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Study of soil cover of *Veronica spuria* L. populations in Ile Alatau mountains, Kazakhstan

Yerkebulan Balkybek[1], Bekzat Tynybekov[1*], Kanat Kulymbet[2], Ussen Kurmanbay[3], Zoya Umirbayeva[4], Zinat Nurakyn[1], Assiya Myltykbayeva[1], Alibek Ydyrys[5], Murat Toktar[6,7*]

[1] Faculty of Biology and Biotechnology, Al-Farabi Kazakh National University, Almaty, Kazakhstan
[2] U.U.Uspanov Kazakh Research Institute of Soil Science and Agrochemistry, Almaty, Kazakhstan
[3] Department of Chemistry and Biology, Faculty of Pedagogical and Natural Sciences, Zh. Tashenev University, Shymkent, Kazakhstan
[4] Department of biology, Institute of Natural Sciences, NPJSC «Kazakh women's teacher training university», Almaty, Kazakhstan
[5] Biomedical Research Centre, Al-Farabi Kazakh National University, Kazakhstan
[6] Department of Mine Surveying and Geodesy, Institute Mining and Metallurgical Institute named after O.A. Baikonurov, Satbayev University, Almaty, Kazakhstan
[7] Department of Soil Ecology, Kazakh Research Institute of Soil Science and Agrochemistry named after U.U. Uspanov, Almaty, Kazakhstan.

*Corresponding author Email: tynybekov.bekzat.72@gmail.com, murat-toktar@mail.ru

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Abstract
The article studies the natural conditions of soils of Kimasar, Big Almaty and Kaskelen gorges belonging to the Ile Alatau mountain range. From the received soil samples the types of soils, morphological features of soils, amounts of nutrient elements (mobile nitrogen, mobile phosphorus, mobile potassium), humus content, reaction of soil medium (pH), carbon content in soil layers (CO_2), mobile forms of heavy metals (Zn, Cu, Cd, Pb), sum of salts in soils (salt composition) and mechanical composition of soils were determined. According to morphological features of soils, mountain-meadow dark chestnut soils (Population-1), mountain-meadow soddy chestnut soils (Population-2), and mountain-thermoxerophilic dark chestnut soils (Population-3). The amount of humus, which is the main indicator of soil fertility, in the dark chestnut soils was higher compared to the soils of the other two studied gorges, i.e. it was 3.44-8.54%. On mobile amounts of nutrient elements in dark chestnut soils revealed high amounts of mobile nitrogen, phosphorus and potassium, nitrogen – 547.6-100.8 mg/kg, phosphorus – 28-46 mg/kg, potassium – 170-450 mg/kg. Among microelements mobile forms of zinc (Zn), copper (Cu), lead (Pb) did not exceed MPC of these elements in all types of soils, only mobile cadmium (Cd) exceeded MPC several times. By mechanical composition of soil dark chestnut soils has light loamy (24,69 %), chestnut soils has light loamy (28,52 %), dark chestnut soils was sandy (7,32 %). In terms of salt content, all soil samples turned out to be non-saline (salt content below 0.025%).

Keywords
soil, morphology, heavy metals, mechanical composition.

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Introduction

In Kazakhstan, the mountain zone occupies quite a large part of the territory, as these areas are located at an altitude of more than 4000 meters above sea level, which causes a high-band distribution of soils. Depending on the altitude, the amount of moisture increases, and due to the decrease in temperature from the desert-steppe belt of the foothills to the high altitude levels, several mountain belts are formed. The soil-vegetative cover in these zones is diverse (Oku *et al.,* 2018; Ason *et al.,* 2022). Ile Alatau is a part of the Northern mountain chain of the Tien-Shan mountain system, extends for 350 km. It consists of a chain of high mountains between the rivers Kaskelen and Turgen (Imanaliyeva *et al.,* 2024). The relief of the Ile Alatau is very complex, consisting of six ridges and vast intermountain lowlands, forming a complete mountain system. As soil-forming rocks there are limestone, sands, flagstones, weathering products of igneous rocks. In addition, it consists of aeolian and deluvial deposits distributed from loess and clays (Akhmetova *et al.,* 2015). The distribution of the soil-vegetative cover of the Ile Alatau repeats the altitudinal landscape zones, and its formation is directly related to the height of the upper part of the ridge and climate change (Ydyrys *et al.,* 2020). The center of the belt in Ile Alatau is fully manifested in the highest part, towards the edge of the ridge the climate becomes drier, and then the belt shifts upwards. Other factors violate the general laws of location of the altitude zone, i.e., slope exposure, location of the ridge towards the prevailing winds, etc. (Toktar *et al*., 2019; Aitbekov *et al.,* 2024).

