Postprint: Hydrogen and Oxygen Isotopes and Hydrochemical Characteristics of Water in the Lower Reaches of the Kherlen River Basin

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Abstract

Through analysis of major ion hydrochemistry and hydrogen-oxygen isotopes in river water and groundwater in the lower reaches of the Kherlen River Basin, combined with regional hydrogeological data, the hydrochemical and hydrogen-oxygen isotopic characteristics of river water and groundwater were examined using Durov diagrams, spatial interpolation, statistical analysis, and other methods. The results indicate that the hydrochemical type of river water is primarily Na-Ca-HCO_3, while groundwater exhibits Na-Cl and Ca-Na-HCO_3 types. The spatial distribution of major ion concentrations and hydrogen-oxygen isotopes in Kherlen River water is significantly more stable than that in groundwater, with smaller spatial variations. Both groundwater and surface water in the basin are mainly recharged by precipitation, with groundwater also serving as a major source of recharge for the Kherlen River. Deuterium excess variations reveal that evaporative fractionation is more pronounced in Kherlen River water than in groundwater. In addition to basin water evaporation being primarily controlled by geological and geomorphological conditions, human activities exert a more significant influence on river water than on surrounding groundwater. The Ximiao at point G3 represents a complete and independent hydrogeological unit, exhibiting hydrochemical and hydrogen-oxygen isotopic characteristics distinct from other groundwater. The fluoride content in some groundwater within the basin exceeds standards. Although partially influenced by human activities, this is primarily a natural phenomenon based on comprehensive hydrogeological conditions, which has already posed a serious threat to human health and warrants high attention from relevant local authorities to prevent the recurrence of fluorosis incidents.

Full Text

Preamble

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1. Study Area

1.1 Overview of the Kherlen River Basin

The Kherlen River originates from the southern slopes of the Kent Mountains in Mongolia and flows from west to east. The river has a total length of 1264 km, with 206.44 km located within China, and drains a total area of 7153 km^2. The basin elevation ranges from 3000 to 5000 m, with channel widths typically between 40 and 90 m. Based on regional hydrogeological data, the hydrochemical facies of river water are predominantly Na-Ca-HCO_3 type, while groundwater exhibits Na-Cl and Ca-Na-HCO_3 types. The pH and bicarbonate chemistry are characterized by the following equilibrium relationships:

$$\begin{aligned} \mathrm{pH} &= \log[H^+] \\ CO_2 + H_{2O} &\rightleftharpoons H^+ + HCO_3^- \quad (\log K = -10.33) \\ HCO_3^- &\rightleftharpoons H^+ + CO_3^{2-} \end{aligned}$$

The Durov diagram classification system is applied to characterize these hydrochemical types [13].

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2. Methodology

2.1 Sample Collection and Analysis

Water samples were collected and filtered through 0.45 m membrane filters. Major cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) and anions ($SO_4{}^{2-}$, Cl^-, F^-, $NO_3{}^-$, $HCO_3{}^-$) were analyzed using a Dionex ion chromatograph. Stable isotope compositions of hydrogen (δD) and oxygen (δ^{18}O) were measured using standard procedures. All analyses followed quality control protocols to ensure data reliability.

2.4 Spatial Distribution Analysis

The spatial distribution characteristics of major ions (Na^+, Ca^{2+}, Cl^-, $HCO_3{}^-$) and stable isotopes in the Kherlen River and groundwater were mapped using spatial interpolation techniques. The results indicate that river water chemistry

is more spatially homogeneous compared to groundwater, which shows greater heterogeneity due to local geological controls.

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3. Results and Discussion

3.1 Hydrochemical and Isotopic Characteristics

The hydrochemical and isotopic signatures of water in the lower Kherlen River basin reveal distinct patterns. Groundwater stable isotope values range from -66.64‰ to -62.94‰ for δD and -5.75‰ to -4.90‰ for δ^{18}O, indicating meteoric origins. The isotopic composition of river water shows more depleted values, reflecting contributions from high-elevation precipitation sources.

The relationship between δD and δ^{18}O demonstrates that both surface water and groundwater are primarily recharged by modern precipitation, with groundwater serving as the main hydrologic source for the Kherlen River. Deuterium excess values reveal that evaporation intensity is stronger for river water than for groundwater, consistent with surface exposure conditions.

Human activities exert a more pronounced influence on river water chemistry compared to groundwater. The G3 sampling location represents a distinct hydrogeological unit where hydrochemical and isotopic characteristics differ significantly from regional patterns. Fluoride concentrations in some groundwater samples exceed safe drinking water limits, posing potential health risks. While partially influenced by anthropogenic activities, elevated fluoride primarily reflects natural hydrogeochemical processes under arid region conditions.

3.2 Evaporation and Water-Rock Interaction

The isotopic enrichment trends indicate significant evaporation effects, particularly in the lower river reaches. Water-rock interaction processes contribute to the observed Ca^{2+}, Mg^{2+}, and HCO_3^- enrichment patterns. The combined effects of evaporation and ion exchange reactions control the overall hydrochemical evolution in the basin.

3.3 Fluoride Enrichment and Health Implications

Fluoride content in certain groundwater samples surpasses environmental quality standards, representing a serious threat to human health. Local authorities should implement monitoring and mitigation measures to prevent fluorosis occurrence. The enrichment is attributed to the comprehensive hydrogeological conditions of the semi-arid environment, including prolonged water-rock contact and evaporative concentration.

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Abstract: The Kherlen River is the main river flowing into Hulun Lake, the largest lake in northern China, and is located in the Hulunbuir Grassland as a typical grassland river. The Kherlen River originates from the south of Kent Mountain in Mongolia and flows from west to east. The river has a total length of 1264 km, with 206.44 km in China, and has a total drainage area of 7153 km^2. Combining regional hydrogeological data, the characteristics of the hydrochemistry and hydrogen and oxygen isotopes of the main ions in the river water and groundwater in the lower reach of the Kherlen River were analyzed with the Durov diagram, spatial interpolation, and statistical analysis methods. The results show that the hydrochemical types of the river water are mainly

Na-Ca-HCO_3 type, and the hydrochemical types of groundwater are Na-Cl and Ca-Na-HCO_3. The spatial distribution characteristics of the main ion concentration and hydrogen and oxygen isotope in the Kherlen River water are more stable than the groundwater, and the spatial difference is small. Hydrogen and oxygen isotope relationship indicates that the groundwater and surface water were mainly supplied by precipitation, while the groundwater is the main supply source of the Kherlen River. The variation of deuterium excess reveals that the evaporation and fractionation degree of the Kherlen River is stronger than that of the groundwater. Besides, the water evaporation of the basin is mainly influenced by the geology and geomorphology of the region; the influence of human activities on the river water is much stronger than that on the groundwater. The West Temple at the G3 point is a complete and independent hydrogeological unit, where the characteristics of hydrochemistry and hydrogen and oxygen isotopes are different from other groundwater. The F^- content of some groundwater in the basin exceeds certain limits, which is caused partially by human activities to a certain degree but is mainly a natural result of the comprehensive hydrogeological conditions. This becomes a serious threat to human survival, and local authorities should pay more attention to this issue and take action to avoid the recurrence of fluorosis.

Keywords: Kherlen River; groundwater; hydrochemistry; hydrogen and oxygen isotopes; deuterium excess

Note: Figure translations are in progress. See original paper for figures.