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Geochemistry of Macroelements in Irrigated Arzyk-Shokh Hydromorphic Soils

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Abstract

This study examines the chemical composition and geochemical behavior of water-soluble salts in irrigated meadow saz soils, focusing on the impact of cemented shokh-arzyk horizons on salt migration and accumulation. Physicochemical analysis of soil samples from different genetic horizons revealed that the cemented layer significantly affects ion mobility, leading to variations in salt distribution. The findings highlight the role of shokh-arzyk horizons in soil salinity dynamics and provide insights for improving soil fertility management in saline-affected regions.

Citation
Turdaliyev, A. T., Turebaeva, S., Khalilov, A. A., Mukhammadov, Y., Egamberdieva, S., & Usarboeva, S. (2025). Geochemistry of Macroelements in Irrigated Arzyk-Shokh Hydromorphic Soils. J Open, 01(01), 14–20.

Submitted: January, 2025
Accepted: February, 2025
Published: March, 2025

Vol. 01, **No.** 01, 2025.
10.70728/jopen.be.0125.004

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Keywords: irrigated meadow saz soils, water-soluble salts, shokh-arzyk horizon, soil salinity, geochemical differentiation, ion migration

1 Introduction

Currently, many landscapes around the world, particularly irrigated soils, have undergone significant changes since the Quaternary period. These changes have been driven by factors such as land leveling, irrigation, plowing, excessive use of mineral fertilizers and pesticides, livestock grazing, the presence of quarries, and other anthropogenic activities.

However, the salinization of soils characteristic of these regions and the increased accumulation of ash elements in plant composition continue to persist. Therefore, studying such landscapes requires a comprehensive research approach based on the principles of B.B. Polinov [3], V.V. Dobrovolsky [5], V.A. Kovda [4], and A.I. Perelman [1].

In this region, relict residues and soil horizons also influence the landscape. The study of geochemical relics is considered part of historical geochemical research.

For this purpose, clay formations, arzyk-shokh layers, and gypsum layers hold great theoretical and practical significance. Therefore, our landscape geochemical research focuses on studying the accumulation, differentiation, and other characteristics of macroelements within these formations.

Thus, these buried layers cannot be directly classified as soil, as they lack certain functions characteristic of soil and have instead become an integral part of the natural system. According to I.P. Gerasimov [6], such formations, or layers, can be referred to as "pedoliths."

2 Materials and Methods

The microelement composition of the soil was studied using the neutron activation method at the Activation Analysis Laboratory of the Institute of Nuclear Physics of the Republic of Uzbekistan. In this process, the samples were irradiated in a nuclear reactor with a neutron flux of 5×10^{13} neutrons/cm^2·s, and the quantities of chemical elements were determined based on their half-life periods.

3 Results and Discussion

Pedoliths are enriched and cemented with lessivage products, possessing distinct mineralogical and geochemical characteristics that differentiate them from the soil layers above and below.

When the genetic horizons of the soil contain organogenic, eluvial, carbonate, gypsum, or saline layers, elements undergo strong differentiation.

The elemental composition of the soil depends on its granulometric composition, type, layers, and the specific properties of each element.

Several elements are inherited from the parent material, resulting in similar concentrations. These include Si, Al, Fe, Mg, K, Na, Mn, and others.

Metals contained in simple salts such as $CaCO_3$, $CaSO_4$, $MgSO_4$, NaCl, $NaHCO_3$, and Na_2SO_4 exhibit unique characteristics. These metals can be leached from the soil as water-soluble salts, leading to a decrease in their concentration or their accumulation in other areas. This process is directly influenced by the soil's water regime.

There are also differences in carbonate concretions. For example, in steppe soils, carbonate concretions contain 60-80% $CaCO_3$, 15-30% SiO_2, 2-5% Al_2O_3, 1% Fe_2O_3, and small amounts of Na, K, and S.

As with other soils, the elemental composition is the primary and fundamental characteristic of irrigated soils. This, in turn, determines the genesis and fertility of the soil and its individual layers.

It is well known that more than a century has passed since the publication of Clarke's Table. Significant research has been conducted on the Clarke values of the Earth, soil, plant cover, atmosphere, and biosphere. Among these studies, the work of A.P. Vinogradov [2] is particularly noteworthy.

The elemental composition plays a decisive role in assessing the potential fertility of soils, as well as in determining salinization, heavy metal contamination, toxicity, and other characteristics. The migration and accumulation properties of elements in the soil depend mainly on internal and external factors.

