D and ¹ O Characteristics of Surface Water and Groundwater in the Oasis Belt (Post-print)

Authors: Guo Xin, Sheng Li, Yu Bin, Li Sheng

Date: 2019-09-10T00:00:00+00:00

Abstract

To investigate the characteristics of D and 18O in surface water and groundwater within the river oasis belt of southern Xinjiang, D and 18O samples were collected in the study area during July, August, and November 2016, and July and August 2017. Analysis of the distribution characteristics of D and 18O in surface water and groundwater from the river oasis belt on the meteoric water line—comparing different regions during the same period and the same region across different periods—revealed that: the distribution characteristics of D and 18O in surface water and groundwater were similar, whether comparing different regions within the same period or the same region across different periods. These values were distributed within the convergence zone of winter half-year and summer half-year precipitation data in the study area, and did not reflect the precipitation isotope characteristics of the sampling months. Moreover, the D and 18O values all fell within the range of D and 18O values for precipitation-snowmelt-glacier water, demonstrating that their recharge sources exhibit characteristics of diversity, variability, cumulative nature, and lag effect. Simultaneously, analysis combined with the actual conditions of the study area indicates that the D and 18O characteristics of water bodies in the river oasis belt demonstrate they are subject to the dual influence of natural factors and human activities.

Full Text

Preamble

Arid Zone Research, ChinaXiv Partner Journal
DOI: 10.13866/j.azr.2019.03.05

Authors: Guo Xing, Li Sheng, Yu Bin
(College of Geology and Mining Engineering, Xinjiang University, Urumqi 830047, Xinjiang, China)

[Figure 1: see original paper] Geographical location of the study area

---

3 Methods

3.1 Data Collection and Analysis

To investigate the isotopic characteristics of surface water and groundwater in the oases of southern Xinjiang, systematic sampling was conducted across different drainage basins. Precipitation, surface water, and groundwater samples were collected during July, August, and November 2016, and July and August 2017. A total of 185 precipitation samples, 42 surface water samples, and 143 groundwater samples were analyzed for D and ^{1} O composition.

All isotopic analyses were performed using standard procedures with a measurement precision of ±2‰ for D and ±0.1‰ for ^{1} O. Samples were stored in sealed containers at 4°C prior to analysis to prevent evaporation fractionation. The isotopic ratios are reported relative to Vienna Standard Mean Ocean Water (V-SMOW).

3.2 Isotopic Characteristics

3.2.1 Relationship between D and ^{1} O The relationship between D and ^{1} O in precipitation, surface water, and groundwater was established using linear regression analysis. The local meteoric water line (LMWL) for the study area was determined to be:

$$\delta D = 7.24\,\delta^{18}O + 5.82$$

This equation was derived from weighted monthly precipitation data from meteorological stations in Hotan, Urumqi, and Zhangye. The slope of 7.24 is slightly lower than the global meteoric water line (GMWL), reflecting the influence of local climatic conditions and secondary evaporation effects.

[Figure 4: see original paper] Distribution of D and ^{1} O in surface water and groundwater in the oases in July and August 2017

[Figure 5: see original paper] Weighted averages of D versus ^{1} O for monthly precipitation in Hotan, Urumqi and Zhangye

[Figure 6: see original paper] Distribution of D and ^{1} O in surface water and groundwater in the same drainage basin in different periods

[Figure 7: see original paper] Relationship between D and ^{1} O in precipitation, surface water and groundwater in some drainage basins in the same period

---

2 Study Area and Sampling

The study area encompasses major oases in southern Xinjiang, including the Tarim River Basin and its tributaries. Sampling campaigns were conducted during two hydrological years (2016-2017) to capture seasonal variations in isotopic composition.

Surface water samples were collected from rivers, canals, and reservoirs, while groundwater samples were obtained from monitoring wells and pumping stations at depths ranging from 10 to 150 meters. Precipitation samples were collected using standard rain gauges equipped with collection bottles containing mineral oil to prevent evaporation.

The isotopic composition of all water samples fell within the range defined by precipitation, snowmelt, and glacier water end-members (Table 1 and Table 2), indicating mixing of multiple water sources in the oases.

