J Open
http://dx.doi.org/10.70728/jopen.be.0325.004

ARTICLE

Concentration and Distribution of Macroelements in Irrigated Calcisols

Avazbek T. Turdaliev[1,*] and **Mashkhura M. Khaydarova**[1]

[1] Fergana State University, 19, Murabbiylar Street, Fergana City, 712000, Uzbekistan

Abstract

This paper examines the abundance, migration dynamics, concentration, and distribution of macronutrients in the genetic horizons of irrigated light, typical, and dark sierozem soils in the Fergana Valley. Differences in the clarke concentration, clarke distribution, and radial migration coefficients of macroelements were identified across sierozem soil types. These geochemical properties were also described as geochemical spectra.

Keywords: irrigated sierozem (calcisols), accumulation, migration, distribution, dynamics, geochemical spectrum.

1 Introduction

Currently, considerable attention is being devoted worldwide to scientific research addressing urgent issues in soil science, including the agro-ecological state of irrigated soils, their humus content, degumification, chemical composition, and related matters. In particular, the chemical elemental composition of soils holds significant theoretical and practical importance for studying soil formation processes, determining soil fertility, and identifying the direction of various geochemical processes occurring within them.

Understanding soil composition and the processes taking place within it is especially complex and important, as the compound and elemental composition of soils is fundamental; indeed, most elements of the periodic table can be found in soil.

Citation
Avazbek T. Turdaliev, Mashkhura M. Khaydarova (2025). Concentration and Distribution of Macroelements in Irrigated Calcisols. J Open, 01(03), 15–19.

Submitted: June, 2025
Accepted: August, 2025
Published: September, 2025

Vol. 01, **No.** 03, 2025.
10.70728/jopen.be.0325.004

***Corresponding author:**
Avazbek T. Turdaliev
avazbek1002@mail.ru

2 Literature Review

The primary and fundamental characteristic of soil is its elemental composition, which, in turn, determines the genesis of the soil and its horizons, as well as its fertility. It is well known that more than a century has passed since Clarke values were first developed. Considerable work has been conducted on Clarke values of the Earth, soil, vegetation cover, atmosphere, and biosphere, among which the studies of A.P. Vinogradov [1] hold a prominent place.

A.E. Fersman emphasized in this regard that “Geochemistry occupies a new constant of the world” [2]. At present, the universal distribution of chemical elements is known as the Clarke–Vernadsky law.

In studying the processes of migration and accumulation of chemical elements in soils, the geochemical barriers developed by A.I. Perelman [3] are of great significance, as they explain the sharp decrease in the rate of element migration over short distances and the resulting increase in their concentration.

Numerous researchers have conducted scientific investigations aimed at studying the properties of calcisols, including A.P. Vinogradov [1], V.V. Dobrovolskiy [4], G. Yuldashev, Sh. Y. Eshpulatov [5], A.T. Turdaliev [6], M.M. Haydarov [7, 8], I.I. Musaev [9, 11], among others.

3 Research Methodology

Field investigations were conducted in accordance with V.V. Dokuchaev's genetic–geographic, profile–geochemical, morphogenetic, and stationary methods. In the geochemical analysis of chemical elements, the integrated methods of A.I. Perelman and M.A. Glazovskaya were employed. The total contents of macroelements in the soil were determined using the neutron activation analysis method at the Institute of Nuclear Physics of the Academy of Sciences of the Republic of Uzbekistan.

4 Analyses and Results

The quantities of chemical elements in irrigated calcisols and their various types may differ or be relatively similar. The distribution of the analyzed macroelements across soil layers—that is, the differences among the genetic horizons of these soil profiles—can be observed through the following Geochemical Spectrum 1.

