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STUDY OF PATTERNS OF ACCUMULATION AND DISPERSION OF CHEMICAL ELEMENTS IN SOILS OF THE SOUTHERN ARAL SEA REGION

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Abstract

The article provides information on the results of a study of the patterns of dispersion of chemical elements in the soils of the Southern Aral Sea region. Comparative analysis of the chemical composition of soils from north to south according to the Muynak-Nukus-Ellikkala scheme, Republic of Karakalpakstan. The content of many elements in soils is low (with the exception of Na, K), and due to the alkaline reaction of the environment and the oxidizing conditions, their mobility in the conditions of the Aral Sea region is low.

Keywords: *Karakalpakstan, Aral Sea region, soil, geochemistry, Muynak, Nukus, Ellikkala, environmental conditions, content*

Introduction

The ecological crisis of the Aral Sea region is a result of irresponsible human interaction with nature and the environment. Specifically, over a short historical period (1960–2017), we have witnessed a profound ecological disaster in the Aral Sea region. Due to the increase in water consumption in the agriculture of the republic, the Aral Sea did not receive the necessary amount of water (about 1000 km³), resulting in the sea's desiccation. The severity of the ongoing processes, both in terms of ecological-geochemical and socio-economic aspects, is quite complex and requires the unification of scientific efforts and the economic potential of the global community.

The causes and effects of the ecological crisis in the Aral Sea region have been thoroughly researched by scientists from Karakalpakstan and the Republic of Uzbekistan, as well as by scientists from other

countries – Russia, Kazakhstan, and others. However, published works lack data on the ecological-geochemical state of the environment in the region. There is no information on the biogeochemistry of individual chemical elements, and background levels of chemical elements in the biosphere, which are essential for predictive assessments of the ecosystem's condition and the development of measures to prevent the worsening of the current level of ecological disaster or its improvement, have not been established.

The aim of the study and discussion of the results

The initial studies on the ecological-agrogeochemical conditions of soils were conducted from 2010 to 2012 by Ibragimov B., Jumamuratov A. (Zhumamuratov A., Ibragimov B. A., 2014; Zhumamuratov A., Zhumamuratov M. A., Sdykov I. M., Usmanov U., 2017). These studies demonstrated soil enrichment with Na, Cl, Zn, Cu, As, Sb, Se, Br, Hf, Ta, U, REE, while simultaneously observing a depletion of K, Sc, Mn, Fe, Co, Ba, Sr, and included a cartogram of Na distribution in the soils of the northern part (above Nukus) of Karakalpakstan. Subsequent observations of the ecological-agrogeochemical condition of soils at the same control points were continued by us in the following years – not only to assess the degree of soil contamination but also to establish other soil parameters. Soil samples were collected during 2017–2022.

Soil samples were collected from the arable layer of the Ellikkala district (Bostan farm) – moderately saline soils, and samples of highly saline soils in the Muynak district (vicinity of Muynak city) and the surroundings of Nukus city. Given that the Ellikkala district is located far from the Aral Sea (380 km) and, according to data (Zhumamuratov A., Ibragimov B. A., 2014), the soils of this district are less prone to salinization, this area was taken as a benchmark, and the data on the elemental composition of soils obtained from the other two districts were compared with Ellikkala. Let's examine these relationships, i.e., the comparison of the average content of elements in the soils of the Muynak (Cm) and Nukus (Cn) districts with the data for the Ellikkala (Ce) district. Soil samples were collected from the arable layer of the Ellikkala district (Bostan farm) – moderately saline soils, and samples of highly saline soils in the Muynak district (vicinity of Muynak city) and the surroundings of Nukus city. Given that the Ellikkala district is located far from the Aral Sea (380 km) and, according to data (Zhumamuratov A., Ibragimov B. A., 2014), the soils of this district are less prone to salinization, this area was taken as a benchmark, and the data on the elemental composition of soils obtained from the other two districts were compared with Ellikkala. Let's examine these relationships, i.e., the comparison of the average content of elements in the soils of the Muynak (Cm) and Nukus (Cn) districts with the data for the Ellikkala (Ce) district.

