
[1]*Сибирский федеральный научный центр агробиотехнологий Российской академии наук*
Новосибирская область, р.п. Краснообск, Россия
[2]*Институт почвоведения и агрохимии Сибирского отделения Российской академии наук*
Новосибирск, Россия
(✉) e-mail: semendyeva@ngs.ru

При освоении адаптивно-ландшафтных систем земледелия особое внимание уделяется изучению эколого-токсикологического и санитарно-гигиенического состояния используемой территории. Особенно это важно для засоленных агроландшафтов, которые широко распространены в Барабинской равнине (Барабе). Исследования проведены в северо-восточной части Барабы в пределах Новосибирской области. Изучены почвы элювиальной (лугово-черноземной), транзитной (черноземно-луговой) и аккумулятивной (солонец глубокий) зон катены. Почвы различались по физико-химическим свойствам и микроэлементному составу. В профиле почв от элювиальной к аккумулятивной зоне увеличивалась щелочность, уменьшилось содержание гумуса и изменялся гранулометрический состав. Эти показатели влияют на микроэлементный состав. Определено содержание умеренно опасных микроэлементов (второго класса опасности): хрома, никеля, кобальта и молибдена. Установлено, что максимальное содержание валового хрома приходится на профиль лугово-черноземной почвы в элювиальной позиции. В пахотном горизонте подвижного хрома менее 0,00001 мг/кг, что не попадает в диапазон определения прибора. Отмечено некоторое передвижение подвижных форм хрома с элювиальной позиции в аккумулятивную. Максимальное содержание валового никеля и кобальта обнаружено в профиле лугово-черноземной почвы, но оно находится в количестве значительно ниже ПДК. По профилю почв валовое содержание никеля и кобальта изменяется незначительно, что свидетельствует об их слабой подвижности. Валовое содержание молибдена в почвах находится в пределах кларка и примерно одинаково по всей глубине. Установлено, что в почвах засоленных агроландшафтов Барабы по катене содержание умеренно опасных микроэлементов никеля и кобальта ниже ПДК и не представляет опасности с эколого-токсикологической точки зрения. Содержание валового хрома и молибдена находится на грани ПДК, поэтому в определенных случаях может возникнуть напряженность эколого-токсикологической обстановки территории. На это следует обращать внимание при сельскохозяйственном использовании засоленных агроландшафтов.

Ключевые слова: микроэлементы, хром, никель, кобальт, молибден, катена, засоленная почва

MODERATELY HAZARDOUS MICROELEMENTS IN THE SOILS OF SALINE AGROLANDSCAPES OF THE BARABA PLAIN

(✉) **[1]Semendyaeva N.V., [1,2]Morozova A.A., [2]Elizarov N.V.**
[1]*Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences*
Krasnoobsk, Novosibirsk region, Russia
[2]*Institute of Soil Science and Agrochemistry of the Siberian Branch of the Russian Academy of Sciences*
Novosibirsk, Russia
(✉) e-mail: semendyeva@ngs.ru

When developing adaptive-landscape farming systems, special attention is paid to the study of the ecological, toxicological and sanitary-hygienic state of the territory used. This is especially important for saline agro-landscapes, which are widespread in the Barabinskaya plain (Baraba). The studies were conducted in the northeastern part of the Baraba within the Novosibirsk Region. The soils of the eluvial (meadow-chernozem), transit (chernozem-meadow), and accumulative (deep solonetz) zones of the catena were studied. The soils differed in physicochemical properties and microelement composition. In the soil profile from the eluvial to accumulative zone, alkalinity increased, humus content decreased, and the granulometric composition changed. These indicators affect the microelement composition. The content of moderately hazardous trace elements (hazard class 2): chromium (Cr), nickel (Ni), cobalt (Co) and molybdenum (Mo) were determined. It was found that the maximum content of total chromium falls on the profile of meadow-chernozem soil in the eluvial position. In the arable horizon there is less than 0.00001 mg/kg of mobile chromium, which does not fall within the detection range of the device. Some movement of mobile forms of chromium from the eluvial to accumulative position was noted. The maximum content of total nickel and cobalt was found in the profile of meadow-chernozem soil, but it is in amounts well below the LOC. The total content of nickel and cobalt varies insignificantly across the soil profile, indicating their low mobility. The total content of Mo in soils is within the clarke range and is approximately the same over the entire depth. It was found that the content of moderately hazardous trace elements of nickel and cobalt in the soils of saline agro-landscapes of Baraba by catena is below the LOC and cannot be a hazard from the ecological-toxicological point of view. The content of total chromium and molybdenum is on the verge of the LOC and therefore, in certain cases, tension in the ecological and toxicological situation of the territory may arise. This should be taken into account in the agricultural use of saline agrolandscapes.