Internal factors include the valency, atomic mass, atomic number, ionic radius, Cartledge potential, energy constant, and other properties of migrating ions. External factors include various soil-related properties such as salinity, redox conditions, humus content, and absorbed cations.

Under ideal conditions and in ideal solutions, the migration of cationogenic elements such as Na, Mg, K, Ca, Fe, Rb, Sr, and Ba decreases as their atomic number and atomic mass increase. However, in actual soil conditions, this trend is not always straightforward, as other physicochemical properties influence their behavior.

Therefore, to study the geochemical properties of these elements in soil, their chemical and geochemical characteristics are presented in Table 1.

Ionic Radius According to Fersman A.E.;

Cartledge Potential $J = \frac{W}{R}$;

Energy Constant According to Perelman A.I.;

Conditionally Added Energy to the Crystal Lattice U=ec1070,74;

^{x}- Calculated by the Authors.

According to the table data, as the atomic number of the studied elements increases, their atomic masses also increase. There is no clear pattern in the changes of valency; moreover, the valency of Fe in the given case is +3, while the other elements predominantly have valencies of +1 or +2.

The ionic radii of these elements indicate their ability to exchange or not exchange within the soil adsorption complex and in the composition of various minerals. This is based on their paragenetic properties, as described by Vernadsky's genetic pair concept.

From this perspective, according to Fersman's law, elements whose ionic size differences are less than 20% can substitute for one another in minerals and other environments depending on the conditions.

In our case, the elements Na, Mg, K, Ca, and Fe form one group, while Sr, Ba, and Pb form another.

Regarding the Cartledge potential, relatively high values are observed for Mg and Fe, while the lowest

Table 1. Chemical and Geochemical Properties of Macroelements

Properties	Na	Mg	K	Ca	Fe	Rb	Sr	Ba
Atomic Number	11	12	19	20	26	37	38	56
Atomic Mass	23	24.3	39	40	56	87	87.6	137
Valency	+1	+2	+1	+2	+2	+1	+2	+2
Ionic Radius, A°	0.98	0.74	1.33	1.04	0.80	1.43	1.20	1.38
Cartledge Potential^x	1.02	2.70	0.75	1.92	2.50	0.70	1.67	1.45
Energy Constant^x	0.45	2.10	0.36	1.75	1.125	0.30	1.53	1.35
Conditionally Added Energy to the Crystal Lattice, kJ^x	482.28	2250.65	385.83	1875.54	1205.71	321.71	1639.76	1446.85

potential belongs to Rb. The rest of the elements have intermediate values.

If the Cartledge potential is equal to or less than one, the element behaves as a typical alkali metal under natural soil conditions.

Thus, in our soils, Rb, Na, and K exhibit properties characteristic of typical alkali metals.

When the Cartledge potential (CP) ranges between 1 and 3, the elements behave as alkaline earth metals. If the CP value is higher than 3, the elements exhibit non-metallic or amphoteric properties.

As seen from the table, the smallest energy constant values correspond to alkali metals, which in turn indicates their low contribution to the structural energy of minerals in the soil, making them relatively more mobile.

The smaller the energy constant, the higher the solubility of the salt or mineral formed by that element.

There is a direct correlation between the energy constant and the migration ability of elements.

Thus, Na (482.28 kJ), K (385.83 kJ), and Rb (371.52 kJ), which are present in the crystal lattice, exhibit higher migration properties, whereas elements with energy constants of 2250.65 kJ and 1875.54 kJ have lower migration capabilities.

The amounts of these elements in different types of soil may vary and can be relatively close to each other. Such cases can be observed in irrigated meadow-swamp soils with weak and moderately saline genetic horizons, which contain a deep arzik-shokhli layer. This is presented in Table 2 [7].

The amounts of Na+ and Mg^{2+} in the genetic layers of irrigated meadow-swamp soils fluctuate between 0.50% and 1.72%. In the plow layer, their amounts range from 0.92% to 0.81%.

In the studied soil layers, the highest amount of elements corresponds to Ca, followed by Fe and Na. The lowest differentiation is observed in Rb and Ba.

When analyzing the geochemical spectrum of Fe, K, Ca, Na, Mg, Ba, Sr, and Rb between the arzik-shokh genetic horizon, plow layer, and parent material, the differences between these soil layers are clearly visible in Figure 1.