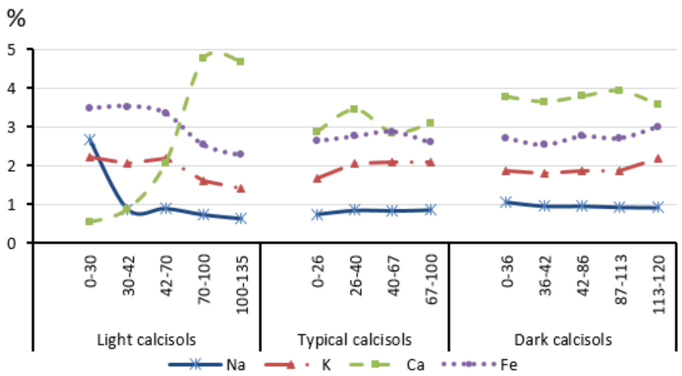

Figure 1. Diagram of Na, K, Ca, and Fe contents in irrigated calcisols

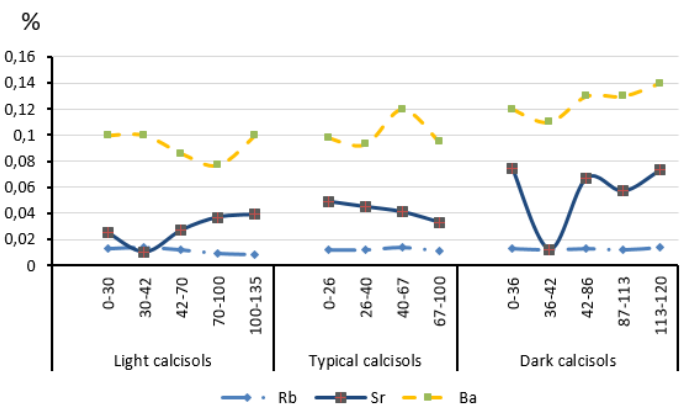

Figure 2. Diagram of Rb, Sr, and Ba contents in irrigated calcisols

The accumulation, migration, and differentiation characteristics of these macroelements within soil layers can be observed through their concentration Clarke values, Clarke distributions, and radial stratification patterns.

During the study, the Clarke concentrations of Na, Mg, K, Ca, Fe, Rb, Sr, and Ba were determined for light, typical, and calcisols of the calcisols region in relation to the lithospheric Clarke values developed by I.P. Vinogradov (1962), and they are presented in Table 1 below.

Table 1. Clarke Concentrations of Macroelements in Irrigated Calcisols

Profile No.	Depth, cm	Na	K	Ca	Fe	Rb	Sr	Ba
Dark Calcisols								
Profile 2x	0–30	1,07	0,89	0,18	0,74	0,87	0,74	1,54
	30–42	0,35	0,82	0,29	0,76	0,93	0,29	1,54
	42–70	0,36	0,88	0,70	0,72	0,80	0,79	1,32
	70-100	0,30	0,64	1,60	0,55	0,61	1,09	1,18
	100-135	0,26	0,56	1,58	0,49	0,54	1,15	1,54
	135–170	0,29	0,60	1,60	0,52	0,67	1,62	1,20
Typical Calcisols								
Profile 4x	0–26	0,30	0,67	0,97	0,57	0,80	1,44	1,51
	26–40	0,34	0,82	1,16	0,59	0,80	1,32	1,43
	40–67	0,34	0,84	0,96	0,62	0,93	1,21	1,85
	67–100	0,34	0,83	1,04	0,56	0,73	0,97	1,46
Light Calcisols								
Profile 6x	0–36	0,42	0,74	1,27	0,58	0,87	2,18	1,85
	36–42	0,38	0,72	1,23	0,54	0,80	0,35	1,69
	42–86	0,38	0,74	1,28	0,59	0,87	1,97	2,00
	87–113	0,37	0,75	1,32	0,58	0,80	1,68	2,00
	113–120	0,37	0,88	1,21	0,64	0,93	2,15	2,15

As the data indicate, the concentration Clarke value of strontium is highest in light calcisols, reaching up to 2.18. It is followed by barium, which ranges from 1.18 to 2.15 across all soil types. Calcium also exhibits Clarke concentration values greater than 1 in all layers except the upper horizons of dark and light calcisols, indicating accumulation of this element in those layers.

The concentration Clarke values of sodium, potassium, iron, and rubidium are less than 1, showing that these elements are not accumulated in the soil layers.