Materials and Methods

Study area

Soils of Kimasar Gorge (Population-1), Big Almaty Gorge (Population-2) and Kaskelen Gorge (Population-3), which are part of the Ile Alatau mountain range, served as the object of the study.

Relief. The glacial-alpine relief of the Ile Alatau mountain range includes faceted meadows, pointed peaks, rocky precipices, and snow. At the northern foot of the mountain is the city of Almaty. Ile Alatau consists of a number of high peaks (5000 m) and gradually spreads to the west and east of the central upland, the southern slope is steep and low-resistant, the northern slope is somewhat gentle (Ivashchenko *et al.,* 2021; Mussina *et al.,* 2023).

Climatic conditions. The climate is temperate, continental. The average temperature in January is 13.7 degrees and in July 14.8 degrees. The soil is purplish gray, mixed with gravel, brown, chernozem. Spruce, pine, birch, poplar, maple, elm, spirea, dereza, sagebrush, fescue, wormwood, etc. grow. (Medeu *et al.,* 2022; Amirov *et al.,* 2023). The temperature increases slightly up to an altitude of 1500 - 1600 m due to inversion and decreases again. Annual precipitation in the foothill belt is over 500 - 600 mm, in the mountain belt up to 800-900 mm. The slopes on the southern side are generally warmer and drier than on the northern side. This difference provokes the development of different plants, this situation contributes to the formation of different soils (Bolch, 2006).

Field survey and laboratory methods

Field studies in the mountainous areas of Ile Alatau and laying soil profiles were conducted in 2024. Soil profiles were laid on the soils of Kimasar Gorge, Big Almaty Gorge and Kaskelen Gorge. In the course of field studies 3 soil profiles were laid and investigated.

1. field (field determination of morphology of soil profiles).
2. laboratory (study of chemical properties and granulometric composition of soils).

Field studies were carried out using the key transect method (Uteulin *et al.,* 2023). In the course of field studies the natural conditions of the objects of study were described, soil profiles were laid down, their morphological state was determined and soil samples were selected for laboratory analysis. The following chemical parameters were determined from the soil samples: mobile nutrient elements (nitrogen, phosphorus, potassium) according to GOST 26205-91 (MFNPK, 2024), the sum of salts in soil, cations and anions (CO_3^{2-}. HCO_3. Cl^-. SO_4^-) and cations (Ca^{2+}. Mg^{2+}. Na^+. K^+) was determined according to GOST 26425-85 (SCGOST, 2024) reaction of soil pH was determined according to GOST 26423-85 (SPGOST, 2024), content of humus content according to GOST 23740-79 (HCGOST, 2024), CO_2 content according to GOST 26425-85 (CCGOST, 2024), content of trace elements was determined according to GOST 33850-2016 (HMGOST, 2024).

Results and Discussion

Morphological description of soils

Population-1. The left mouth of Almaty is the Kima-

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sar Gorge, which has a nature known for its air and its color in the four seasons (Medeu *et al.,* 2007). Coordinates of soil survey locations: 43°10'1" N. 77°3'53" E. Altitude above sea level: 1950 m.

