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ARTICLE

Geochemistry of Cyclic Elements in the Irrigated Soils of Southern Fergana

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Abstract

This study investigates the distribution and concentration of cyclic elements in irrigated typical gray soils formed in the Shahimardonsoy alluvial fan of Southern Fergana. Field research and geochemical analysis were conducted using morphogenetic and comparative-geographical methods, along with systematic pedogeochemical approaches. The findings reveal a twofold increase in iron content within the geochemical carbonate-illuvial barrier, which also acts as an accumulation zone for other macroelements such as K, Na, Cr, and Sr, as well as cyclic microelements including Mn, Co, and Hf. These results indicate that irrigation significantly influences the migration and redistribution of elements in soil profiles, impacting soil fertility and agricultural productivity.

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1 Introduction

Soil genesis and evolution under the influence of irrigation have become crucial areas of scientific research in modern soil science. The geochemical properties of soils, including the processes of accumulation, migration, and transformation of chemical elements, play a fundamental role in understanding soil fertility and environmental stability. The study of these factors is essential for developing sustainable land-use strategies and mitigating the negative impacts of agricultural practices.

The scientific foundations of soil genesis were established by V.V. Dokuchaev, who emphasized the role of geological parent materials, biological activity, climate, topography, and hydrological conditions in soil formation. Later, A.I. Perelman and M.A. Glazovskaya expanded on these principles by introducing geochemical and pedogeochemical approaches to soil research, allowing for a more comprehensive understanding of elemental distribution and transformation within soil profiles.

Geochemical studies emerged as a distinct scientific field in the 19th century, driven by advancements in chemistry and geology. These studies aimed to analyze the chemical composition of various natural environments and the proportions of their constituent elements. Over time, geochemical methods have been widely applied to investigate soil properties, particularly in regions subjected to anthropogenic pressure such as irrigated agricultural lands.

This, in turn, enables the comparative analysis of gray soils that have developed under similar natural soil-climatic conditions and have been subjected to anthropogenic pressure, facilitating the comparison of various processes occurring within them [1].

It is well known that the quantity and quality of chemical elements are assessed in geochemical and biogeochemical studies by considering the landscape and all its characteristics. In scientific and practical research, the geochemical and biogeochemical properties of elements in both soil and plants are examined. Additionally, in specific geochemical systems, it is necessary to determine these elements, classify the system, and establish permissible concentrations along with Clarke and background levels.

For the gray soil region, the hygienic standards, background, and Clarke values of many chemical elements [2] have not been sufficiently studied. The composition, concentration, migration, and accumulation processes of the relatively less explored cyclic elements in the research area, as well as their differentiation within soil genetic horizons, are of particular importance.

2 Materials and Methods

2.1 Materials

The study of the geochemical properties of soils has been the focus of many researchers. Scientists such as Ya.V. Peyve, O.V. Makeyev, V.B. Ilin, I.V. Yakushevskaya, G.Ya. Rinkis, J. Sattorov, M. Toshqoziev, L. G'ofurova, G'. Yuldashev, M. Isagaliyev, A. Turdaliyev, D. Xoldarov, G. Sotiboldiyeva, and Z. Isomiddinov have conducted extensive research on soil genesis, elemental composition, migration, and accumulation processes. Their studies have contributed to understanding the impact of natural and anthropogenic factors on soil formation and chemical properties.

This research focuses on the irrigated typical gray soils formed in the Shahimardonsoy alluvial fan of Southern Fergana. The study area is characterized by specific geomorphological conditions influenced by irrigation, leading to geochemical differentiation. Soil samples were collected from various genetic horizons to analyze the distribution and concentration of cyclic elements such as K, Na, Cr, Sr, Mn, Co, and Hf.

2.2 Research Methods

Field studies were conducted based on the morphogenetic and comparative-geographical methods developed by V.V. Dokuchaev. This approach enables the identification of soil formation processes based on their genetic characteristics and spatial distribution. Additionally, to study the migration, accumulation, and transformation of elements in soils, M.A. Glazovskaya and A.I. Perelman's systematic pedogeochemical approaches were applied. This methodology allows for a deeper analysis of geochemical processes influencing soil fertility and stability.

Soil samples were collected from the genetic horizons of irrigated typical gray soils in the Shahimardonsoy alluvial fan of Southern Fergana. The samples were taken along the A, B, and C horizons, with three replications at each depth level. To ensure reliability, the samples were air-dried, passed through a 2 mm sieve, and homogenized before analysis.

Chemical analyses were performed following the methodologies described in "Methods of Agrochemical, Agrophysical, and Microbiological Research in Irrigated Cotton-Growing Areas" and Ye.V. Arinushkina's "Guide to Soil Chemical Analysis." These methods were selected for their high precision in determining the concentration of macro- and microelements in soil matrices.

The chemical composition of soil elements was analyzed at the Institute of Nuclear Physics of the Academy of Sciences of Uzbekistan using the neutron activation analysis (NAA) method. This technique is characterized by high sensitivity and accuracy, making it highly effective in detecting trace elements at very low concentrations.

The obtained experimental data were processed through mathematical and statistical analysis to assess the distribution patterns of cyclic elements across the soil profile.

Data processing was conducted using specialized software developed by G. Yuldashev and Sh. Karimov. Diagrams, graphs, and mathematical modeling were carried out using Microsoft Excel and OriginPro, enabling the visualization of geochemical changes in soil development.

