Characteristics of Hydrogen and Oxygen Isotopes and Major Hydrochemical Parameters in Water Bodies of the Yinchuan Plain: Postprint

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Abstract

Employing environmental isotope and hydrochemical techniques, this study investigated the characteristics of hydrogen and oxygen isotopes and basic hydrochemical parameters of different water bodies in the Yinchuan Plain through field testing and laboratory analysis. The results indicate that the $ $18O and δD values of various water bodies in the Yinchuan Plain are generally distributed below both the local meteoric water line and the Yellow River water δD-$ $18O relationship line. Due to intense evaporation, lake water exhibits significantly enriched isotopic composition compared to other surface waters, yet its deuterium excess (negative values) is substantially lower than that of the global meteoric water line. Isotopic signatures demonstrate that both surface water and groundwater receive recharge from the Yellow River, with river water, canal water, and some groundwater showing consistent isotopic compositions, thereby indicating a very close hydraulic connection between surface water and groundwater. The groundwater $ 17O− 18Ofittingline(ln(17O + 1) = 0.524ln(18O + 1) + 0.00094)inthestudyareaapproximatestheglobalmeteoricwaterline(ln(17O + 1) = 0.528ln($18O+1)+0.00033), but the 17O excess exceeds that of seawater. All water bodies in the Yinchuan Plain are alkaline, with predominant hydrochemical types of HCO3-Na and HCO3-Ca · Mg, where Na+ constitutes the primary cation and HCO3- the primary anion. Gibbs diagrams reveal that the ionic composition of these water bodies is primarily associated with rock weathering and evaporative crystallization.

Full Text

Isotopic and Hydrochemical Characteristics of Water in the Yinchuan Plain

Isotopic Composition and Water Provenance

The δD and δ^{18}O values of stream systems in the Yinchuan Plain plot below both the local meteoric water line (LMWL) and the δD-δ^{18}O regression line for Yellow River water. Compared with other surface water bodies, lake water exhibits more enriched isotopic compositions and significantly lower d-excess values (negative) than the global meteoric water line (GMWL), attributable to strong evaporative effects. Isotopic evidence demonstrates that both surface water and groundwater in the plain receive recharge from the Yellow River, with the consistent isotopic signatures of river water, canal water, and groundwater indicating a very close hydraulic connection between these systems.

The δD-δ^{18}O relationship for the study area follows the equation: $\delta D = 1.88 \times \delta^{18}O + 27.82$ ($R^2 = 0.72$) [Figure 2: see original paper]. Monthly weighted mean δ^{18}O values show distinct seasonal patterns in their correlation with precipitation and temperature. During June-September (months 6-9), δ^{18}O is negatively correlated with precipitation amount ($R^2 = 0.64$) but only weakly correlated with temperature ($R^2 = 0.16$), indicating that rainfall amount effects dominate isotopic variation during the summer monsoon period. In contrast, during other months (October-May), the correlation patterns differ, with temperature exerting greater influence on isotopic fractionation [Figure 3: see original paper].

Triple Oxygen Isotope Systematics

The relationship between δ^{17}O and δ^{18}O follows the equation: $\ln(\delta^{17}O + 1) = 0.524 \ln(\delta^{18}O + 1) + 0.00094$ ($r = 0.9999$) [Figure 4: see original paper]. This slope (0.524) and intercept (0.00094) are similar to the global meteoric water line [$\ln(\delta^{17}O + 1) = 0.528 \ln(\delta^{18}O + 1) + 0.00033$], but the ^{17}O-excess values are higher than those of seawater. The ^{17}O-excess ranges from -159.99 to 419.04 per meg, with a mean of 140.62 per meg. For comparison, the alternative formulation $1000 \times \ln(\delta^{17}O + 1) = 0.552 \ln(\delta^{18}O + 1) \times 1000 + 0.44$ yields a slope of 0.528 and intercept of 0.033, with ^{17}O-excess ranging from -90.78 to 699.04 per meg (mean = 248.45 per meg). The ^{17}O-excess parameter provides additional constraints on evaporative processes and water-rock interactions beyond those available from δD and δ^{18}O alone.