According to V.I. Vernadsky and other scholars, Clarke distribution is considered the inverse of Clarke concentration [10]. From this perspective, the Clarke distribution of the studied soils was developed and is presented in Table 2 below.

Table 2. Clarke Distribution (Kt) of Macroelements in Irrigated Calcisols

Profile No.	Depth, cm	Na	K	Ca	Fe	Rb	Sr	Ba
Dark Calcisols								
Profile 2x	0–30	0,93	1,12	5,58	1,34	1,15	1,36	0,65
	30–42	2,84	1,21	3,40	1,32	1,07	3,40	0,65
	42–70	2,78	1,14	1,44	1,39	1,25	1,26	0,76
	70-100	3,38	1,56	0,62	1,83	1,65	0,92	0,84
	100-135	3,91	1,79	0,63	2,05	1,85	0,87	0,65
	135–170	3,42	1,67	0,62	1,91	1,50	0,62	0,83
Typical Calcisols								
Profile 4x	0–26	3,33	1,49	1,03	1,77	1,25	0,69	0,66
	26–40	2,94	1,21	0,86	1,69	1,25	0,76	0,70
	40–67	2,98	1,20	1,04	1,62	1,07	0,83	0,54
	67–100	2,91	1,20	0,96	1,80	1,36	1,03	0,68
Light Calcisols								
Profile 6x	0–36	2,36	1,34	0,79	1,72	1,15	0,46	0,54
	36–42	2,60	1,39	0,81	1,84	1,25	2,83	0,59
	42–86	2,60	1,35	0,78	1,69	1,15	0,51	0,50
	87–113	2,69	1,34	0,76	1,72	1,25	0,60	0,50
	113–120	2,72	1,14	0,83	1,56	1,07	0,47	0,46

According to the data in Table 2, the Clarke distribution of Ca is highest in calcisols, reaching 5.58, while sodium shows slightly higher values in the dark and typical grey soil layers (3.33–3.91) compared to the light grey soil layers (2.36–2.72). The lowest values were observed for barium, as well as for strontium in typical and light calcisols. In these cases, the Clarke distribution of calcium in typical and light calcisols is also less than 1.

The radial differentiation of all macroelements is nearly uniform in the light and typical grey soil layers, with slight variations observed only in the radial differentiation of sodium and calcium in calcisols.

Overall, sodium, potassium, iron, rubidium, and barium exhibit higher values in calcisols compared to typical and light calcisols, while calcium is higher in light calcisols than in calcisols. Strontium shows a higher radial stratification coefficient only in typical calcisols, with minimal variation in other cases.

If we examine sodium, its radial stratification coefficient (Kr) fluctuates between 0.87 and 3.67 across all layers of the studied soils, while the indicator for potassium ranges from 0.81 to 1.49. For calcium, the values vary between 0.11 and 1.11; for iron, between 0.85 and 1.45; for rubidium, between 0.81 and 1.40; for strontium, between 0.16 and 1.48; and for barium, between 0.79 and 1.28.

The geochemical spectrum formulas for the radial stratification differentiation of macroelements in the upper layer (i.e., the A horizon) of irrigated calcisols are as follows.

Table 3. Radial Differentiation Coefficients (Kr) of Macroelements in Irrigated Calcisols

Profile No.	Depth, cm	Na	K	Ca	Fe	Rb	Sr	Ba
Dark Calcisols								
Profile 2x	0–30	3,67	1,49	0,11	1,42	1,30	0,45	1,28
	30–42	1,21	1,37	0,18	1,45	1,40	0,18	1,28
	42–70	1,23	1,47	0,43	1,38	1,20	0,49	1,10
	70-100	1,01	1,07	1,00	1,05	0,91	0,67	0,99
	100-135	0,88	0,93	0,98	0,93	0,81	0,71	1,28
	135–170	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Typical Calcisols								
Profile 4x	0–26	0,87	0,81	0,93	1,02	1,09	1,48	1,03
	26–40	0,99	0,99	1,11	1,06	1,09	1,36	0,98
	40–67	0,98	1,00	0,92	1,11	1,27	1,24	1,26
	67–100	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Light Calcisols								
Profile 6x	0–36	1,15	0,85	1,06	0,91	0,93	1,01	0,86
	36–42	1,04	0,82	1,02	0,85	0,86	0,16	0,79
	42–86	1,04	0,84	1,06	0,92	0,93	0,92	0,93
	87–113	1,01	0,85	1,10	0,90	0,86	0,78	0,93
	113–120	1,00	1,00	1,00	1,00	1,00	1,00	1,00