3 Results and Discussion

The concentration of chemical elements within landscapes and their subunits, particularly in soils, exhibits notable spatial heterogeneity. This variability arises due to multiple factors, with element migration being a primary driver. However, migration alone does not fully account for these disparities; certain characteristics can also be explained through the average content of elements in soil or the lithosphere.

A.I. Perelman categorized chemical elements into

geochemical groups, identifying 44 elements as cyclic elements, which collectively constitute 99.8% of the Earth's crust by mass [3]. These elements undergo continuous biogeochemical cycling, playing a crucial role in soil formation and fertility.

In the irrigated typical gray soils of the Shahimardonsoy alluvial fan, where this study was conducted, the concentrations of cyclic elements such as Fe, Ca, K, Na, Mn, Ba, and Sr were analyzed [4]. The results indicate that even though these soils originate from the same parent material, the geochemical system does not exhibit uniform elemental distribution. This suggests that irrigation and agricultural activities have induced significant mineralogical and chemical transformations (Figure 1).

A notable example is iron (Fe), a key cyclic element in the lithosphere's primary components. As a cascade element, iron participates in various oxidation-reduction processes, influencing soil mineralogy and fertility. According to A.P. Vinogradov, the Clarke value of iron in the lithosphere is 4.65%, with a dominant presence in magmatic rocks. However, at a global scale, iron's total distribution reaches approximately 45% [5].

These findings emphasize the role of geochemical barriers in regulating the accumulation, leaching, and redistribution of elements within soil profiles. The carbonate-illuvial horizon, for instance, functions as a chemical filter, concentrating specific elements while depleting others.

Further analysis of cyclic elements' geochemical behavior in irrigated soils will provide deeper insights into their migration patterns and ecological implications, particularly in agricultural sustainability and soil conservation efforts.

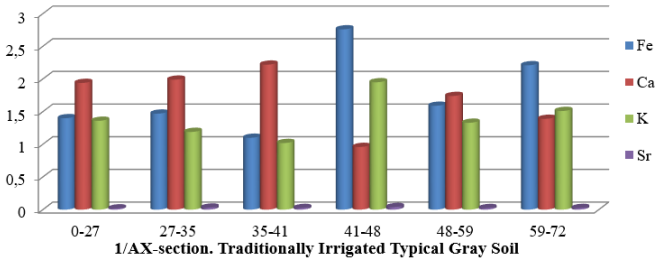

Figure 1. The Content of Certain Cyclic Elements in Irrigated Typical Gray Soils (in %)

As seen from the data in the figure above, the concentration of iron (Fe) in the irrigated soils and parent rocks of the Shohimardonsoy alluvial fan varies within the range of 1.10–2.76%. The findings indicate that as the degree of assimilation increases, iron gradually yields its dominance to calcium, reflecting mineralogical transformations in the alluvial soils [6].

The distribution of cyclic elements is closely associated with their Clarke values in the soil, as well as with humus content and mechanical composition. In the plow layer of irrigated typical gray soils, the concentration of cyclic elements follows a decreasing order as listed below:

1/AX- section:

Ca	>	Fe	>	K	>
1.94		1.40		1.36	
Na	>	Ba	>	Mn	>
0.64		0.064		0.032	
Sr	>	Zn	>	Cr	>
0.019		0.007		0.0034	
Ni	>	As	>	Sb	>
0.0022		0.0019		0.0017	
Co	>	Hf	>	Mo	
0.0006		0.00036		0.00006	

The obtained data suggest that after calcium, iron is the most predominant element in irrigated typical gray soils, which serves as a distinctive geochemical feature of these soils.

Research findings further indicate that the increase in iron concentration follows an inverse proportional pattern during the assimilation process. That is, under the influence of irrigation, Fe particles migrate along with clay colloids [7] toward the lower carbonate-illuvial horizon, where they accumulate. This carbonate-illuvial layer functions as a geochemical barrier in irrigated typical gray soils.

Moreover, along with Fe, other cyclic elements such as K, Na, Mn, Sr, Cr, Co, and Hf also accumulate in this barrier [8]. The increased concentration of these elements leads to their enrichment beyond their Clarke values in the soil, resulting in the formation of geochemically enriched horizons.

4 Conclusions

Thus, in soil genesis and evolution, the redistribution of elements under natural and anthropogenic pressure leads to the formation of excess or deficient amounts

in genetic soil horizons. This phenomenon affects not only the geochemical state of the landscape and its blocks but also directly influences the quantity and quality of agricultural crop yields.

In the studied irrigated typical gray soils, the migration and accumulation processes of cyclic elements such as Fe, Ca, K, Na, Mn, Sr, Cr, Co, and Hf were observed to vary. The carbonate-illuvial layer acts as a geochemical barrier, leading to the accumulation of these elements and resulting in changes in the mineralogical composition of the soil.

Additionally, the increasing iron concentration in the lower layers indicates a progressive accumulation process driven by irrigation and the migration of clay colloids. This redistribution affects the chemical properties of the soil and influences the uptake of essential nutrients by plants.

The findings of this study contribute to a deeper understanding of geochemical processes in irrigated regions and provide a scientific basis for developing efficient land-use strategies. Future research should focus on assessing the long-term migration of elements, their bioavailability, and potential ecological risks associated with continuous irrigation.

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