The Meteoric Relationship for ^{18}O and ^{2}H in Precipitations and Isotopic Compositions of water resources in Mashhad Area (NE Iran)

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Abstract

For regional and local isotopic investigations, it is important to compare isotopic data of surface water and groundwater with the local meteoric relationship for ^{18}O and ^{2}H in precipitations. In this paper, the Mashhad meteoric water line (MMWL) is defined for the first time, based on samples of precipitation collected from several rain stations located within and around of Mashhad city - NE of Iran. Both the slope and δ^2H intercept for MMWL ($\delta^2H = 7.17\ \delta^{18}O + 11.22$) are deviated from the global meteoric water line - GMWL ($\delta^2H = 8.13\ \delta^{18}O + 10.8$). The huge variation in isotopic compositions of the Mashhad rain (from -198.2 to +38.1‰ and from -26.1 to +3.7‰ for δ^2H and $\delta^{18}O$, respectively) is because of strong seasonal changes in precipitations in this area. The ^{2}H and ^{18}O isotopes of local water resources show evaporative enrichment in comparison with local meteoric water.

Keywords: *Isotope; precipitation; Mashhad meteoric water line (MMWL); Water resources*

1. Introduction

Stable isotope is a reliable technique to trace water cycle. For regional and local isotopic investigations, it is important to compare isotopic data (δ^2H and $\delta^{18}O$) of surface and groundwater resources with the local meteoric relationship for ^{18}O and ^{2}H in precipitations. The Mashhad area is located in northeastern Iran, about 1000 km from Tehran, the capital of Iran. The objectives of the present study were to (1) develop the mashhad meteoric relationship for ^{18}O and ^{2}H in precipitations in order to obtain Mashhad meteoric water line (MMWL), (2) compare MMWL with global meteoric water line (GMWL) and other available local meteoric water line in Iran, and (3) compare the isotopic composition of water resources in Mashhad area with that of local meteoric eater.

2. Sampling and analytical methods

To measure the δ^2H and $\delta^{18}O$ of the water, 25 ml samples were collected using plastic bottles. The samples were taken from rain stations and water resources in 2008 and 2009. Rain samples were taken from six stations located outside of the Mashhad City (Torogh dam-TDR, Karedeh dam-KDR, Olang Asadi-OAR, Goosh, GR, Zoshk-ZR, and Jaghargh-JR), and two stations located within the city (Mashhad water autority station-MR and Ahmadabad-AhmR). An isotope ratio mass spectrometry (IRMS) was used to analyse isotopic compositon (δ^2H and $\delta^{18}O$) of water samples. All measurements were performed in the G.G. stable isotope laboratory at the University of Ottawa.

3. Results and discussion

Figure 1 shows the isotopic composition for rainwater samples from different events in Mashhad area. The local meteoric water lines for various weather stations (TDR, KDR, OAR, GR, AhmR, MR, ZR, and JR) were driven on δ^2H vs. $\delta^{18}O$ plot (Figure 1) and the meteoric relationship (correlation equations and R^2 coefficients) for ^{18}O and ^2H in precipitations of Mashhad area are as following:.

TDR ➔ $\delta^2H = 8.945\ \delta^{18}O + 18.649 \quad R^2 = 0.9704$
KDR ➔ $\delta^2H = 7.1099\ \delta^{18}O + 10.851 \quad R^2 = 0.9275$
OAR ➔ $\delta^2H = 5.2687\ \delta^{18}O + 5.0467 \quad R^2 = 0.8487$
GR ➔ $\delta^2H = 6.9767\ \delta^{18}O + 14.001 \quad R^2 = 0.9588$
AhmR ➔ $\delta^2H = 6.9685\ \delta^{18}O + 4.8368 \quad R^2 = 0.9841$
MR ➔ $\delta^2H = 7.2287\ \delta^{18}O + 8.0336 \quad R^2 = 0.9819$
ZR ➔ $\delta^2H = 8.1247\ \delta^{18}O + 17.83 \quad R^2 = 0.9533$
JR ➔ $\delta^2H = 8.6596\ \delta^{18}O + 15.803 \quad R^2 = 0.986$

Due to variations in temperature and the amount of rainfall, the isotopic compositions of meteoric water had wide ranges. This huge variation in isotopic compositions of the Mashhad rain events (from -198.2 to +38.1‰ and from -26.1 to +3.7‰ for δ^2H and $\delta^{18}O$, respectively) is because of strong seasonal changes in precipitations in this area. In addition, the Mashhad meteoric water line ($\delta^2H = 7.17\ \delta^{18}O + 11.22$), which is derived for the first time (Figure 2), shows deviation in both the slope and δ^2H intercept from the global meteoric water line ($\delta^2H = 8.1\times\delta^{18}O + 10.8$). The local meteoric water lines for some large cities of Iran (Tehran, Mashhad, Shiraz, Isfahan, and Rafsanjan) were also tabulated in Table 1.

