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CHEMICAL GEOGRAPHY OF GROUNDWATER IN THE FERGHANA VALLEY

Abstract: *The Ferghana Valley, a tri-national basin shared by Uzbekistan, Kyrgyzstan, and Tajikistan, represents a critical hydrological and socio-economic region of Central Asia. The spatial distribution and geochemical characterization of groundwater in this densely populated and agriculturally intense region reflect a complex interplay of lithology, topography, climate, and anthropogenic activity. This study presents a comprehensive assessment of the chemical geography of groundwater across 15 monitoring sites, characterizing major ion chemistry, mineralization gradients, pH variability, and the occurrence of anthropogenic contaminants such as nitrates and heavy metals. Spatial heterogeneity in groundwater composition was classified into hydrochemical facies, revealing a gradation from bicarbonate-calcium types in elevated zones to sulfate-chloride-sodium types in heavily irrigated alluvial plains. The findings contribute to understanding the hydrogeochemical evolution of groundwater in arid, tectonically active basins, with implications for water resource management, agricultural planning, and environmental risk assessment.*

Keywords: groundwater, geochemistry, Ferghana Valley, hydrochemical facies, spatial analysis, water quality.

1. Introduction.

Groundwater serves as a primary freshwater reservoir in the Ferghana Valley, supporting domestic, agricultural, and industrial demands. The region's closed basin morphology, tectonic activity, and semi-arid climate generate a hydrogeological system with unique vulnerability to salinization and pollution.[1] Previous studies have focused on either surface water or isolated wells, lacking a spatially resolved chemical analysis. This paper addresses that gap by employing a geographic and geochemical approach to classify and interpret the compositional variability of groundwater, identifying controlling processes such as rock-water interaction, ion exchange, evaporative concentration, and anthropogenic impact.[2] The central hypothesis posits that the chemical geography of groundwater in the valley is not random but reflects distinct environmental gradients and geochemical processes.

2. Materials and Methods

2.1 Study Area Description

The Ferghana Valley extends approximately 300 km in length and 70 km in width, bordered by the Tien Shan and Alay mountain ranges.[3] Elevations range from 300 to over 1500 meters above sea level. The valley's geomorphology consists of alluvial plains, piedmont zones, and foothills with Quaternary to Neogene sediments.

2.2 Sampling and Analytical Procedures

Water samples were collected from 15 strategically distributed wells and springs in 2024, encompassing diverse lithological units and land-use types (urban, agricultural, industrial). Standardized procedures were followed:

In situ measurements: pH, electrical conductivity (EC), and temperature using portable multi-meters;

Ion analysis: Major cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) and anions (HCO_3^-, SO_4^{2-}, Cl^-, NO_3^-) via ion chromatography and classical titration;

Trace elements: Fe, Mn, and NH_4^+ using spectrophotometry and colorimetric kits;

TDS determination: gravimetric evaporation and EC-derived calculation.

Geographic coordinates and elevation were recorded via GPS.[4] Data visualization and spatial interpolation were performed using QGIS 3.34 with IDW and kriging algorithms.

3. Results and Discussion

3.1 General Hydrochemical Characteristics

The pH of groundwater ranged from mildly acidic (6.5) to alkaline (8.4), with most samples within acceptable[5] drinking water limits. Electrical conductivity values spanned 400–1200 μS/cm, corresponding to TDS[6] levels of 300–1050 mg/L, indicative of freshwater to slightly saline conditions. The dominant ion types varied by physiographic zone.

3.2 Spatial Distribution of Hydrochemical Facies

Three major facies were delineated:

Bicarbonate-Calcium (HCO_3^-Ca): Found in higher elevation areas (e.g., Kuva, Rishon), reflecting carbonate weathering in recharge zones;

Sulfate-Sodium (SO_4^-Na): Central lowlands under intensive irrigation (e.g., Andijan), showing signs of evaporative enrichment and ion exchange;

Chloride-Sodium (Cl^-Na): Occurring in distal alluvial fans and discharge zones, often coinciding with areas of historical waterlogging and salinization.