Keywords: microelements, chromium, nickel, cobalt, molybdenum, catena, saline soil.

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INTRODUCTION

The development of adaptive-landscape farming systems and precision agriculture required the development of new, more detailed approaches to the use of soil cover of territories. These approaches should include a comprehensive study of the soil properties of a particular agrolandscape. Special attention should be paid to the microelement composition, as it determines both the fertility and the ecological and hygienic conditions of the agrolandscape.

Currently, agroecological zoning of agrolandscapes has been developed for the forest-steppe zone using the example of the Novosibirsk region[1]. In particular, it has been found that the Barabinsk plain (Baraba), which occupies about 65.5%, or 11.7 million ha of the Novosibirsk region, is dominated by saline agrolandscapes, represented by semihydromorphic and hydromorphic analogues of zonal soils (chernozems) – meadow-chernozem, black-meadow and meadow soils of various degrees

[1]Dobrotvorskaya N.I., Semendyaeva N.V., Ponko V.A., Ivanova M.I. Methodology and methods for assessing the ecological and resource potential of agrolandscapes in the Western Siberia: a methodological handbook. Novosibirsk: SFSCA RAS, 2018. 99 p.

of salinity and alkalinity in complex with saline soil, alkaline soil and solod soil.

In the study of the properties of saline soils a special place is given to trace elements - heavy metals and metalloids. They are extremely necessary in small quantities for plants, living organisms, as well as humans, because they are part of enzymes, vitamins, lipids, etc. Increased and decreased content of trace elements can cause various diseases.

The aim of the study was to study the content of moderately hazardous trace elements - chromium, nickel, cobalt and molybdenum (the second class of danger)[2] - in the soils of the katena saline agrolandscape of the north-eastern part of Baraba within the Novosibirsk region.

Research objectives:

– to study the morphological and physicochemical properties of soils by catena (eluvial, transit and accumulative positions);

– to determine the content and character of movement of moderately dangerous microelements in soils;

– to give an ecological and hygienic assessment of the content of moderately dangerous trace elements in soils of saline agro-landscapes of Baraba for animals and humans.

MATERIAL AND METHODS

The studies were carried out on the territory of JSC "Bolshenikolskoye", Chulymsky District, Novosibirsk Region. This territory is a two-stage lake-alluvial plain. Its northeastern part, where the research was conducted, belongs to the high structural-geomorphological surface, and the southwestern part to the low one.

The relief of the northeastern part of this area is represented by an alternation of ancient interfluves and runoff gullies stretching from northeast to southwest.

The interfluves are flat, elevated above the gullies by only 5-15 m. In some places, there are blurred low ridges. Small hollows in gullies can be occupied by lakes and bogs. The microrelief is knob and kettle, which facilitates redistribution of moisture and easily soluble salts from ridges to inter-ridge depressions[3].

Annual precipitation varies from 225 to 350-400 mm. Hydrothermal coefficient varies from 0.6-0.8 to 1.0-1.2. Baraba is characterized by climate cyclicity, which has a significant impact on soil composition and properties, especially on redistribution of easily soluble salts. During humid periods there is some desalinization of soil profiles and strengthening of reductive processes, in droughty periods - opposite phenomena are observed.