Sodium and potassium. The content of Na decreases from north to south in the sequence Muynak-Nukus-Ellikkala. The potassium content is highest (2.2%) in the soils surrounding Nukus and lowest in the soils of the Ellikkala district (1.1%). The high potassium content indicates that these soils have either not been used in agricultural rotation for a long time or are contaminated by uncontrolled application of potassium fertilizers (Fig. 1).

Iron, Manganese, Cobalt. For this group of elements, an enrichment of the soils in the Ellikkala district is observed. Compared with other areas, it is noted that the contents of Fe, Mn, Co in the soils are relatively low compared with other republics (Zhumamuratov A., Ibragimov B. A., 2014), and a deficiency of these elements can cause anemia and other diseases, i.e., the content is insufficient for the normal progression of metabolic processes in plants, animals, and humans (Tarmaeva I. Yu., Boeva A. V. 2014).

Scandium and REEs (La, Ce, Sm, Eu, Tb, Yb, Y). The biological role of this group of elements is not well understood, although these elements are always found in the composition of soils, plants, in the organs and tissues of animals and humans. The work (Tarmaeva I. Yu., Boeva A. V. 2014) demonstrates the involvement of these elements in the pathogenesis of cotton wilt, hepatitis, and diabetes in humans, in particular, a correlation was found between the content of scandium and the blood sugar levels in sick and healthy individuals. From table 1., it is

apparent that the soils of the Ellikkala district and the surroundings of Nukus and Muynak districts are enriched with these elements and are more evenly distributed within the limits of elemental determination errors. We tend to explain this situation by the fact that this group of elements is part of phosphate fertilizers, and their application has led to the contamination of the soils in this region (since within).

Table1. *Content of chemical elements in the arable layer of soils from characteristic regions of Karakalpakstan (mg/kg)*

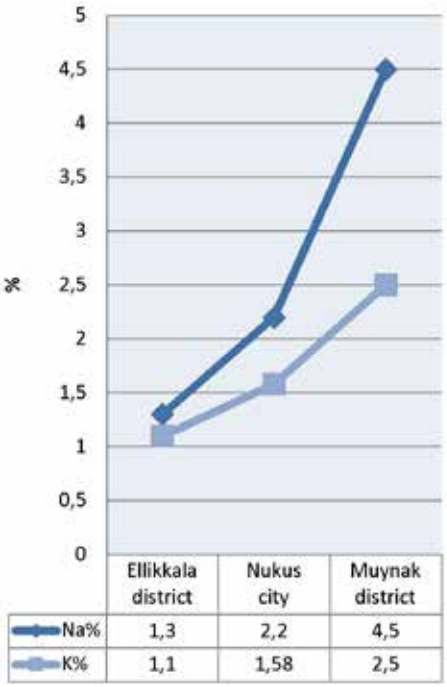
	Ellikkala district	Muynak district		Nukus district		$\bar{C}$	$\bar{C}$ [3]	$\bar{C}/\bar{C}$ [3]
	Ce	Cm	$\bar{C}_м/\bar{C}_э$	$\bar{C}_н/\bar{C}_э$	$\bar{C}_н/\bar{C}_э$			
Na%	1.3	4.5	3.5	2.8	2.2	2.87	1.7	1.69
K%	1.1	1.58	1.43	2.2	2.0	1.63	1.8	0.91
Sc	11.5	7.3	0.60	9.8	0.8	9.54	7.8	1.22
Cr	46.7	25.8	0.50	55.0	1.1	24.3	75.3	0.32
Mn	624.0	450.0	0.72	496.8	0.80	523.6	434	1.21
Fe%	1.85	1.52	0.84	1.35	0.73	1.57	1.4	1.12
Co	11.7	8.2	0.70	9.84	0.86	9.91	8.9	1.11
Rb	35.9	50.9	1.42	41.2	1.15	56	52.7	1.06
Y	29.0	34.0	1.17	33.0	1.3	32	–	–
Zr	11.0	13.2	1.2	12.4	1.1	12.2	–	–
Sb	3.6	2.61	0.72	2.25	0.61	2.82	1.6	1.76
Cs	6.50	3.86	0.59	3.50	0.54	4.29	1.6	2.68
Ba	967.0	635.0	0.66	400.0	0.41	667.3	340	1.96
La	33.6	19.2	0.57	26.9	0.80	26.53	19	1.59
Ce	30.6	26.7	0.87	27.0	0.73	28.1	18.1	1.56
Sm	2.5	2.1	0.84	3.7	1.48	2.77	2.9	0.96
Eu	0.90	1.07	1.18	1.72	1.91	1.23	1.0	1.23
Tb	3.7	3.5	0.95	5.2	1.41	4.13	3.3	1.25
Yb	1.2	1.50	1.25	1.38	1.15	1.36	1.8	0.78
Hf	2.3	2.12	0.91	2.30	1.0	2.21	3.5	0.63
Th	5.2	4.88	0.94	6.3	1.21	5.7	5.3	1.1
U	2.82	2.60	0.93	2.1	0.75	2.51	2.1	1.2