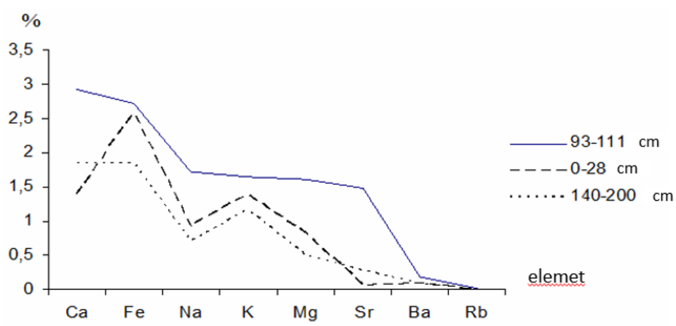

Figure 1. Section 7A. Geochemical spectrum of macroelements

According to the geochemical spectrum, the highest indicator corresponds to the 93-111 cm genetic horizon. If expressed in the form of a geochemical formula, it will have the following representations.

Section 7A. Quantitative Spectra of Macroelements in Deep Arzik-Shoh Soils.

Table 2. Chemical composition at different depths in section 7A

Section No.	Depth, cm	Na^{+}	Mg^{2+}	K^{+}	Ca^{2+}	Fe^{3+}	Rb^{+}	Sr^{2+}	Ba^{2+}
7A	0-28	0.92	0.81	1.38	1.39	2.57	0.0011	0.05	0.10
	28-36	1.02	0.92	1.62	1.42	2.56	0.010	0.05	0.10
	36-93	1.29	1.10	1.64	1.28	1.74	0.011	0.44	0.18
	93-111	1.72	1.62	1.65	2.93	2.72	0.017	1.48	0.18
	111-140	0.57	0.61	1.16	1.83	1.84	0.008	0.27	0.10
	140-200	0.70	0.50	1.16	1.86	1.85	0.008	0.27	0.10

$$\mathrm{A_x}.0-28cm.\ \begin{array}{cccccc} \frac{\mathrm{Fe}}{2.57} & > & \frac{\mathrm{K,Ca}}{1.38-1.39} & > & \frac{\mathrm{Na}}{0.92} & > \\ \frac{\mathrm{Mg}}{0.91} & > & \frac{\mathrm{Ba}}{0.10} & > & \frac{\mathrm{Sr}}{0.05} & > \\ \frac{\mathrm{Rb}}{0.001} & ; & & & & \end{array}$$

$$Ash.93-111cm.\ \begin{array}{cccccc} \frac{\mathrm{Ca}}{2.93} & > & \frac{\mathrm{Fe}}{2.72} & > & \frac{\mathrm{Na}}{1.72} & > \\ \frac{\mathrm{Mg,\ K}}{1.62-1.65} & > & \frac{\mathrm{Sr}}{1.48} & > & \frac{\mathrm{Ba}}{0.18} & > \\ \frac{\mathrm{Rb}}{0.02} & ; & & & & \end{array}$$

$$C.140-200m.\ \begin{array}{cccccc} \frac{\mathrm{Ca,\ Fe}}{1.85-1.86} & > & \frac{\mathrm{K}}{1.16} & > & \frac{\mathrm{Na}}{0.70} & > \\ \frac{\mathrm{Mg}}{0.50} & > & \frac{\mathrm{Sr}}{0.27} & > & \frac{\mathrm{Ba}}{0.10} & > \\ \frac{\mathrm{Rb}}{0.01} & . & & & & \end{array}$$

According to the given formulas, calcium (Ca) is the most abundant element in the deep arzik-shokh layer, occupying the first position in the sequence, followed by iron (Fe) and others. In most layers, Fe and Ca are closely related and appear sequentially due to their similar ionic radii and their ability to form carbonate and sulfate salts in a similar manner.

Strontium (Sr), on the other hand, accumulates up to 1.48% in the deep arzik-shokh layers, while its concentration is significantly lower in other layers.