A characteristic feature of the vegetation cover of Baraba is the change of forest vegetation to steppe vegetation. Park-type birch knolls alternate with steppe meadows. Steppification of the territory leads to desiccation of forestland and salinization of the soil cover. Periodic over-moistening and elevation of saline groundwater contribute to development of sod formation process and formation of meadow-chernozem, chernozem-meadow and meadow soils of different degrees of gleying, salinization, as well as development of soils of halogen process of soil formation - saline soil, alkaline soil and solod soil.

In the northeastern part of Baraba in the wide valley of the Karasuk River, soil sections were laid along the catena (eluvial, transitional, and accumulative positions). In them, soil samples were selected according to genetic horizons, in which the following types of analyses were performed: granulometric composition according to Kachinsky, humus according to Tyurin, pH value according to potentiometric analysis[4]. Determination of gross and mobile forms of trace elements was carried out by atomic-emission spectroscopy on DAEP device (double-beam atomic-emission plasma torch) (see footnote 4). The mobile forms of chromium, nickel, and cobalt compounds were extracted from soils with acetate-ammonium buffer solution with pH 4.8. Statistical processing of the obtained data was performed using the Excel software package.

[2]GOST 17.4.1.02-83. Nature Conservation. Soils. Classification of Chemical Elements for Pollution Control. Moscow, 1983.12 p.

[3]Semendyaeva N.V., Galeeva L.P., Marmulev A.N. Soils of the Novosibirsk region and their agricultural use: a textbook. Novosibirsk, 2010. 187 p.

[4]Practical agrochemistry: textbook; 2nd ed. / Ed. by V.G. Mineev. Moscow: Publishing house of the Moscow State University, 2001. 689 p.

RESULTS AND DISCUSSION

When studying the ecotoxicity of trace elements in soil, it is necessary to know the pH value, humus content, and granulometric composition, since these parameters determine the geochemical properties of elements and their compounds. The characteristic of these properties of soils of katena is presented in table 1.

In the eluvial position, zonal meadow-chernozem soil has a neutral pH (6.6-6.7) up to a depth of 80 cm, and then it is alkaline. In the transitional position, the meadow-chernozem soil is alkaline throughout the profile, and alkalinity increases with depth. In the accumulative - deep solonetz - soil is strongly alkaline: in the horizon A (0-20 cm) - 9.8, then the pH is 10 or more. The content of humus is high in the A horizons of eluvial and transitional soils - 9.7 and 10.8%, respectively. In accumulative - deep solonetz - the content of humus is reduced to 5%, with depth it sharply decreases. Granulometric composition is different: in meadow-chernozem soil of eluvial position in A horizon it is medium-loamy, with depth it is heavy-loamy. In the transitional position the granulometric composition of the meadow-chernozem soil is loamy in the A horizon, then it gets heavier to light loamy and then it gets further heavier. It should be noted that such a diverse granulometric composition is characteristic of soils formed in floodplains. A similar situation is noted in the accumulative zone, but here the granulometric composition is heavier, from mid-loamy to light loamy.

The gross content of moderately hazardous chemical trace elements is presented in Table 2.

Chromium is a biogenic element that is constantly present in plant and animal cells. It participates in protein synthesis in plants and increases chlorophyll content in leaves. But chromium is a highly toxic trace element: in small amounts it is a plant stimulant, in larger amounts it is an inhibitor. In excessive amounts, chromium inhibits plant development; in very high concentrations, it causes plant death.