The ^2H and ^{18}O isotopes of groundwater in alluvial aquifer (average of -50.9 and -8.3‰) and in discharge water from springs (average of -50.7 and -7.8‰) show minimal evaporative enrichment. The isotopic compositions of runoff for rainfall events (average of -49.4 and -7.7‰) and of water for dams (average of -42.9 to -6.3‰) show greater evaporative enrichment. In general groundwater samples gave a different isotope than surface water samples, due to the different physical processes that occur, which will affect their isotope values (Clark 1997). Surface water is subjected to higher evaporation, due to direct solar radiation, which results in a shallower slope compared to ground waters on δ^2H vs. $\delta^{18}O$ diagramme. Limestone formations outcrop within the catchment area of Kardeh dam causes high dissolved inorganic carbon concentration and slightly enrichment in ^{13}C isotopic composition.

4. Conclusions

Based on measured δ^2H and $\delta^{18}O$ values of rain events during 2008 and 2009, the Mashhad meteoric water line (MMWL) is derived as $\delta^2H = 7.17\ \delta^{18}O + 11.22$, which shows some deviation in both the slope and δ^2H intercept from the global meteoric water line ($\delta^2H = 8.1\times\delta^{18}O + 10.8$) and also from other available local meteoric water line in Iran (Tehran, Mashhad, Shiraz, Isfahan, and Rafsanjan). Due to evaporation and different physical processes, the isotopic compositions of local water resources show some discrepancy from that of precipitation.

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6. References

[1] Craig, H., 1961. Isotopic variations in meteoric waters. Science 133, 1702-1703.

[2] IAEA, Global Network of Isotopes in Precipitation. The GNIP Database. Accessible at http://isohis.iaea.org.

[3] Gat, J.R., 1980. The isotopes of hydrogen and oxygen in precipitation. In: Fritz, P., Fontes, J.Ch. (Eds.), Handbook of Environmental Isotope Geochemistry. The Terrestrial Environment, A vol. 1. Elsevier, Amsterdam, pp. 21- 47.

[4] Khademi, H., Mermut, A.R., Krouse, H.R., 1997. Isotopic composition of gypsum hydration water in selected landforms from central Iran. Chem. Geol. 138, 245-255.

[5] Farpoor, M.H., Eghbal, M.K., Khademi, H., Eghbal, M.K., Krouse, H.R., 2004. Mode of gypsum deposition in southeastern Iranian soils as revealed by isotopic composition of crystallization water. Geoderma 121, 233-242

[6] Clark, I.D., Fritz P., 1997. Environmental isotopes in hydrogeology. Lewis Publishers, Boca Raton, FL, 328 pages.

Table 1: The meteoric relationship (correlation equations and R^2 coefficients) for ^{18}O and ^2H in precipitations of Iran.

Meteoric Water	Correlation equation	R^2	Reference
Global meteoric water	$\delta^2H=8.13\ \delta^{18}O+ 10.8$	na	Craig (1961)
Tehran meteoric water	$\delta^2H=6.46\ \delta^{18}O+ 0.24$	0.91	I.A.E.A data base
Mashhad meteoric water	$\delta^2H=7.17\ \delta^{18}O+ 11.22$	0.945	Present study
Shiraz meteoric water	$\delta^2H=8\ \delta^{18}O+ 20$	na	Gat (1980)
Isfahan meteoric water	$\delta^2H=7.1\ \delta^{18}O+ 12.3$	0.979	Khademi (1997)
Rafsanjan meteoric water	$\delta^2H=5.9\ d^{18}O+ 13$	0.96	Farpoor (2004)

