Chemical Characteristics of Major Ions and Genesis Analysis in the Upper Reaches of the Keriya River, Xinjiang (Postprint)

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Abstract

Taking the upper reaches of the Keriya River basin as the research object, hydrological data from the Keriya Station for 2004–2013 and partial data from before the 1990s were collected. Combined with temperature, precipitation, and other data, comprehensive analysis was conducted using multivariate correlation statistical methods and hydrochemical graphical methods to reveal the ionic chemical composition and variation characteristics of the Keriya River water and to explore its influencing factors. The results show: The mineralization of the Keriya River water varies between 203–1,081 mg · L-1, with an average value of 518 mg · L-1, which is relatively higher than the average level of world rivers; The cation Na++K+ has the highest content in the river water, with the major cation concentrations following the order (Na++K+) > Ca2+ > Mg2+; the anions in the river water are dominated by HCO3-, with the major anion concentrations following the order HCO3- > SO42- > Cl-; In summer, the ion concentration of river water is most obviously controlled by discharge, i.e., the greater (smaller) the discharge, the smaller (greater) the mineralization; during the high-flow period, the Keriya River water is mainly recharged by surface runoff, while during the low-flow period, the river water almost entirely comes from groundwater; due to different convergence paths in different periods, the ion concentration of river water shows intra-annual variation with discharge; The ions in the river water mainly originate from rock weathering, among which the weathering of evaporite rocks has the greatest influence.

Full Text

Preamble

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2. Study Area and Data Sources

The upper reaches of the Keriya River served as the study area. Data collection encompassed: (1) meteorological records from the $]: 1 9 5 9 T、1 9 7 9 —1 9 8 4 T、2 0 0 4—2 0 1 3 T w 4 o $ station, and (2) hydrological and hydrochemical data spanning 1957-2014, including precipitation and streamflow measurements from 1986-2014. Specifically, the 2004-2013 dataset comprised consecutive annual measurements from a hydrological station at the mountain pass, representing six elevation zones: 3,000 m, 3,200 m, 3,500 m, 3,700-3,800 m, 3,900 m, and 4,100 m.

The Keriya River originates in the Kunlun Mountains at coordinates 36°27 N, 81°28 E. The hydrological station (Φ20) is situated at an elevation of 1,922 m, where the multi-year average precipitation reaches 1922 mm. Precipitation predominantly occurs during May-September, accounting for 62% of annual totals, with single-day maximum rainfall exceeding 1 mm. Temperature records from 1986-2014 show a mean annual temperature of 19.5°C.

The river channel above the hydrological station extends 530 km with an average gradient of 0.92%. The watershed area measures 8,347 km^2, with a maximum elevation of 6,962 m. Areas above 5,500 m consist of perennial snow and glacier zones; elevations of 3,000-5,000 m comprise alpine cold desert zones, while 2,000-3,000 m represent alpine steppe and meadow zones that serve as the primary runoff generation areas.

[FIGURE 1]

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3. Hydrochemical Characteristics

3.1 Ion Composition and Measurement Methods

Major ions analyzed included Ca^2 , Mg^2 , K , Na , HCO , Cl , SO^2 , CO^2 , and pH. Analytical procedures followed standard methods: CO^2 and HCO were determined by acid-base titration; Cl by AgNO titration; SO^2 by BaCl gravimetry; Ca^2 and Mg^2 by EDTA complexometric titration; and K +Na by flame photometry.

Ion concentration ranges were as follows: K +Na (19.5-196.5 mg·L^{1}, mean 95.7 mg·L^{1}), Ca^{2} (21.6-60.1 mg·L^{1}), Mg^{2} (3.2-117.0 mg·L^{1}, mean 37.7 mg·L^{1} and 24.7 mg·L^{1} respectively), HCO (104-291 mg·L^{1}, mean 198.5 mg·L^{1}), SO ^{2} and Cl (17.5-446 mg·L^{1} and 17.1-194 mg·L^{1} respectively, with means of 90.1 mg·L^{1} and 89.9 mg·L^{1}). Total dissolved solids (TDS) ranged from 203 to 1081 mg·L^{1} (mean 550.5 mg·L^{1}), substantially higher than the global river average. Electrical conductivity varied from 29 to 216 S·cm^{1} (mean 115 S·cm^{1})〔15〕. The pH ranged from 8.0 to 8.6, indicating weakly alkaline conditions typical for rivers in arid regions.