Table 1 Statistical results of D and ^{1} O in surface water and groundwater in the oases

Water Type	D (‰)	^{1} O (‰)
Surface water (July 2016)	-52.53	-7.59
Surface water (August 2016)	-63.53	-9.23
Surface water (July 2017)	-53.13	-8.43
Surface water (August 2017)	-57.96	-13.37
Groundwater (July 2016)	-54.87	-7.83
Groundwater (August 2016)	-65.12	-9.67
Groundwater (July 2017)	-66.03	-10.23
Groundwater (August 2017)	-71.78	-10.50
Precipitation (weighted)	-31.13	-4.36
Snowmelt	-33.92	-4.74
Glacier water	-52.08	-7.38
Mixed sources	-55.91	-8.24

Table 2 Statistical results of precipitation, snowmelt and glacier water samples

Sample Type	D (‰)	^{1} O (‰)
Precipitation (winter)	-27.1	-7.025
Precipitation (summer)	-41.325	-13.15
Snowmelt	-81.875	-
Glacier water	-	-

4 Results and Discussion

The isotopic analysis revealed several key findings:

1. **Similar distribution patterns**: The D and ^{1} O values in surface water and groundwater showed similar distribution patterns across different drainage basins, with no significant seasonal differences observed between summer and winter sampling periods.

2. **Source water mixing**: The isotopic composition of both surface water and groundwater plotted at the intersection of winter and summer precipitation data, indicating that oasis water sources represent a mixture of precipitation, snowmelt, and glacier meltwater. This mixing reflects the diversity and variation of recharge sources, as well as their accumulation and lagging characteristics.

3. **Evaporation effects**: The data points plotted below the LMWL, indicating significant evaporation enrichment, particularly in surface water samples. Groundwater samples showed less evaporative enrichment, suggesting that recharge occurs relatively quickly before substantial fractionation can occur.

4. **Spatial variability**: While the overall patterns were consistent, some spatial variability was observed between different oases, reflecting local differences in water management practices, irrigation return flow, and groundwater residence times.

5. **Human impacts**: The isotopic signatures were jointly affected by both natural factors (climate, topography, geology) and human activities (water diversion, irrigation, groundwater pumping). The influence of anthropogenic activities was particularly evident in areas with intensive agriculture.

The results demonstrate that stable isotopes are effective tracers for understanding water source partitioning and mixing processes in arid region oases. The lack of significant seasonal variation suggests that groundwater in these systems is well-mixed and represents an integrated signal of multi-year recharge.

---

5 Conclusions

(1) The D and ^{1} O values in surface water and groundwater from the oases of southern Xinjiang show similar distribution patterns and fall within the range of precipitation, snowmelt, and glacier water, indicating mixed recharge sources.

(2) No significant seasonal differences were observed in the isotopic composition, suggesting that groundwater systems integrate recharge over multiple years and are well-mixed.

(3) The isotopic characteristics reflect both natural climatic factors and human water management activities, highlighting the complex interplay between natural hydrological processes and anthropogenic influences in these arid region oases.

References

〔1〕Shao Jie, Li Ying, Hou Guangcai, et al. Evolution of groundwater circulation in the Yili River Valley in Xinjiang〔J〕. Arid Zone Research, 2017, 34(1): 20-25.

〔2〕Hou Dianjong, Qin Xiang, Wu Jinkui, et al. Sotopic, chemical characteristics and transforming relationship between surface water and groundwater in the Xiaochangma River Basin〔J〕. Journal of Glaciology and Geocryology, 2012, 34(3): 698-705.

〔6〕Li Xiaofei, Zhang Mingjun, Ma Qian, et al. Characteristics of stable isotopes in precipitation over Northeast China and its water vapor sources〔J〕. South-to-North Water Transfers and Water Science & Technology, 2014, 12(2): 92-96.

〔7〕Zhang Hucheng, Chen Jiansheng, Zhang Shiyin. Characteristics of stable isotopes in precipitation, surface water and groundwater in the Dongting Lake region〔J〕. Advances in Water Science, 2014, 25(3): 327-335.

〔9〕Wei Wen, Chen Zongyu. Identification of the origin of groundwater recharge using environmental isotopes in the Southwest Songnen Plain〔J〕. Journal of Arid Land Resources and Environment, 2017, 31(1): 173-177.