The phytotoxicity of chromium depends on its valence, which determines its toxicity

Табл. 1. Физико-химические свойства почв катены засоленных агроландшафтов Барабинской равнины

Table. 1. Physical and chemical properties of catena soils in saline agricultural landscapes of the Baraba plain

Geomorphological position, soil crossover number, soil	Horizon, sampling depth, cm	pH_{H_2O}	Humus, %	Physical clay, particles < 0,01%	Short name by granulometric composition
Eluvial, soil crossover No. 1, meadow-chernozem moderately deep middle-loamy	$A_{пах}$ 0–18	6,62	9,67	36,5	Middle loamy
	A_1 25–35	6,57	7,74	31,1	»
	AB 50–60	6,26	1,29	53,5	Heavy loamy
	B_1 70–80	6,71	Not defined	53,9	»
	$B_к$ 110–120	8,40	» »	56,3	»
Transit, soil crossover No. 2, meadow-chernozem saline loamy sand	$A_д$ 0–10	7,90	10,75	14,0	Loamy sand
	A_1 10–24	8,20	4,51	8,8	Sandy
	AB 30–40	8,30	1,00	21,4	Light loamy
	B_q 50–60	8,44	0,55	22,6	»
	A_{error} 80–90	8,91	0,88	53,3	Heavy loamy
	B_{error} 100-110	9,13	0,59	56,1	»
Accumulative, soil crossover No. 3, deep solonchak slightly saline heavy loamy	A 0–20	9,8	5,16	60,6	Moderately clayey
	B_1 20–30	10,12	2,58	60,2	»
	B_2 30–50	10,16	0,86	41,2	Light clayey
	B_3 50–60	10,00	Not defined	41,2	»
	B_4 70–80	10,04	» »	54,6	Moderately clayey

in the soil and its availability to plants. Cr^{6+} is most accessible to plants. It is unstable under normal soil conditions. Cr^{3+} usually prevails in soils, which compounds are weakly soluble in an acidic environment [1]. In an alkaline environment, Cr^{3+} is oxidized to Cr^{6+} to form soluble chromates. Trivalent chromium is well absorbed by soil, so it has little toxicity.

In soil, the MAC of Cr^{3+} is 100 mg/kg, Cr^{6+} is 0.05 mg/kg [2]. Chromium clark in the Earth's crust is 200 mg/kg [3], but its gross content in the soils of the world varies widely [4]. In the process of detailed study clark chromium changed mainly in the direction of reduction [5]. It has been found that the gross chromium content in soils increases from rural settlements (50-58 mg/kg) to cities with developed industrial industry (90-100 mg/kg). Excess chromium sharply reduces the biological activity of soils.

In the soils of the studied catena in the eluvial position the gross chromium content in the arable horizon of meadow-chernozem soil was 79.5 mg/kg, mobile - less than 0.00001 mg/kg, which is below the detection range of the instrument. With depth, the content of gross chromium increased to 141 mg/kg. Its noticeable movement along the catena was not found, in the transit zone the amount varied with depth from 51 to 92 mg/kg. In the accumulative zone there is slightly more gross chromium than in the transit zone, but lower

Табл. 2. Профильное распределение валового содержания умеренно опасных микроэлементов в почвах засоленных агроландшафтов Барабы

Table. 2. Profile distribution of the total content of moderately hazardous microelements in the soils of saline agricultural landscapes of the Baraba plain