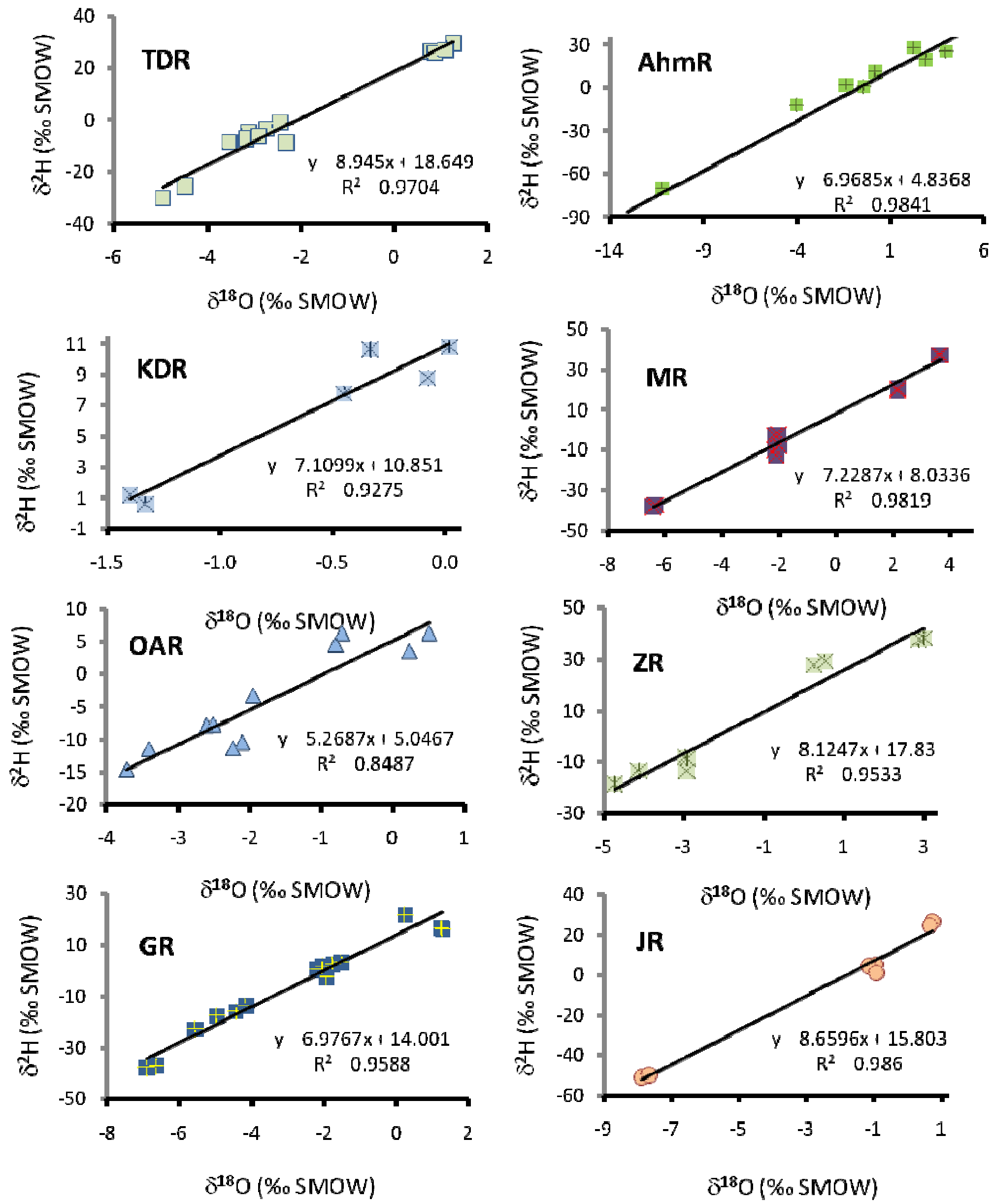

Figure 1: The isotopic composition for rainwater samples from different events in Mashhad area and the local meteoric water lines from various weather stations (Torogh dam-TDR, Karedeh dam-KDR, Olang Asadi-OAR, Goosh, GR, Zoshk-ZR, and Jaghargh-JR).

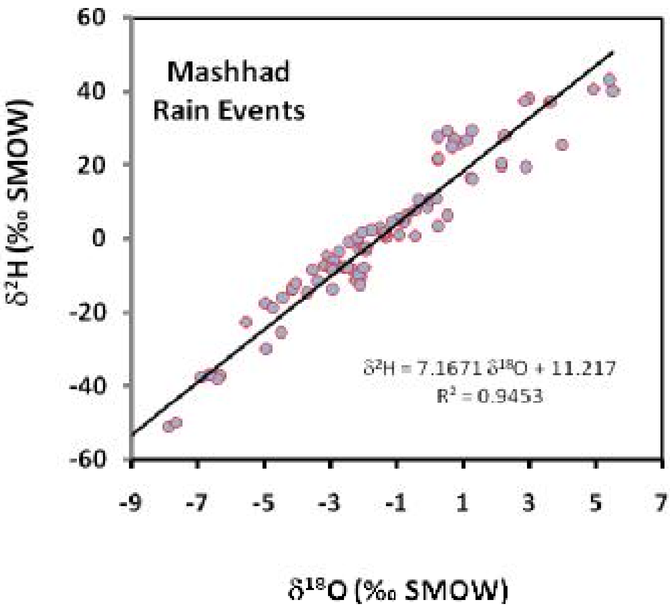

Figure 2: The Mashhad meteoric water line (MMWL), driven based on all available data from different rain stations.