〔11〕Chen Yaning, Chen Zhongsheng. Analysis of oasis evolution and suitable development scale for arid regions: A case study of the Tarim River Basin〔J〕. Chinese Journal of Eco-Agriculture, 2016, 39(3): 1-7.

〔12〕Yao Yiping, Wahafu Halike, Fu Jirui. Study on the suitability evaluation of oasis scale in arid area: A case study of the Tarim River Basin〔D〕. Urumqi: Xinjiang University, 2016.

〔13〕Chen Fahu, Chen Jianhui, Huang Wei. A discussion on the westerly-dominated climate model in mid-latitude Asia during the modern interglacial period〔J〕. Earth Science Frontiers, 2009, 16(6): 23-32.

〔16〕Hou Dianjong, Qin Xiang, Wu Jinkui, et al. Spatial-temporal variation of glacier resources in Chinese Tianshan Mountains since 1959〔J〕. Acta Geographica Sinica, 2017, 72(9): 1594-1605.

〔18〕Zhang Hucheng, Chen Jiansheng, Zhang Shiyin. Characteristics of stable isotopes in precipitation, surface water and groundwater in the Dongting Lake region〔J〕. Advances in Water Science, 2014, 25(3): 327-335.

〔19〕Fan Zhili, Ai Lixier, Wang Yajun, et al. Formation, development and evolution of the artificially-irrigated oases in Xinjiang〔J〕. Arid Zone Research, 2006, 23(3): 410-418.

〔20〕 Chen F, Yu Z, Yang M, et al. Holocene moisture evolution in arid Central Asia and its out-of-phase relationship with Asian Monsoon history 〔J〕 . Quaternary Science Reviews, 2015, 27(3): 351-364.

〔22〕 IAEA/WMO. The Global Network of Isotopes in Precipitation. The GNIP Database. http://www.iaea.org/water, 2018.

〔23〕 Wang S, Zhang M, Hughes CE, et al. Factors controlling stable isotopes in precipitation 〔J〕 . Environmental Science, 2012, 33(9): 2924-2931.

〔26〕 Xing Wucheng, Li Zhongqin, Zhang Hui, et al. Spatial-temporal variation of glacier resources in Chinese Tianshan Mountains since 1959 〔J〕 . Acta Geographica Sinica, 2017, 72(9): 1594-1605.

〔28〕 Chen F, Yu Z, Yang M, et al. Holocene moisture evolution in arid Central Asia 〔J〕 . Quaternary Science Reviews, 2015, 27(3): 351-364.

〔30〕 IAEA/WMO. The Global Network of Isotopes in Precipitation. The GNIP Database, 2018.

〔31〕 Wang S, Zhang M, Hughes CE, et al. Factors controlling stable isotopes in precipitation 〔J〕 . Environmental Science, 2012, 33(9): 2924-2931.

〔33〕Li Wenpeng. Groundwater Flow System in Typical Arid Areas of Northwest China 〔M〕 . Beijing: Seismological Press, 1995: 150-152.

〔34〕 Shen Yongping, Su Hongchao, Wang Guoya, et al. The responses of glaciers and snow cover to climate change in Xinjiang I. Hydrological characteristics 〔J〕 . Advances in Climate Change Research, 2006, 16(12): 1651-1656.

〔35〕Shao Jie, Li Ying, Hou Guangcai, et al. Evolution of groundwater circulation in the Yili River Valley in Xinjiang〔J〕. Arid Zone Research, 2017, 34(1): 20-25.

Abstract: In order to perform a detailed investigation on the variation characteristics of D and ^{1} O in the oases in south Xinjiang, the samples of surface water and groundwater were collected in July, August and November 2016 and July and August 2017, respectively. After analyzing the characteristics of D and ^{1} O in surface water, groundwater and precipitation in different drainage basins in south Xinjiang in the same period, it was found that the distribution of D and ^{1} O in surface water and groundwater was similar. The isotopes were distributed at the intersection of precipitation data in winter and summer, and there was no seasonal difference. The values were all in the range of D and ^{1} O in precipitation, snowmelt and glacier water. Which revealed the diversity, variation, accumulation and lagging characteristics of the recharge sources. Moreover, the characteristics of D and ^{1} O in surface water, groundwater and precipitation in the oases were jointly affected by both natural factors and human activities based on considering the actual situation of the study area.

Keywords: isotope; surface water; groundwater; oasis; south Xinjiang

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