Geomorphological position of the soil crossover, soil	Horizon, sampling depth, cm	Trace elements, mg/kg soil					
		Chromium		Nickel		Cobalt	Molybdenum
		gross	mobile	gross	mobile	gross	gross
Eluvial, soil crossover No. 1, meadow-chernozem moderately deep middle-loamy	$A_{пах}$ 0–18	79,5	0,0	50,1	0,02	14,6	1,24
	A_1 25–35	109	«0,1	52,1	0,03	17,6	2,32
	AB 50-60	107	0,12	66,7	0,04	16,3	2,5
	B_1 70–80	141	0,12	58,3	0,04	13,4	2,03
	$B_к$ 110–120	102	0,15	51,9	0,04	10,9	2,31
Transit, soil crossover No. 2, meadow-chernozem saline loamy sand	$A_д$ 0–10	51,0	0,14	50,5	«0.01	15,4	3,85
	A_1 10–24	66,0	0,14	58,7	0,01	13,3	2,77
	AB 30–40	48,2	0,15	36,4	0,01	7,4	1,83
	B_q 50–60	50,8	0,18	32,9	0,01	7,0	2,22
	$A_{погр}$ 80–90	92,0	0,13	52,1	0,02	15,6	1,84
	$B_{погр}$ 100-110	59,8	0,13	47,1	0,03	11,8	1,88
Accumulative, soil crossover No. 3, deep solonchak slightly saline heavy loamy	A 0–20	74,4	0,32	44,2	0,060	9,9	2,25
	B_1 20–30	56,7	0,31	47,4	0,040	10,5	1,31
	B_2 30–50	77,1	0,13	43,6	0,020	10,5	2,79
	B_3 50–60	83,4	0,21	44,4	0,014	10,5	1,85
	B_4 70–80	87,4	0,17	40,1	0,014	8,5	2,02
Clarke [3]		200		40		10	2,0
MAC[5]		100		50		50	5,0

[5]The list of Maximum Permissible Concentrations (MPC) and Approximately Permissible Amounts (APC) of chemical substances in the soil. Special edition. Moscow: Goskomsanepidnadzor of Russia Publishing House. 1991. 18 p.

than in the eluvial. There was a tendency of insignificant movement of mobile chromium from the eluvial to accumulative zone, which, in our opinion, is associated with the movement of silty particles and humus with surface water flows.

The results obtained on the content of gross chromium in the soils of saline agro-landscapes of Baraba indicate that its movement along the catena is insignificant. However, the mobility of chromium in the upper humus horizons increases from the eluvial position through the transitional to accumulative position due to an increase in pH and the movement of silty particles with surface water. It is cumulated in the accumulative zone. The content of both gross and mobile chromium in the soils of the catena is below the MAC and does not contribute to environmental pollution.

Nickel in trace amounts is essential for plants and living organisms. It accelerates plant emergence from dormancy, promotes nitrogen movement and seed germination, and affects urease activity. Nickel stimulates photosynthesis, promotes the formation of the spiral structure of nucleic acids, and affects the absorptive capacity of plant roots. However, its increased content in soils inhibits plant growth and reduces the amount of chlorophyll in the leaves [6].

Nickel clark in soils equals 40 mg/kg. TAC (tentative allowable concentration) of its gross content in sandy and sandy loam soils is 20 mg/kg, in loamy and clayey (acidic) soils - 40, loamy and clayey (neutral) soils - 80 mg/kg. The TAC of the exchangeable form (acetate-ammonium buffer, pH - 4.8) is 4 mg/kg of soil [7]. In soils, nickel, as a rule, is concentrated in the silty fraction which is enriched in montmorillonite. Nickel forms soluble chelate compounds with organic matter. It has been established that nickel migrates, although weakly, along the soil profile in cationic form in the form of true solutions, compounds in colloidal form, and in the form of mechanical suspensions [7]. According to S.V. Lukin [1], the gross nickel content in the chernozems of the Belgorod region is about 25 mg/kg and does not change reliably with depth. In the Novosibirsk region, the gross nickel content in zonal soils is higher, from 32 mg/kg of soil in humus horizons to 43-45 mg/kg and more in saline landscapes [7].

In particular, the soil profile of the studied catena contains the greatest amount of bulk nickel in the eluvial position: in the humus layer - 50.1-52.1 mg/kg of soil; in the AB and B horizons it increases to 66.7-58.3, at a depth of 110 cm it decreases again to 52 mg/kg (see Table 2). In the transit zone, its content in the humus layer of soil is about the same as in the eluvial zone, and decreases with depth. In the accumulative zone, the gross nickel content tends to increase as compared to the transit zone. The gross nickel content in the saline agrolandscape soils is slightly higher than the clark, but significantly lower than the MAC.