The studied elements serve as a specific background for these soil layers, and their values are represented by the following figures.

$$\begin{array}{cccccc} \frac{\mathrm{Fe}}{2.19} & > & \frac{\mathrm{Ca}}{2.05} & > & \frac{\mathrm{K}}{1.48} & > \\ \frac{\mathrm{Mg}}{1.0} & > & \frac{\mathrm{Na}}{0.96} & > & \frac{\mathrm{Sr}}{0.39} & > \\ \frac{\mathrm{Ba}}{0.1} & > & \frac{\mathrm{Rb}}{0.008} & & & \end{array}$$

The obtained results indicate that Na and Mg, Ca and Fe, as well as Ba and Sr, exhibit a correlation relationship due to their ionic radius differences being less than 20%. Additionally, such elements have a paired genesis and can substitute each other in the crystal lattice. In this correlation pattern, Ba and Sr show a weak connection, Ca and Fe demonstrate a moderate bond, while Na and Mg exhibit a strong correlation.

The accumulation and differentiation characteristics of elements in the layers can be observed through their concentration Clarke values.

For irrigated meadow-swamp soils in the desert region with a deep arzik-shokh layer, the concentration Clarke values of Na, Mg, K, Ca, Fe, Rb, Sr, and Ba, relative to Vinogradov's Clarke, are presented in the following Table 3.

Table data show that the concentration Clark of strontium has the highest values, fluctuating in the range of 1.47-43.5. The next element is Ba, ranging between 0.15-2.77. The concentration Clark of other elements is less than one. In certain layers, we can observe that some elements have relatively higher concentration Clark values. If we examine the geochemical spectrum and formula of the concentration Clark of Na, Mg, K, Ca, Fe, Rb, Sr,

Table 3. Clarke Concentration of Macroelements

Section No.	Depth, cm	Na	Mg	K	Ca	Fe	Rb	Sr	Ba
7A	0-28	0.37	0.43	0.55	0.47	0.55	0.67	1.47	1.54
	28-36	0.41	0.49	0.65	0.48	0.55	0.67	1.47	1.54
	36-93	0.52	0.59	0.66	0.43	0.37	0.67	12.9	2.77
	93-111	0.69	0.87	0.67	0.98	0.58	1.13	43.5	2.72
	111-140	0.23	0.33	0.46	0.62	0.40	0.53	7.94	0.15
	140-200	0.28	0.27	0.46	0.63	0.40	0.53	7.94	0.15
Vinogradov Clark		2.50	1.87	2.50	2.96	4.65	0.015	0.034	0.065

and Ba, we see that in the plow layer of the soil (7A, 0-28 cm), the concentration Clark of Ba is 1.54.

In a specific layer, namely the argic-humic layer, the concentration Clark of strontium is 43.5, which significantly differs from other values. In other words, strontium accumulates in the argic-humic layer. The next element, primarily Ba, follows. The concentration Clark of barium is not very high and is 2.72 in this specific layer.

It is necessary to emphasize the presence of a distinct strontium province in the argic-humic layer. These conditions can be observed in Figure 2 and from the geochemical spectrum formulas below.

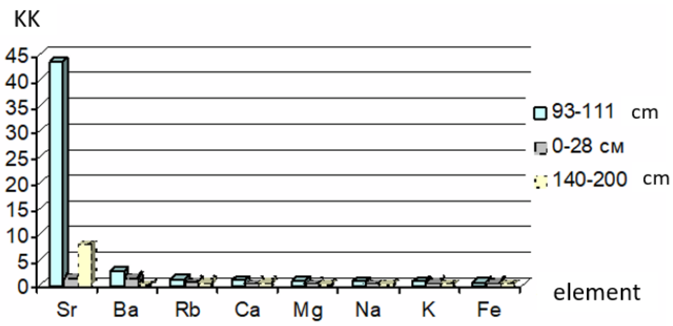

Figure 2. Section 7A. Concentration Clark of Macroelements

Section 7A, 0-28 cm.

$$KK\ \begin{array}{cccccc} \text{Ba} & > & \text{Sr} & > & \text{Rb} & > \\ 1.54 & & 1.47 & & 0.67 & \\ \text{Fe, K} & > & \text{Ca, Mg} & > & \text{Na} & \\ 0.55 & & 0.43-0.47 & & 0.37 & \end{array}$$

93-111 m., Arzik-shokhly layer

$$KK\ \begin{array}{cccccc} \text{Sr} & > & \text{Ba} & > & \text{Rb} & > \\ 46.5 & & 2.72 & & 1.13 & \\ \text{Ca} & > & \text{Mg} & > & \text{Na} & > \\ 0.97 & & 0.87 & & 0.69 & \\ \text{K} & > & \text{Fe} & & & \\ 0.67 & & 0.58 & & & \end{array}$$

140-200 m.

$$KK\ \begin{array}{cccccc} \text{Sr} & > & \text{Ca} & > & \text{Rb} & > \\ 7.94 & & 0.63 & & 0.53 & \\ \text{K} & > & \text{Fe} & > & \text{Na, MG} & > \\ 0.46 & & 0.40 & & 0.27-0.28 & \\ \text{Ba} & & & & & \\ 0.15 & & & & & \end{array}$$

4 Conclusions

The elemental composition plays a crucial role in determining the salinity, heavy metal contamination, toxicity, and other characteristics of the studied soils.