Hydrochemical Properties

Hydrochemical data for water samples are summarized in . The waters are alkaline, with pH values ranging from 7.1 to 8.8. Electrical conductivity varies by water type: lake water shows the highest values (up to 4840 $S \cdot cm^{-1}$), followed by groundwater, while river water exhibits the lowest conductivity. The dominant cation is Na^+, with significant contributions from Ca^{2+} and Mg^{2+}; the primary anion is HCO_3^-, with variable concentrations of Cl^- and SO_4^{2-}. For example, in groundwater samples (b7), mean conductivity is 1746 $S \cdot cm^{-1}$, with Na^+ averaging 151.9 $mg \cdot L^{-1}$, Ca^{2+} 85.6 $mg \cdot L^{-1}$, Mg^{2+} 36.4 $mg \cdot L^{-1}$, and HCO_3^- 275.2 $mg \cdot L^{-1}$.

Water Type Classification

The Piper diagram [Figure 5: see original paper] reveals that water chemistry is dominated by HCO_3^--Na and HCO_3-Ca$\cdot$Mg types, with some samples plotting in the Cl$\cdot SO_4$-Na field. The relative distribution of major ions shows that Na^+ and HCO_3^- are the predominant cation and anion, respectively. The cation composition shows Na^+ enrichment relative to $Ca^{2+} + Mg^{2+}$ in most samples, while the anion composition varies between HCO_3^--dominated and mixed Cl^--SO_4^{2-} types. Evaporative concentration and rock weathering processes control these hydrochemical facies, as confirmed by Gibbs diagrams [Figure 6: see original paper].

Controlling Mechanisms

Gibbs plots of $Na^+/(Na^+ + Ca^{2+})$ versus $Cl^-/(Cl^- + HCO_3^-)$ demonstrate that water chemistry in the Yinchuan Plain is primarily controlled by rock weathering and evaporation [Figure 6: see original paper]. Most samples plot in the intermediate zone between rock-dominance and evaporation-dominance, with $Na^+/(Na^+ + Ca^{2+})$ ratios ranging from 0.1 to 0.6 and $Cl^-/(Cl^- + HCO_3^-)$ ratios around 0.1-0.6. This indicates that carbonate dissolution and silicate weathering provide the major ionic solutes, which are subsequently modified by evaporative concentration, particularly in lake waters and shallow groundwater.

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Abstract

Hydrogen and Oxygen Isotopes and Hydrochemical Parameters of Water Samples from the Yinchuan Plain

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Abstract: Hydrochemical techniques and environmental isotopes were employed to analyze the hydrogen and oxygen isotopic compositions and hydrochemical properties of water samples from the Yinchuan Plain. The results demonstrate that δD and δ^{18}O values of stream systems plot below the local meteoric water line (LMWL) and the Yellow River water line. Compared with other surface waters, lake water exhibits more enriched isotopic compositions and substantially lower (negative) d-excess values than the global meteoric water line (GMWL) due to intense evaporation. Isotopic evidence indicates that both surface water and groundwater are recharged by the Yellow River, with the uniform isotopic signatures of river water, canal water, and groundwater reflecting a very close hydraulic connection.

The correlation between δ^{17}O and δ^{18}O follows the equation $\ln(\delta^{17}O + 1) = 0.524 \ln(\delta^{18}O + 1) + 0.00094$, which is similar to the global meteoric water line [$\ln(\delta^{17}O + 1) = 0.528 \ln(\delta^{18}O + 1) + 0.00033$], but the ^{17}O-excess exceeds that of seawater. The waters are alkaline, with conductivity decreasing in the order: lake water > groundwater > river water. The primary hydrochemical types are HCO_3-Na and HCO_3-Ca $\cdot$ Mg, with Na^+ and HCO_3^- as the dominant cation and anion, respectively. Gibbs plots reveal that water chemistry is mainly controlled by rock weathering and evaporation. The combined isotopic and hydrochemical data indicate strong hydraulic connectivity between surface water and groundwater systems.

Keywords: water body; hydrogen and oxygen isotopes; hydrochemistry; Yellow River water; ^{17}O-excess; Yinchuan Plain

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

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