Soil type: Mountain-meadow dark chestnut soil

Horizon	Depth (cm)	Thickness (cm)	Description
A_1	0-6	6	Dark chestnut brown, granular lumpy, with a lot of roots, not compacted, does not react with acid (no violent reaction).
AB	6-35	29	Chestnut, granular lumpy, light loamy, with a lot of roots, stony and rubbly, there are traces and burrows of insects, weakly reacts with acid, the transition to the next layer is clear.
BC	35-80	45	Light chestnut, stony-rubble, light loamy, roots, very dense layer, reacts moderately with acid.

Population-2. The Big Almaty Gorge is one of the largest peaks of the Northern Tien Shan, the height of the Big Almaty Peak reaches 3680 meters. In the east the border of the gorge passes in the area of the Big Almaty ridge, in the south - with the main Ile Alatau ridge, in the west - with the Kargala ridge (Lebedeva *et al.,* 2007). Coordinates of the study area: 43°4'52" N. 76°358'59" E. Altitude above sea level: 2100 m.

Soil type: Mountain-meadow soddy chestnut soil

Horizon	Depth (cm)	Thickness (cm)	Description
A_1	0-9	9	Chestnut, fresh, loose, many roots, light loamy, granular and lumpy, small roots present, not reactive with acids.
AB	9-42	33	Chestnut, fresh, light loamy, nutty-grained, with plant residues, stones, slightly reactive with acid, transition to the next layer is clear.
BC	42-65	23	Light chestnut, light brown, light loamy, stones, crushed stone, moderately reactive with acid, transition to the next layer is clear.
C_1	65-90	25	Light gray, compacted, clayey, stony-rubble, strongly reactive with acid.

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Population-3. Kaskelen Gorge is located 25 kilometers from the western border of Almaty city, is part of the Ile Alatau National Park (Kaparbay *et al.,* 2023) in the gorge there are large coniferous forests, in the lower part - fruit trees. Barberry, apricot, wild apple and pear trees grow. Coordinates of the study area: 43°0'49" N. 76°36'54" E. Altitude above sea level 1880 m.

Soil type: Mountain-thermoxerophilic dark chestnut soils

Horizon	Depth (cm)	Thickness (cm)	Description
A_1	0-10	10	Dark chestnut, fresh, compacted, granular, light loamy, many roots are found, weakly reactive with acids.
AB	10-30	20	Chestnut, dense, granular, sandy-clayey, with plant remains, stony-rubble, weakly reactive with acids, transition to the next layer is clear.
BC	30-60	30	Gray, stony and rubbly, with predominance of sand, with small roots, moderately reactive with acid, transition to the next layer is gradual.
C_1	60-90	30	Gray, pulverized, with predominance of fine sand, stony-rubbly, with a large number of stones, moderately reactive with acid.

Soil chemistry

Humus, pH, CO_2. The results of laboratory studies of Population-1 (P-1) from Kimasar gorge showed that the humus content in 0-80 cm soil layer was very high (Ametov *et al.,* 2016), in the range of 3.44-8.54% (Figure1). The reaction of soil medium had pH between 6.27-6.61, i.e. acidic reaction, acidity increased according to soil depth, CO_2 content was between 0.13-0.17. The humus content in the 0-80 cm layer from the Big Almaty Gorge (P-2) is also high, within the range of 0.99-6.83%, the reaction of the soil medium - within the range of pH 7.03-8.03, that is slightly alkaline, depending on the depth of the soil alkalinity increases, the content of CO_2 is within the range of 0.27-10.86 (Fig. 1). In the Kaskelen Gorge (P-3), the humus content in the 0-90 cm layer was moderate, ranging from 0.65% to 5.85%. The soil pH was in the acidic range, from 6.41 to 6.84, and the CO_2 content ranged from 0.1% to 0.23% (Fig. 1). The highest humus content compared to the other two study sites was found in population-2