Profile 2x, 0–30 cm, Kr: $\frac{Na}{3,67} > \frac{K}{1,49} > \frac{Fe}{1,42} > \frac{Rb}{1,30} > \frac{Ba}{1,28} > \frac{Sr}{0,45} > \frac{Ca}{0,11}$;

Profile 4x, 0–26 cm, Kr: $\frac{Sr}{1,24} > \frac{Rb}{1,09} > \frac{Ba}{1,03} > \frac{Fe}{1,02} > \frac{Ca}{0,93} > \frac{Na}{0,87} > \frac{K}{0,81}$;

Profile 6x, 0–36 cm, Kr: $\frac{Na}{1,15} > \frac{Ca}{1,06} > \frac{Sr}{1,01} > \frac{Rb}{0,93} > \frac{Fe}{0,91} > \frac{Ba}{0,86} > \frac{K}{0,85}$.

5 Conclusion

The soil cover represents a medium that balances the chemical elements present within it, as well as those entering and leaving the soil system. In this context, soil functions not only as a powerful accumulator but, in most cases, also as a substrate regulating migration and accumulation processes.

In soils and their genetic horizons, chemical elements migrate at varying rates and accumulate in different quantities and at different depths, depending on soil–climatic conditions, the intensity of redox reactions, and other environmental factors.

Information obtained through the study of accumulation, differentiation, and migration processes of chemical elements in soils can be effectively used in the monitoring of irrigated soils, thereby contributing to improved management and evaluation of their agroecological condition.

Author Contributions:

Conceptualization, A.T.T, M.M.X.; methodology, A.T.T.; software, A.T.T, M.M.X.; validation, A.T.T, M.M.X.; formal analysis, M.M.X.; investigation, M.M.X.; resources, A.T.T., M.M.X.; data curation, A.T.T.; writing—original draft preparation, A.T.T.; writing—review and editing, A.T.T.; visualization, A.T.T., M.M.X.; supervision, M.M.X.; project administration, A.T.T.; funding acquisition, A.T.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 J. 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.

References

[1] Vinogradov, A.P. (2021). Geokhimiya redkikh i rasseyannykh elementov v pochvakh [Geochemistry of rare and dispersed elements in soils]. Moscow: RAN. 298 p. (In Russian).

[2] Fersman, A.E. (1939). Geokhimiya [Geochemistry] (Vol. 4). Leningrad: ONTI. p. 46. (In Russian).

[3] Perel'man, A.I. (1989). Geokhimiya [Geochemistry]. Moscow. 419 p. (In Russian).

[4] Dobrovol'skiy, V.V. (2008). Geokhimicheskoe zemlevedenie: Uchebnoe posobie [Geochemical earth science: Textbook]. Moscow: Vlados. 208 p. (In Russian).

[5] Eshpulatov, Sh., Yuldashev, G. (2010). Khimicheskie i geokhimicheskie svoystva pochv svetlykh serozemov [Chemical and geochemical properties of light sierozem soils]. (Source not specified), 89–97. (In Russian).

[6] Turdaliev, A.T., Abakumov, E.V., Musayev, I.I. (2023). Sug'oriladigan och tusli bo'z tuproqlarning morfologik belgilaridagi o'zgarishlar [Changes in morphological characteristics of irrigated light sierozem soils]. International Scientific-Practical Conference "Actual Issues of Agricultural Development: Problems and Solutions", June 6–7. https://doi.org/10.5281/zenodo.8007312

[7] Khaydarov, M.M. (2020). Osnovy primeneniya guminovykh veshchestv v svetlykh serozemakh [Fundamentals of the application of humic substances in light sierozems]. Scientific Bulletin of Namangan State University, 2(8), 87–93. (In Russian).