To improve the fertility of deep argillic-horizon soils, it is necessary to consider the migration and distribution of chemical elements throughout the soil layers. Agronomic measures such as increasing the thickness of the plow layer and loosening or breaking the argillic horizon should be implemented. Additionally, fertilizers and other chemical treatments should be applied in accordance with the soil composition and properties, with appropriate dosages determined by specialists to achieve optimal results.

Author Contributions: Conceptualization, A.T.T. and S.T.; methodology, A.T.T.; software, A.T.T.; validation, S.T., A.A.K., Y.K.M., S.F.E., Sh.Sh.U.; formal analysis,

A.A.K.; investigation, A.T.T.; resources, A.T.T., S.T.; data curation, A.T.T.; writing—original draft preparation, S.T.; writing—review and editing, S.T.; visualization, A.A.K.; supervision, A.T.T.; project administration, A.T.T.; funding acquisition, A.T.T., S.T. All authors have read and agreed to the published version of the manuscript.

Funding: The authors declare that no funds, grants, or other financial support were received during the preparation of this manuscript.

Institutional Review Board Statement: This research did not include any experiments involving human participants or animals, so Institutional Review Board (IRB) approval was not necessary.

Informed Consent Statement: This study did not involve human subjects; therefore, informed consent was not required.

Data Availability Statement: Data supporting the report's findings can be found here.

Acknowledgments: The authors express their sincere gratitude to Associate Professor (PhD) **Zokirjon Isomiddinov** of Kokand State University for his valuable review of the study's results and his contributions to its publication.

Conflicts of Interest: The authors declare no conflicts of interest related to this study.

Declaration of generative AI and AI-assisted technologies in the writing process: During the preparation of this work, the author used Grammarly to assist with readability and language improvement in the writing process. After using this tool, the author reviewed and edited the content as needed and takes full responsibility for the content of the published article.

References

[1] 1. Perelman, A. I. (1989). Geokhimiya [Geochemistry]. Moscow, 419 p. [Google Scholar]

[2] 2. Vinogradov, A. P. (1957). Geokhimiya redkikh i rasseyannykh khimicheskikh elementov v pochvakh [Geochemistry of Rare and Dispersed Chemical Elements in Soils]. Moscow, 238 p. [GeoKniga]

[3] Polynov, B. B. (1985). Uchenie o landshaftakh [The Doctrine of Landscapes]. Leningrad, Vol. XIII, pp. 493-511.

[4] Kovda, V. A. (1973). Osnovy ucheniya o pochvakh [Fundamentals of Soil Science]. Moscow, Vol. 1-2, pp. 432-467.

[5] Dobrovolsky, V. V. (1983). Khimia zemli [Chemistry of the Earth]. Moscow, 175 p. [Violity]

[6] Gerasimov, I. P. (1976). Geneticheskie, geograficheskie i istoricheskie problemy sovremennogo pochvovedeniya [Genetic, Geographical, and Historical Problems of Modern Soil Science]. Moscow, 298 p. [Google Scholar]

[7] Turdaliyev, A. (2016). Genesis, Physicochemical, and Biogeochemical Properties of Arzik-Shokhli and Shokh-Arzik Layers in the Central Fergana Lands: Abstract of the Doctoral Dissertation (DSc) in Biological Sciences.

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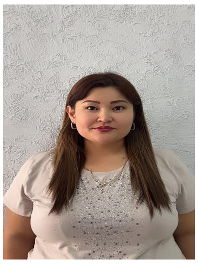

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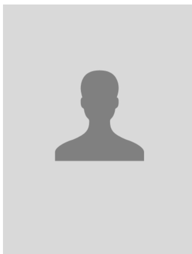

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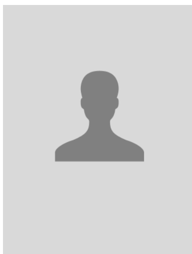

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