The content of mobile forms of nickel is the highest in the meadow-chernozem soil. It is approximately the same throughout the entire profile, only in the A horizon it is slightly lower. In the accumulative position, more mobile nickel was found in the upper humus horizons, which indicates its movement from the eluvial zone through the transit zone, as well as some cumulation in the accumulative zone.

Thus, in the studied saline agro-landscape of Baraba no deficiency or excess of nickel was found. However, its accumulation in the accumulative position is possible due to the movement of nickel compounds with surface water, as indicated by the studies of V.B. Ilyin and A.I. Syso [7]. Nickel is geochemically related to cobalt, since their atomic masses are close [1].

Cobalt takes an active part in physiological processes of plant and living organisms. It significantly enhances nitrogen-fixing ability of microorganisms, synthesis of chlorophyll, proteins, and carbohydrates. It promotes the formation of vitamin B_{12}, extremely necessary for living organisms[6] [8]. Clark cobalt is equal to 10 mg/kg [3, 8, 9]. In the soil cover, its distribution depends on the composition of the parent rock, in the soil profile - on the content of physical clay, silt fraction, iron oxides and organic matter, as these indicators are able to fix and accumulate cobalt. It has been established that the proportion of substances capable of fixing cobalt in soils into immobile and low-mobile compounds is 95% of its gross content. In natural environments, cobalt can be in two oxidation states, Co^{2+} and Co^{3+}, as well as in the form of the complex compound Co $(OH)^{3}$-. Co^{2+} and Co^{3}+ ions are almost completely fixed by the soil absorbing complex, in the soil profile more mobile are complex compounds Co (OH)[7] (see footnotes 2-6).

The average content of cobalt in plants is 0.01-0.6 mg/kg of dry matter. In leguminous plants there is more of it than in cereals [10]. When the content of cobalt in soils is less than 5 mg/kg, its deficiency in herbaceous vegetation is noted. In this case, animals begin to show signs of avitaminosis, the formation of hemoglobin, nucleic acids, and proteins slows down, and endemic goiter appears. The critical level of cobalt content in plants for normal animal development is 0.08-0.1 mg/kg of plant dry weight [3, 11]. External cobalt deficiency in plants manifests itself similarly to nitrogen deficiency - leaf chlorosis, slowed plant growth and short development cycle.

Under natural conditions, an excess of cobalt in soils is rare. It usually accumulates in the edges and tips of leaves; they turn white and die off. Excess cobalt has a negative effect on animals. Its maximum allowable concentration in grasses should not exceed 60 mg/kg dry matter.

Cobalt toxicity is manifested by a decrease in vitamin B_{12} content and lack of fruiting.

According to V.B. Ilyin and A.I. Syso, the soils of the Novosibirsk region in Baraba and Priob'ye are characterized by high gross content of trace elements, which is associated with their heavy granulometric composition and high humus content, especially in meadow-chernozem soils and in saline (solonets and solonchaks). In particular, they found that the soils of Baraba are characterized by increased and high content of cobalt [7].

In the studied soils of katena the highest content of gross cobalt is concentrated in meadow-chernozem soil of eluvial position. Its maximum is in the A and AB horizons and is 17.6-16.3 mg/kg of soil, respectively (see Table 2). In the A_{nax} horizon, the content of gross cobalt is somewhat lower than in the A_1 horizon, which is probably associated with its movement to the transit zone with water flows containing mud particles and humus. According to the regulations (see footnote 5), this content of cobalt in the soil is high and very high (10-15 and 15-22 mg/kg). In the lower horizons it decreases to 13-10 mg/kg. In the transit zone of chernozem-meadow soil in the upper humus horizons, the content of cobalt, despite the light granulometric composition, is high - 15.4-13.3 mg/kg. This is associated with its movement from the upper positions to the lower ones, where a significant part of cobalt is absorbed, most likely, by soil organic matter. In the AB and Bq horizons, the amount of bulk cobalt decreases sharply to 7 mg/kg of dry soil. In the buried soil, its content increases again and approaches the content in the upper horizons. This phenomenon indicates weak movement of cobalt along the catena. It is practically all fixed in the upper soil horizons of the transit zone. In the accumulative zone, the gross content of cobalt throughout the profile of deep solonetz is distributed approximately equally. Its accumulation at any depth was not detected, although the gross amount of cobalt according to the grading is high. As noted earlier, in an alkaline environment mobility of cobalt decreases sharply, as evidenced by our data. Mobile cobalt in the studied soils is less than 0.00001 mg/kg, except for deep solonetz A horizon (0.0118 mg/kg).