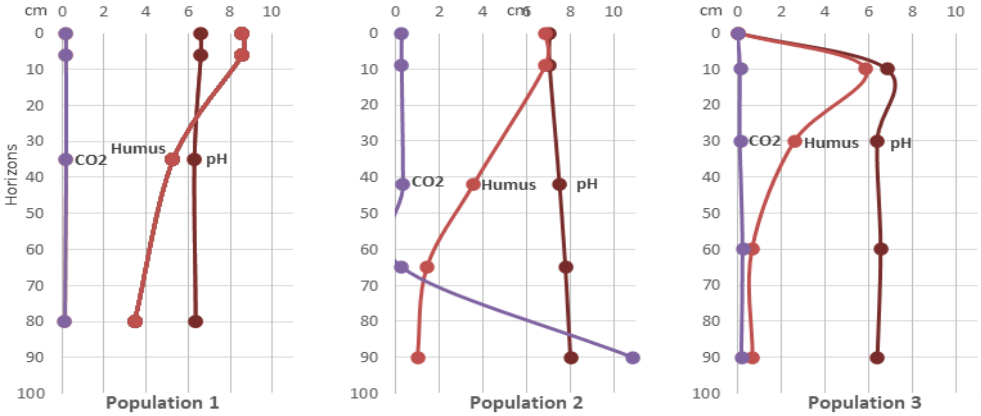

Figure 1
The content of pH, CO_2, and humus in soil, %

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Nutrient elements are also one of the main indicators of soil fertility. In particular, their mobile forms are accessible to plants (Rehman *et al.,* 2024). The content of mobile forms of nutrient elements in the soils of the Kimasar Gorge (P-1) is characterized by the following values: nitrogen – 547.6-100.8 mg/kg, phosphorus – 28-46 mg/kg, potassium – 170-450 mg/kg. High levels of mobile nitrogen and potassium were observed. In the Big Almaty Gorge (P-2), the mobile forms of nutrients were distributed as follows: nitrogen 50.4–89.6 mg/kg, phosphorus 4-26 mg/kg, potassium 60-270 mg/kg. The mobile forms were at a medium level. In the Kaskelen Gorge (P-3), the mobile forms of nutrient elements were distributed as follows: nitrogen 22.4-75.6 mg/kg, phosphorus – 48–80 mg/kg, potassium 50-180 mg/kg (Fig. 2).

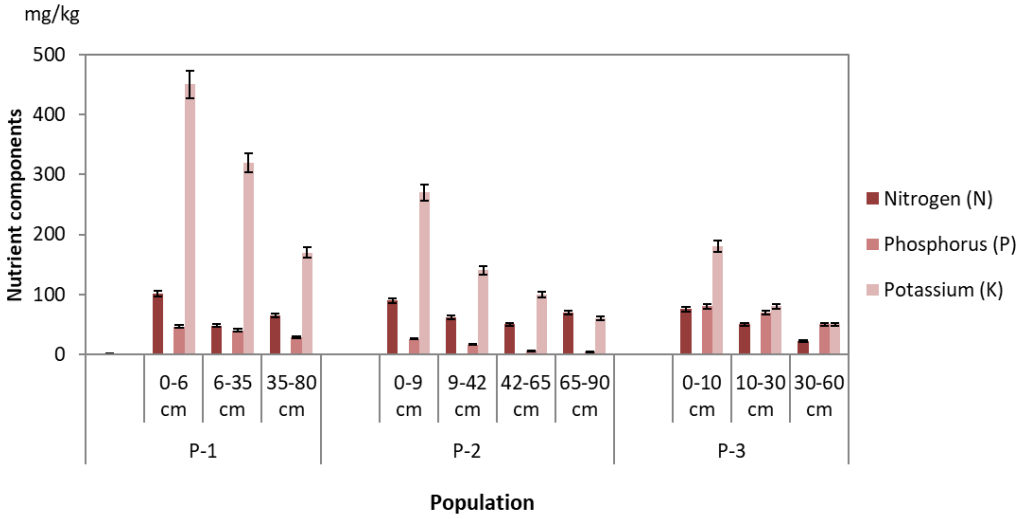

Figure 2
Nutrient elements in the soil compositions from the Kimasar, Big Almaty, and Kaskelen gorges, mg/kg:

