UDC: 551.44: 556.3: 004.4 (575.172)
https://doi.org/10.63241/2025ms228akhv

INFLUENCE OF NATURAL AND ANTHROPOGENIC STRESSORS ON THE DYNAMICS OF GROUNDWATER QUALITY IN THE CONTEXT OF CLIMATE CHANGE

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Abstract. *This study evaluates the seasonal variations in the quality of natural groundwater used for drinking purposes in the southern part of the Republic of Karakalpakstan - the Amudarya district - based on physicochemical parameters (TDS, TH, Cl^-, SO_4^{2-}, NO_3^-). The analyses were carried out using complexometric titration with Trilon B and standard laboratory methods. The results indicate that during the summer season, the concentrations of TDS, TH, Cl^-, and SO_4^{2-} significantly increased, leading to higher mineralization and a sharp decline in drinking water quality. In contrast, during the winter season, the water remained relatively softer, with lower salinity and mineralization levels. The findings demonstrate a strong correlation between groundwater quality in this ecosystem and climatic factors as well as anthropogenic influences.*

Keywords: *groundwater quality, physicochemical parameters, salinity, TDS, water hardness (TH), seasonal variation, climate impact.*

Annotatsiya. *Ushbu tadqiqotda Qoraqalpog‘iston Respublikasining janubiy qismi - Amudaryo tumanida shakllangan tabiiy yer osti ichimlik suvlari sifatining fasliy o‘zgarishlari fizik-kimyoviy ko‘rsatkichlar (TDS, TH, Cl^-, SO_4^{2-}, NO_3^-) asosida baholangan. Tahlillar-Trilon B yordamida kompleksometrik titrlash hamda standart laboratoriya usullari asosida amalga oshirildi. Tadqiqot natijalariga ko‘ra, yoz mavsumida suvning minerallashuvi va salinligi ortib, ichimlik sifatining keskin pasayishi aniqlandi. Qish mavsumida esa suvning salinligi va minerallashuv darajasi pastroq bo‘lib, ushbu ekotizmda yer osti suvlarining sifati iqlim omillari va antropogen ta’sirlar bilan kuchli darajada korrelyatsiya mavjudligini ko‘rsatdi.*

Keywords: *groundwater quality, physicochemical parameters, salinity, TDS, water hardness (TH), seasonal variation, climate impact.*

Аннотация. *В данном исследовании оценены сезонные изменения качества природных подземных питьевых вод, сформировавшихся в южной части Республики Каракалпакстан — в Амударьинском районе, на основе физико-химических показателей (TDS, TH, Cl^-, SO_4^{2-}, NO_3^-). Анализы проводились методом комплексонометрического титрования с использованием трилона Б, а также стандартными лабораторными методами. Согласно результатам исследования, в летний сезон концентрации TDS, TH, Cl^- и SO_4^{2-} значительно увеличиваются, что приводит к повышению минерализации воды и резкому снижению её питьевого качества. В зимний период вода характеризуется более низкой минерализацией и солёностью, оставаясь относительно мягкой. Полученные результаты показывают, что качество подземных вод в данной экосистеме имеет сильную корреляцию с климатическими факторами и антропогенным воздействием.*

Ключевые слова: *качество подземных вод, физико-химические показатели, солёность, TDS, общая жёсткость (TH), сезонные изменения, влияние климата.*

1. Introduction

In Central Asian countries, the quality of water resources is primarily influenced by both natural factors, such as geological structure and precipitation, and anthropogenic activities, particularly agriculture. Under the region’s arid climate and conditions of water scarcity, continuous monitoring and assessment of both surface and groundwater quality are of crucial importance. In Uzbekistan, approximately 70% of irrigated lands suffer from salinization. This problem is further aggravated by irrigation practices using groundwater, which lead to an increase in mineralization, salinity levels, and variations in ionic composition.

According to 2023 data, in the Amudarya district of the Republic of Karakalpakstan, 70.6% of 39.5 thousand hectares of irrigated land are affected by salinity - 2.5% are strongly saline, 35% moderately saline, and 33% slightly saline. The Amudarya district is located in the southern part of Karakalpakstan, where the formation of groundwater is determined mainly by the arid climate, high evaporation rates, and intensive agricultural activities.

The groundwater table in the area lies at a depth of 0-2 meters, and as a result of evaporation, the concentration of Na^+, Cl^-, and SO_4^{2-} ions in the upper soil layers increases, leading to higher total dissolved solids (TDS) and total hardness (TH) levels. Consequently, both the drinking and irrigation quality of water deteriorate. Particularly in spring and summer, the increase in water salinity and mineralization causes a seasonal decline in groundwater quality. The rise in groundwater mineralization, combined with salt crust formation in the upper soil layers and the inefficiency of drainage systems, directly affects both water quality and crop productivity. In this ecosystem, under the influence of global climate change, climatic factors such as increased evaporation and anthropogenic pressures have a significant negative impact on the quality of natural groundwater [1-4].

2. Materials and Methods

2.1. Study Area

The object of this research is groundwater formed at depths of 10–25 meters and above in the Amudarya district. The main objective of the research is to evaluate the suitability of this groundwater for drinking purposes based on international standards and to determine the seasonal dynamics of its quality, particularly between the winter and summer periods. Water samples were analyzed in the laboratory for the following physicochemical parameters: total hardness (TH), chloride (Cl^-), sulfate (SO_4^{2-}), total dissolved solids (TDS), and nitrate (NO_3^-).