Thus, all soils of the catenas of saline agrolandscapes of the Barabinsk plain contain increased and high content of gross cobalt. Despite its high content, it is not an environmental pollutant (MPC = 50 mg/kg) and does not currently aggravate the sanitary and hygienic situation in saline agrolandscapes.

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[6] Protopopova L.G. The behavior of cobalt in the soil-plant system and the effectiveness of cobalt fertilizers in the Altai plains and foothills: Ph. D in Agr. 2002, 232 p.

[7] Bityutsky N.P. Micronutrients and the Plant: Textbook. St. Petersburg: Publishing house of St. Petersburg State University, 1999. 232 p.

In soils, the content of gross molybdenum is in the range 0.013-17 mg/kg, the average value (clark) is 2 mg/kg [3, 12]. S.F. Spitsina et al. [13] found that the soils of the Altai region is characterized by low gross molybdenum content (0.1-1.2 mg/kg), which is associated with its low gross content in the soil-forming rocks (0.2-1.4 mg/kg soil). In the upper humus horizons gross molybdenum is more due to biogenic accumulation [13]. According to V.B. Ilyin et al. [14], the concentration of molybdenum in the south of Western Siberia is much higher and averages about 4.3 mg/kg. Consequently, the soils here are characterized by a high content of this element, whereas the soils of Altai Krai require the application of molybdenum-containing microfertilizers.

The average content of molybdenum in plants ranges from 0.0005-0.002%. Molybdenum is an important and essential chemical element for plants and living organisms, it is a part of enzymes responsible for nitrogen metabolism, it improves phosphorus absorption by plants, it is a part of nitrogenase, which ensures growth and development of legumes and vegetable crops. During vegetation, molybdenum accumulates in the young organs of plants, and at the end of the growing season it is concentrated in the seeds. The availability of molybdenum to plants depends on pH value. In acidic soils its compounds are insoluble, in alkaline soils they are available to plants. It has been established that a significant part of molybdenum in soil is associated with organic matter and aqueous iron oxides [7].

As evidenced by our data (see Table 2), the content of molybdenum in the soils of the studied catenary in all geomorphological positions is within the clark - about 2 mg/kg of dry soil. Only a small accumulation of it in the upper humus layer due to the increased content of organic matter in it was noted [13]. Our data slightly differ from those of V.B. Ilyin et al. [14, 15], which is explained by the high alkalinity of soils in saline agricultural landscapes (up to 10 and more), in which molybdenum compounds become mobile.

A. Azarenko [16] in the study of mobile forms of trace elements in the soils of the Omsk Irtysh Land region found that the largest amount of mobile molybdenum is in alkaline soils. Then come chernozems, the smallest amount of this element is in sod-podzolic soils. As noted by the author, in the profile of chernozems and meadow-chernozem soils there is an accumulation of this element in the upper humus horizons, a decrease in the horizons B and Bk, then its content increases again due to the solubility of this element in an alkaline environment.

Thus, the gross content of molybdenum in the soils of saline agro-landscapes of the northeastern part of the Baraba within the Novosibirsk region is within the Earth clark. Its greatest amount is in the humus layer, in which molybdenum is fixed by soil organic matter. According to the approved sanitary and hygienic standards, its content in soils of the katena is not dangerous for animal and human health.