According to the amount of mobile nutrient elements of Kimasar gorge (P-1) revealed high content of mobile nitrogen, phosphorus, potassium. In addition, the dark chestnut soil of Kaskelen gorge had a high content of mobile potassium. Mobile forms of trace elements in soils were studied. In the Kimasar gorge (P-1): zinc (Zn) was in the range of 0.50-3.00 mg/kg, copper (Cu) 0.40-0.80 mg/kg, cadmium (Cd) 0.20-1.60 mg/kg, lead (Pb) 0.10-0.40 mg/kg. Mobile trace elements in the composition of the Big Almaty Gorge (P-2), were as follows: zinc (Zn) 0.90-3.00 mg/kg, copper (Cu) 0.60-2.10 mg/kg, cadmium (Cd) 0.10-1.50 mg/kg, lead (Pb) 0.10-2.10 mg/kg. Mobile trace elements in the composition of the Kaskelen Gorge (P-3): zinc (Zn) 0.50-6.00 mg/kg, copper (Cu) 0.30-0.60 mg/kg, cadmium (Cd) 0-0.10 mg/kg, lead (Pb) 0.60-0.90 mg/kg (Fig. 3). Among the considered trace elements it was found that mobile forms of zinc, copper, lead did not exceed MPC in all types of soils, only cadmium content exceeded MPC several times (Kabata-Pendias *et al.,* 2011). Soil mechanical composition is of great importance in soil formation,

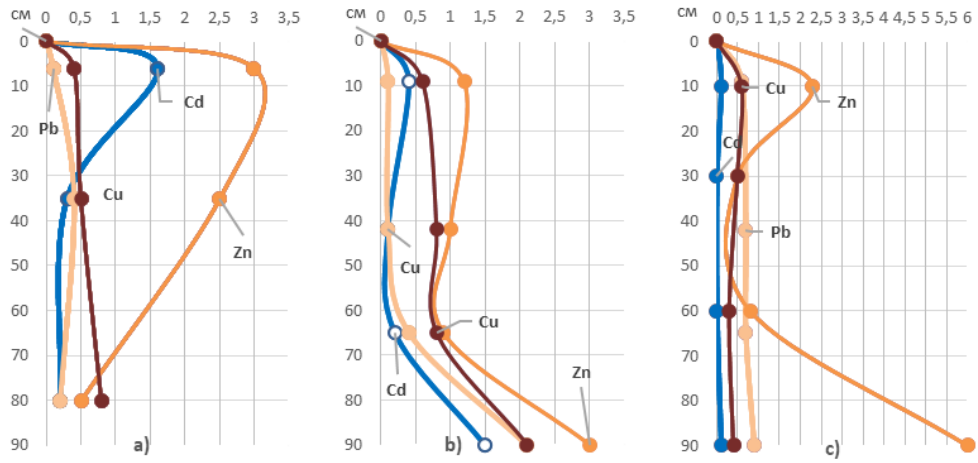

Figure 3
Content of micronutrients, mg/kg. (a) Kimasar Gorge; (b) Big Almaty Gorge; (c) Kaskelen Gorge

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use of soil for agriculture and other purposes. Soil cover, due to its physical and mechanical properties, is a geological environment prone to absorption of harmful substances from the air and formation of secondary sources of pollution in its composition, carrying long-term harmful substances (Kobylina *et al.,* 2024). The mechanical composition of Kimasar Gorge (P-1) was dominated by coarse sand fraction (29.87%), coarse dust fraction (27.9%) had the second advantage. Fraction of 0.01 mm size got 24.69%, the soil represents the mechanical composition of light loamy (Fig. 4).