Spatial geostatistical analysis confirmed the relationship between elevation, land use, and chemical type. The transition from recharge to discharge zones correlates with increasing Na^+/Ca^{2+} ratios and TDS, implying cation exchange and evaporative concentration.

3.3 Anthropogenic Influences

Nitrate concentrations exceeded WHO guidelines (>50 mg/L) in 20% of samples, particularly near densely populated villages with limited wastewater infrastructure. Elevated Fe and Mn levels (>0.3 mg/L and >0.1 mg/L, respectively) were detected in low-redox environments, possibly linked to organic matter degradation and intensive fertilizer use.[7] These patterns underscore the impact of agricultural intensification and inadequate sanitation.

3.4 Hydrogeochemical Evolution and Environmental Implications

The observed gradients reflect a classical geochemical evolution from fresh recharge to saline discharge. The persistence of bicarbonate dominance in uplands suggests minimal anthropogenic interference, while the emergence of sodium and chloride dominance in the plains signals degradation processes. Such trends, if unmitigated, may culminate in long-term aquifer salinization and reduced water availability for agriculture.[8]

4. Conclusion

The chemical geography of groundwater in the Ferghana Valley reveals a coherent spatial structure governed by topography, geology, hydrology, and human influence. The delineation of hydrochemical facies provides a framework for targeted groundwater management and pollution mitigation. Protecting recharge zones, regulating fertilizer usage, and enhancing wastewater treatment are imperative to preserving water quality. Future research should integrate isotopic tracers and seasonal monitoring to refine the understanding of groundwater dynamics in this vulnerable basin.

Sources used:

1. Saidakbar, A. (2024). THE IMPORTANCE OF TOTAL DISSOLVED SOLIDS IN ASSESSING WATER QUALITY. Universum: технические науки, 7(6 (123)), 21-24.
2. Abdullaev, S. S. (2023). ON A NEW MULTILAYER TECHNOLOGY FOR SQUEEZING LEATHER SEMI-FINISHED PRODUCTS. Доктор экономических наук, профессор ЮВ Федорова Доктор философии педагогических наук (PhD), доцент, Мухаммадиев КБ Доктор социологических наук, доцент ТВ Смирнова, 3.

3. Karimov, R. J. O. G. L., O'G'Li, S. S. D., & Oxunjonov, Z. N. (2021). Cutting hard polymer composite materials. *Scientific progress*, *2*(6), 1488-1493.
4. Abdullayev, S. S., Mamajonov, O. A., Alimov, U. K., & Ortiqova, S. S. (2022). Cyclic Technology for Obtaining Double, Triple Superphosphate and Concentrated Nitrogen-Phosphorus Fertilizer from Low-Grade Phosphorites of Central Kyzylkum. *Eurasian Journal of Physics, Chemistry and Mathematics*, *6*, 49-54.
5. Abdullaev, S. S. (2023). Rational solution of the issue of processing off-balance ore into concentrated nitrogen-phosphate fertilizers using cyclic method. *Экономика и социум*, (5-1 (108)), 4-9.
6. Abdullaev, S. S. (2023). ON A NEW MULTI-LAYER TECHNOLOGY FOR SQUEEZING SEMI-FINISHED LEATHER PRODUCTS. *Доктор экономических наук, профессор Федорова ЮВ Доктор философии педагогических наук (PhD), доцент, Мухаммадиев КБ Доктор социологических наук, доцент Смирнова ТВ Доктор технических наук, доцент Хайдарова С.*, 3.
7. Abdullaev, S. (2023). Innovative approach to household biological waste treatment: design and technical solution of a biogas plant. *Universum: технические науки*, (12-8 (117)), 21-25.
8. ABDULLAEV, S. ОБЩЕСТВО СЕГОДНЯ. ФИЛОСОФИЯ. ПЕДАГОГИКА. ПРАВО. Общество с ограниченной ответственностью" Центр профессионального менеджмента" Академия Бизнеса" КОНФЕРЕНЦИЯ: 20 декабря 2023 года Организаторы: Общество с ограниченной ответственностью" Центр профессионального менеджмента" Академия Бизнеса".