3.2 Gibbs Diagram Analysis

Gibbs diagrams were employed to identify hydrochemical genesis mechanisms by plotting TDS against Na /(Na +Ca^{2}) and Cl /(Cl +HCO) ratios. The results revealed three distinct zones: evaporation dominance (10 samples), weathering dominance (5-6, 9 samples), and precipitation dominance (7-8 samples). Most data points clustered in the evaporation and weathering zones, indicating that rock weathering and evaporation-crystallization processes primarily control the river' s hydrochemistry. Notably, Na and Cl exhibited strong correlations, suggesting evaporite dissolution as a major ion source [FIGURE 2].

3.3 Piper Diagram and Water Type Classification

Piper diagrams illustrated that the Keriya River water type transitions seasonally: during high flow periods (July-August), Ca-Mg-HCO types dominate, whereas low flow periods (November-February) exhibit Na-Cl characteristics [FIGURE 3]. Intermediate flow periods show mixed types. This seasonal variation reflects the shift from surface runoff (diluting ions) in summer to groundwater baseflow (enriched in weathering products) in winter. The hydrochemical facies evolution demonstrates that carbonate weathering predominates during high flow, while evaporite dissolution becomes more significant during baseflow conditions [FIGURE 4].

Principal component analysis revealed that the first three components explained 98% of the total variance: Component 1 (46.3%) loaded heavily on K +Na , Mg^{2} , Cl , and SO ^{2} ; Component 2 (33.1%) on Ca^{2} and HCO ; and Component 3 (18.7%) on CO ^{2} [TABLE 2]. These results corroborate that evaporite weathering (Component 1) and carbonate weathering (Component 2) are the primary hydrochemical processes.

[FIGURE 5]

3.4 Correlation Analysis and Ion Sources

Correlation coefficients between major ions provided further insight into their origins. K +Na showed strong positive correlations with Cl ($r = 0.84$) and SO ^{2} ($r = 0.63$), confirming evaporite sources. The Ca^{2} -HCO pair ($r = 0.80$)

indicated carbonate weathering, while the weaker Mg^{2}-SO^{2} correlation ($r = 0.37$) suggested multiple source contributions [FIGURE 6].

The relationship between streamflow and ion concentrations was inverse: higher discharge corresponded to lower salinity, particularly evident for Ca^{2} and HCO ($r = -0.50$). This dilution effect reflects the seasonal mixing dynamics between surface runoff and groundwater. Interannual variations also showed that prolonged low-flow periods led to cumulative ion enrichment, with salinity increasing by 12% over the study period.

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Abstract and Author Information

Title: Hydrochemical Characteristics and Formation Causes of Main Ions in Water of the Keriya River, Xinjiang

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Abstract:
In this study, the multi-year data of hydrochemistry, temperature, and precipitation in the upper reaches of the Keriya River in 10 consecutive years from 2004 to 2013 and in some years before 1990 were collected. The multivariate correlation statistical method and hydrochemical diagrams were used to discuss the chemical composition and variation characteristics of main ions in water of the Keriya River as well as their affecting factors. The results are as follows:

The water salinity varied in a range of 203–1081 mg · L ^{1}, and its mean value was 518 mg · L ^{1}. The salinity was higher than the average level of the rivers in the world;

Na +K were the most abundant cations, and the cation concentration was in an order of (Na +K) > Ca^{2} > Mg^{2} . The main anion was HCO , and the anion concentration was in an order of HCO > SO ^{2} > Cl ;

The ion concentration was mainly affected by streamflow in summer, that is, the higher the flow was, the lower the salinity would be. The Keriya River was mainly supplied by surface runoff in raining season but almost by groundwater in dry season. The concentration of ions varied with the change of streamflow due to the different confluence paths in different periods;

Weathering of rock was the main source of the ions in water of the Keriya River, especially that of evaporite.

Keywords: hydrochemistry; ion concentration; annual change; interannual variation; Principal Component Analysis; Keriya River; Xinjiang