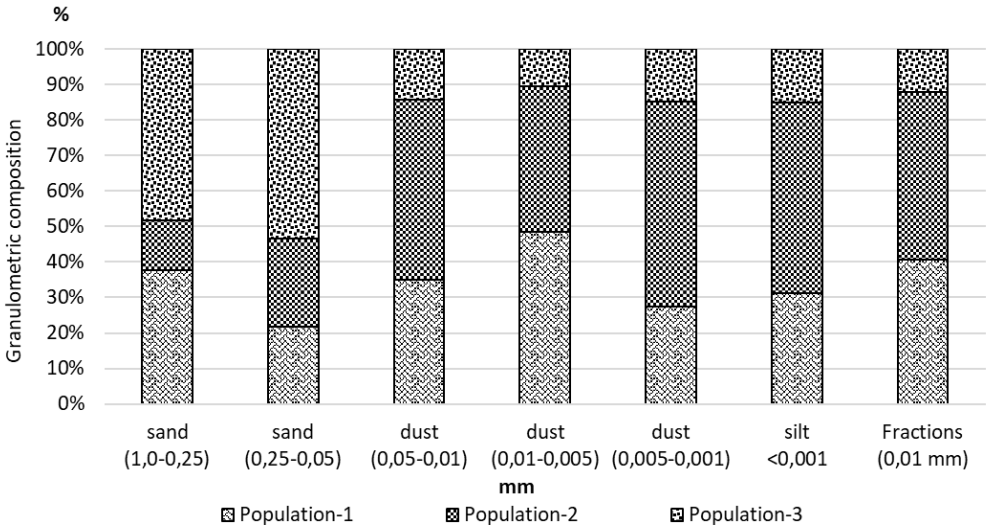

Figure 4
The mechanical composition of soils from the Kimasar, Big Almaty, and Kaskelen gorges.

The mechanical composition in the Big Almaty Gorge (P-2) was dominated by coarse dust fraction (40.43%), followed by fine sand fraction with a share of 21.24%. The average size of 0.01 mm fractions is 28.52%, i.e. the soil is light loamy. In the mechanical composition of dark chestnut soils of Kaskelen Gorge (P-3) predominance was 42.96% for the fraction of fine sand, coarse sand fraction - 38.39%. And the fraction of 0.01 mm was 7.32%, by mechanical composition was defined as sandy (Bayandinova *et al.,* 2018; Toktar *et al.,* 2021) (Figure 5). One of the important directions in soil research is the determination of soil salinity. Soil salinity is formed depending on various conditions. First of all, it will depend on the mineral composition of rocks, which is considered as the beginning of soil. Secondly, in desert steppe regions,