Rubidium, Cesium, Barium. The elements of this group are analogs of Na, K, and Ca. Their content (except for Ba) is higher in the soils of the Muynak district, and slightly lower in the Nukus district. The enrichment of the soils in the Ellikkala district (967.0 mg/kg) with barium can be explained by a disturbance in the Ca/Ba or Mg/Ba ratio, which leads to the depletion of Ca or Mg in the soils and is associated with changes in the pH of the environment (pH-8.9), or the composition of humus in the soils.

Thorium and uranium. The maximum content of thorium was found in the arable layer of soils in the Nukus district (6.6 mg/kg), Ellikkala (5.2 mg/kg), and the minimum in the soils of the Muynak district (4.88 mg/kg). In the case of uranium, we see the opposite picture: Ellikkala (2.82 mg/kg), Muynak (2.60 mg/kg), Nukus (2.10 mg/kg). As will be shown in the next chapter, these elements, along with their natural component, also have anthropogenic components, hence here we find disturbances in their ratios, which are associated with the environmental

situation of the region. The average data we obtained for Th and U are 1.05 and 1.2 times higher, respectively, than the averages for (Karakalpakstan Zhumamuratov A., Ibragimov B. A., 2014). A slight increase in the content of these elements in the soils is observed.

Figure 1. *Comparative analysis from north to south following the scheme Muynak-Nukus-Ellikkala in the Republic of Karakalpakstan (Sodium and Potassium)*



Antimony. The maximum content of antimony was found in the soils of the Ellikkala district (3.60 mg/kg), and the minimum in the soils around Nukus city (2.25 mg/kg). This element is a component of pesticides. The obtained results for antimony do not have an anthropogenic impact on the environment, although this statement requires further research on the participation of antimony in the biogeochemical cycle.

Comparative analysis of the results we obtained with the data presented in the work (Esimbetov A. T., Ametov Ya.I., Allamuratov K. K., 2018) shows that over 8–10 years (our samples were taken at the same points), the arable soil layer has been enriched with Na, Sc, Mn, Fe, Co, Rb, Sb, Cs, Ba, La, Ce, Eu, Tb, Th, U, and other chemical elements. In the soils of the designated sampling points to this day (with the exception of three out of seven sampling points in Muynak), cotton is still being cultivated. Therefore, the decrease in the content of K, Cr, Sm, Yb, Hf can be associated with their removal by cotton.

The process of enrichment with Na, Sb, Cs, Ba, La, Ce is linked to irrigation with saline water, the introduction of aerosol particles, the application of mineral fertilizers (in the case of REEs, Sc, Th, U), and due to the rise of groundwater levels to the surface, which contain high concentrations of many chemical elements (Table 1).

In principle, over 10 years, the content of chemical elements in the arable layer increased by 1.05–2.6 times. To establish the reliability of such a statement, it is necessary to conduct systematic research over time and space on a sufficiently large statistical basis, which is planned for the future.

Study results show, it should be noted that the content of many elements in the soils is small (with the exception of Na, K), and due to the alkaline reaction of the environment and the oxidative conditions, their mobility in the conditions of the Aral Sea region is low. Therefore, plants, animals, and humans may experience their deficiency, which is evident in the example of reduced soil productivity in the region.

Soil salinization has led to a quantitative and qualitative change in the pattern of migration of chemical elements in the biosphere of the region due to the reduction in the accumulation of bio-philic elements, disruption of the ratio between elements, and an increase in the proportion of toxicants in the soil. Therefore, studying the distribution pattern of a wide range of chemical elements across the soil profile is important in this regard.

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