Statistical processing of the material.

Using the correlation analysis of microelement composition and physicochemical properties of soils a direct relationship between the concentration of humus and the gross content of cobalt has been revealed. In the eluvial and transitional positions the correlation coefficient was 0.55, in the accumulative position the correlation relation is weaker ($r = 0.18$). Inverse correlation between the concentration of humus and gross chromium content was recorded on the catena. In the eluvial zone, the correlation coefficient is 0.65, in the transit zone - 0.25, and in the accumulative zone - 0.53. In addition, a close correlation between the content of physical clay (particles < 0.01%) and mobile nickel was detected in all positions. The correlation coefficient varied from 0.83 in the eluvial zone to 0.92 in the transitional zone and 0.74 in the accumulative zone.

CONCLUSIONS

1. The studied area of the northeastern part of the Barabinsk plain within the Novosibirsk region is typical for this geomorphological position, which allows the obtained results of research to be transferred with high probability to the adjacent territories. The character-

istic feature of the territory under study is the presence of meadow-chernozem soils in the eluvial zone of the catena, and of chernozem-meadow soils of various degrees of alkalinity and salinity in the transitional zone. In accumulative zone, alkaline, meadow-marsh and even marsh soils of different degree of alkalinity and salinity can be formed.

2. The physicochemical properties of soils of the catena change from the eluvial to accumulative zone as follows: pH in the soil profile increases from the eluvial position to the accumulative position. Whereas in meadow-chernozem soil it is neutral (alkaline in the parent rock), in deep solonetz it is strongly alkaline (pH 10 and more). The humus content in the A horizons is high, while in the B horizons it decreases sharply.

3. The granulometric composition of soils by genetic horizons changes significantly, which is typical for soils formed on alluvial deposits. It largely determines the elemental composition of soils.

4. In the eluvial position of the catena in the profile of meadow-chernozem soils, the minimum content of gross chromium falls on the A_{nax} horizon - 79.5 mg/kg dry soil. Deeper in the profile it increases to 102-141 mg/kg and is within the limits above the MAC. Some movement of chromium along the profile takes place.

5. The maximum amount of gross nickel and cobalt also falls on the profile of meadow-chernozem soil, but it is within the limits well below the MAC. From the eluvial to accumulative position, the gross content of these elements decreases. Their quantity along the profile of soils varies weakly, indicating their weak mobility. The total content of molybdenum in the studied soils is within the clark and approximately the same throughout the depth.

6. In the studied saline agrolandscapes, the content of nickel and cobalt in the soils by catena is below the MAC and poses no danger from the ecological-toxicological point of view. The gross contents of chromium and molybdenum are within the MAC and in certain cases can cause tension of the ecological-toxicological situation of the territory. This should be taken into account in the agricultural use of saline agrolandscapes.

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ИНФОРМАЦИЯ ОБ АВТОРАХ

(✉) **Семендяева Н.В.,** доктор сельскохозяйственных наук, главный научный сотрудник, профессор; **адрес для переписки**: Россия, 630501, Новосибирская область, р.п. Краснообск, а/я 463; e-mail: semendyeva@ngs.ru

Морозова А.А., инженер, младший научный сотрудник; e-mail: valeri_170886@mail.ru

Елизаров Н.В., кандидат биологических наук, старший научный сотрудник; e-mail: elizarov_89@mail.ru

AUTHOR INFORMATION

(✉) **Nina V. Semendyaeva,** Doctor of Science in Agriculture, Head Researcher, Professor; **address**: PO Box 463, Krasnoobsk, Novosibirsk Region, 630501, Russia; e-mail: semendyeva@ngs.ru

Anna A. Morozova, Engineer**,** Junior Researcher; e-mail: valeri_170886@mail.ru

Nikolay V. Elizarov, Candidate of Science in Biology, Senior Researcher; e-mail: elizarov_89@mail.ru

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