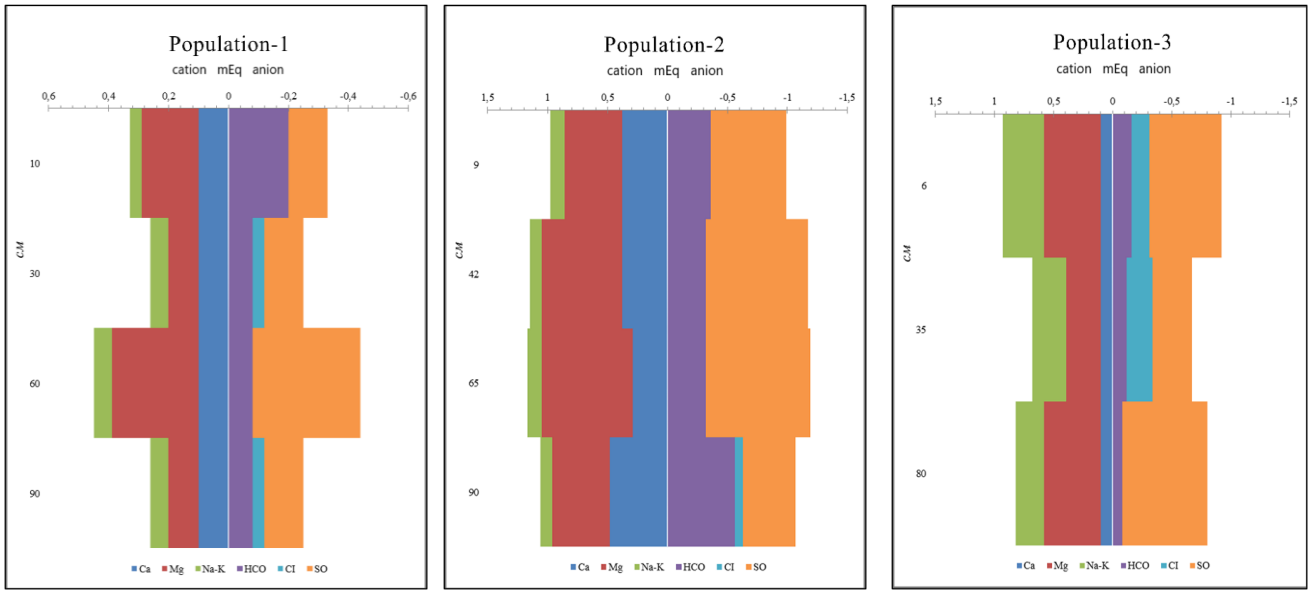

Figure 5. *Salt profile of soils from the Kimasar, Big Almaty, and Kaskelen gorges.*

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saline soils are the most common cause of drought. In these regions, due to hot weather, wind force and water evaporation from the surface of the ground is very intense, as the soil solution in the soil layers evaporates and rises upwards, the dissolved salts also rise upwards and, reaching the soil surface, stagnate and accumulate (Bazilevich, *et al.,* 1972, Glazovskaya *et al.,* 2012. The composition of the water extract of the Kimasar Gorge (P-1) was as follows: CO_3 - not detected; HCO_3^- - 0.08-0.16; Cl^- - 0.15-0.22; SO_4^- - 0.33-0.72; Ca^+ - 0.10; Mg $^{2+}$ - 0.29-0.48; Na^+ - 0.2-0.22; K^+ - 0.02-0.15; Total salts 0.044-0.062%. Salt content of water extract of the Big Almaty Gorge (P-2) was as follows: CO_3 -0.002; HCO_3^- - 0.32-0.56; Cl^- - 0.07; SO_4^- - 0.44-0.87; Ca^+ - 0.29-0.48; Mg $^{2+}$ - 0.48-0.46; Na^+ - 0.10-0.12; K^+ - 0.02; Sum of salts 0.069-0.079%.

The content of salts of water extract of the Kaskelen gorge (P-3) was as follows: CO_3 - not detected; HCO_3^- - 0.08-0.2; Cl^- - 0.04; SO_4^- - 0.13-0.36; Ca^+ - 0.10; Mg $^{2+}$ - 0.10-0.29; Na^+ - 0.02-0.04; K^+ - 0.02; Sum of salts 0.017-0.029% (Fig.5). According to the total salt content in the studied soils, all types of soils turned out to be non-saline.

Conclusions

According to morphological features, mountain-meadow dark chestnut soils in the Kimasar Gorge (P-1), mountain-meadow soddy chestnut soils in the Big Almaty Gorge (P-2) and mountain-thermoxerophilic dark chestnut soils in the Kaskelen Gorge (P-3) were identified. Soil fertility in terms of humus and nutrients was higher of Kimasar Gorge (P-1) compared to the other two studied soils of the gorge, i.e. it was 3.44-8.54%. The amount of mobile nutrient elements of Kimasar gorge (P-1) revealed high levels of mobile nitrogen, phosphorus, potassium, nitrogen 547.6-100.8 mg/kg, phosphorus 28-46 mg-kg, potassium 170-450 mg/kg. Among trace elements it was found that mobile forms of zinc (Zn), copper (Cu), lead (Pb) did not exceed MPC of these elements in all soil types, only mobile cadmium (Cd) exceeded MPC several times. According to mechanical composition of Kimasar Gorge (P-1) has mechanical composition light loamy (24,69 %), Big Almaty Gorge (P-2) has light loamy (28,52 %), Kaskelen Gorge (P-3) with mechanical composition less than 0,01 mm was sandy (7,32 %). In terms of salt content all soil samples are characterized as non-saline.

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