[8] Khaydarov, M.M., Turdaliev, A.T., Saminov, A.A.U. (2017). Energeticheskie osobennosti aminokislot v svetlykh serozemakh [Energy characteristics of amino acids in light sierozems]. Gumanitarnye Nauki, (6), 249–252. (In Russian).

[9] Musayev, I.I., Turdaliyev, A.T. (2024). Sug'oriladigan och tusli bo'z tuproqlarda makroelementlarning geokimyoviy xususiyatlari [Geochemical properties of macroelements in irrigated light sierozem soils]. FarDU Ilmiy Xabarlar, (3), 227–230. (In Uzbek).

[10] Vernadskiy, V.I. (1963). Ocherki geokhimii [Essays on geochemistry]. Moscow: Nauka. 415 p. (In Russian).

[11] Abakumov, E.; Yuldashev, G.; Darmonov, D.; Turdaliev, A.; Askarov, K.; Khaydarov, M.; Mirzayev, U.; Nizamutdinov, T.; Davronov, K. Influence of Mineralized Water Sources on the Properties of Calcisol and Yield of Wheat (Triticum aestivum L.). Plants 2022, 11, 3291. https://doi.org/10.3390/plants11233291.

Avazbek Turdalievich Turdaliev Doctor of Biological Sciences, Professor.

Avazbek Turdalievich Turdaliev was born on 10 February 1980 in an educated family in Mingbulok district of Namangan region. He is Uzbek by nationality. He completed secondary school in 1987, graduated with honors from the Soil Science Department of Fergana State University in 2002, and completed his specialization in Organic Chemistry in 2008.

From 2009 to 2012, he pursued postgraduate studies at Fergana State University and defended his doctoral dissertation in biological sciences in 2016. He earned his Doctor of Science (DSc) degree in 2016 in the specialty 03.00.13 – Soil Science. He was awarded the academic title of Associate Professor in Soil Science in 2020 and Professor in 2024.

He has been engaged in scientific and pedagogical activity in higher education for 15 years.

Avazbek Turdalievich Turdaliev is the author of more than 220 scientific works, including 1 textbook, 6 teaching manuals, 4 instructional-methodological guides, 4 monographs, 4 recommendations, and over 200 scientific articles (published in journals listed by the Higher Attestation Commission and in international journals), as well as numerous theses.

Under the supervision of Professor Avazbek Turdalievich Turdaliev, 2 researchers have obtained the degree of Doctor of Philosophy (PhD) in Biological Sciences, and 2 researchers have earned the PhD degree in Agricultural Sciences. He is also currently supervising 5 researchers and 4 master's students.

Avazbek Turdaliev has served as a senior researcher in one fundamental project and as the head of two applied projects within the framework of state scientific–technical programs.

At present, A.T. Turdaliev is a member of the Scientific Council PhD.03/30.12.2019.B.05.03 at Fergana State University and the Chair of its Scientific Seminar; a member of the Scientific Council PhD.03/5.05.2023.B/Qx.01.17 at the National

University of Uzbekistan named after Mirzo Ulugbek; and a member of the scientific seminar under the Scientific Council DSc25/30.12.2019.Qx/B.43.01 at the Institute of Soil Science and Agrochemical Research.

Along with this, he actively participates in the editorial boards of several international and national scientific journals.

Mashkhura Musinovna Khaydarova is currently working as a chemistry teacher at the Department of Exact and Natural Sciences of the Academic Lyceum of Fergana State University.

Mashkhura Musinovna Khaydarova was born on 27 December 1978 in Fergana region. She graduated from the Faculty of Natural Sciences of Fergana State University with a degree in Chemistry in 1999, and completed her specialization in Organic Chemistry at the same faculty in 2009.

She has been working in the field of education for 25 years, specifically continuing her pedagogical activity at the Academic Lyceum of Fergana State University.

Mashkhura Musinovna Khaydarova is the author of more than 50 scientific publications, including 15 methodological manuals and 35 scientific articles published in international and national scientific journals and conference proceedings.