2.2. Laboratory Analytical Methods

The physicochemical characteristics of the groundwater samples were determined in laboratory conditions following national standards and standard analytical procedures (GOST). Total hardness (TH) was measured using the complexometric titration method with Trilon B. The concentration of total dissolved solids (TDS) was determined by the conductometric method. Nitrate ions (NO_3^-) were analyzed using the ultraviolet spectrophotometric method, while sulfate ions (SO_4^{2-}) were determined by the turbidimetric method. All measurements were conducted in duplicate, and the mean values along with standard deviations (±SD) were calculated. The analyses were performed in accordance with ISO international standards [3].

3. Results and Discussion

3.1. Seasonal Dynamics and Trends of Water Quality Indicators

The observation results indicate that the overall groundwater in the Amudarya district exhibits certain water quality parameters exceeding the limits established by the Uzbekistan National Standards (UzMSt). In particular, during the summer season, the values of total hardness (TH), Cl^-, SO_4^{2-}, and total dissolved solids (TDS) in the groundwater of Amudarya consistently surpass the permissible limits (REM), indicating a high risk of groundwater quality deterioration in this area.

Groundwater quality indicators in the Amudarya district show significant seasonal variations (Figure 1). In this context, water mineralization, ion composition, and temperature are the main controlling factors. Nitrate concentrations in groundwater range from 9.21 to 13.85 mg/L in winter and from 11.70 to 13.70 mg/L in summer. The slight increase observed in summer is associated with fertilizer infiltration during the agricultural season. In the Qo‘ng‘irot district, nitrate concentrations range from 16.5 mg/L in winter to 14.5 mg/L in summer. Although these values are slightly higher compared to Amudarya, they remain well below the UzMSt limit (≤ 45 mg/L) in both areas. These results indicate minimal nitrate pollution risk in Amudarya, although summer anthropogenic load shows an upward trend.

Water hardness ranges from 608.58 to 1,168.08 mg/L in winter and from 712.69 to 1,273.97 mg/L in summer, indicating that the groundwater belongs to the “hard” category. Higher TH values in summer are attributed to increased mineral solubility at elevated temperatures. When comparing these ranges with groundwater hardness in the Qo‘ng‘irot district, located in the northwestern part of the Republic of Karakalpakstan, similar patterns are observed. Specifically, TH values range from 850 mg/L in winter to 680 mg/L in summer, showing a slightly lower range than in Amudarya. In the Amudarya district, TDS values range from 1,067.89 to 1,538.77 mg/L in winter and from 1,664.78 to 1,987.22 mg/L in summer, showing a clear increase during the warmer months. This indicates enhanced water mineralization resulting from increased evaporation and ion concentration. Chloride concentrations in Amudarya range from 232.69 to 511.31 mg/L in winter and from 193.67 to 458.83 mg/L in summer. In Qo‘ng‘irot, chloride levels are 396 mg/L in winter and 294 mg/L in summer. In both areas, Cl^- concentrations are near or slightly above the UzMSt limit (≤ 350 mg/L), with some sampling points in Amudarya exceeding the standard, suggesting intensified salinization processes.

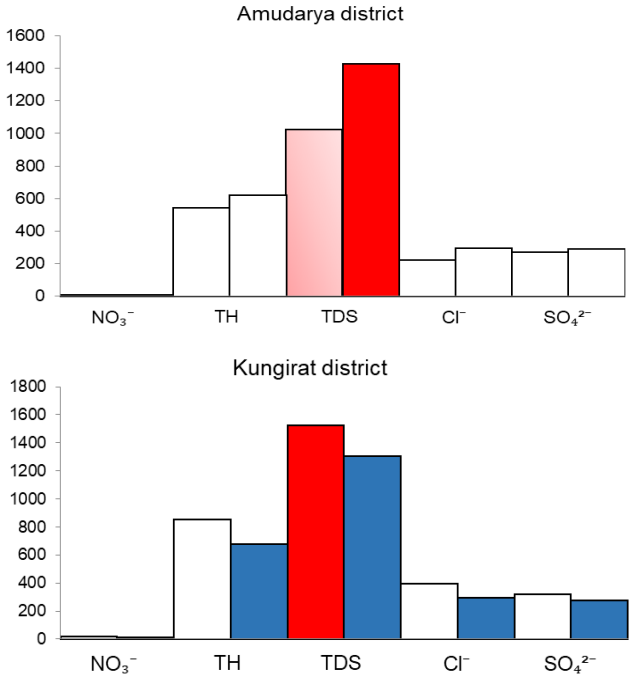

Figure 1. Seasonal Dynamics of Groundwater Quality Indicators in Amudarya District (winter and summer)

Sulfate ion concentrations in Amudarya range from 200.94 to 269.32 mg/L in winter and from 262.20 to 301.80 mg/L in summer. The slight increase in SO_4^{2-} during summer is associated with enhanced evaporation and oxidation processes. pH values vary between 6.6 and 7.5, remaining close to neutral throughout the year. Iron concentrations in Amudarya are very low, indicating limited solubility of iron in the local groundwater.

4. Conclusion

The increase in TDS, TH, and SO_4^{2-} concentrations during the summer season is linked to elevated temperatures, intensified evaporation, and ion concentration processes. In contrast, winter is characterized by relatively lower mineralization and softer water. The slight rise in nitrate (NO_3^-) concentrations during summer is attributed to intensified agricultural activities.

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