**Title:** The Hydrogeochemical and Isotopic ($^{18}$O and $^{2}$H) Characteristics of Alluvial and Karstic Groundwater in Ravansar Area, West of Iran

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**Abstract**

The groundwater resources in Ravansar area, west of Iran, characterized by two major alluvial and karstic aquifers. Due to the broadly expanded and well tectonized Bistoun carbonate formation and the existence of siliceous limestone in radiolarite alluvial bedrock aquifer, the dominant groundwater type in Ravansar area is bicarbonate. The precipitation isotopes in Ravansar area vary seasonally as a function of local atmospheric parameters especially temperature and precipitation amounts. The local meteoric water line for Ravansar (RMWL - $\delta^{2}H = 5.8 \delta^{18}O + 2.7$), which was developed throughout a monthly cumulative approach, was deviated from the Global and Eastern Mediterranean meteoric water lines (GMWL and EMMWL) in both slope and $^{2}$H intercept, suggests the effect of the local conditions on the isotopic content of rains. Depending on the groundwater recharge point and residence time, four categories of groundwater (Bistoon, Radiolarite, Deep and Semi deep groundwaters) were plotted around the RMWL. Moreover, as a result of more evaporation, the groundwater samples collected in dry season were isotopically more enriched than the wet season ones.

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**Introduction**

Iran is an arid and semi-arid country with limited renewable water resources mostly relying on groundwater to meet its water demands for agricultural, industrial, and domestic purposes. Therefore, understanding the role of groundwater in the hydrological cycle and its interactions with the other components is an essential implication in integrated water resource management in Iran. Stable water isotopes are natural tracers to water cycle enabling the assessment of the possible sources of groundwater identification (Yeh et al. 2009; Mohammadzadeh 2010). This paper aims to provide a better understanding of the Alluvial and Karstic groundwater flow system in Ranavsar study area, located in west of Iran, using chemical and stable isotopes.

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**Setting**

Ravansar basin, is located in west of Iran laying between latitudes of 34° 14' 26" and 34° 46' 44" and longitude of 46° 30' 05" and 46° 48' 28" (Fig. 1), which occupies an area of 1262 km$^2$. The mean annual precipitation in Ravansar is about 540 mm 44% of which in winter, 30% in spring, 25% in autumn and the rest in summer. The mean monthly temperatures vary from about 29.5°C in Jul/Aug to about 1.2°C in Jan/Feb. Relative humidity falls within the range of 50% in Jan/Feb and 9% in Aug/Sep. Due to the vast expansion of well tectonized limestone formations coupled with relatively high amount of annual precipitation in Ravansar, the karst formations have formed very rich reservoirs of groundwater, which are a vital resource supplying water for the local socioeconomic development as well as the ecosystem.

The groundwater resources in Ravansar are characterized by two major karstic and alluvial aquifers. Karst groundwaters are emerged from the broadly expanded and well tectonized carbonate formation of Bistoun (Fig. 1). The largest spring in the area emerging from Bistoun is Ranasar spring with the maximum discharge amount of about 6 m$^3$/s. According to the fact that Bistoun formation, with the age of Triassic-Upper Cretaceous, occupies more than 30% of highlands in the study area and receives over 115 MCM precipitation per year, it is supposed to be a source of recharge to the adjacent alluvial aquifer. The alluvial bedrock aquifer is constituted from radiolarite, marl and siliceous limestone which due to its extensive outcrop plays a significant role in determining the quality of recharged groundwater into the alluvial aquifer. The alluvial aquifer is mostly consisted of Quaternary alluvial deposits including unconsolidated clastic deposits and young river terraces. The aquifer is mainly unconfined in Ravansar with a maximum thickness varying from less than 200 m in the...
east to over 300 m in the northwest, however, due to the locally distribution of restrictive clay-containing layers, it operates as an artesian aquifer specially in the western parts.

Fig. 1. Sampling locations and the simplified geological map of the study area (according to Braud, 1978).

Methods

A number of 27 samples were collected from 15 points (Fig. 1); including 21 Groundwater samples (i.e. 12 production wells, 9 karstic springs) which was gathered during both wet (December 2014) and dry (October 2015) season and 6 monthly precipitation samples. The isotope analyses were performed in the geochemistry and environmental isotope laboratories of Universities of Ottawa and Waterloo, respectively.

Results and Discussion

Processes controlling the chemistry of the Ravansar groundwater

According to the significant role of the carbonate formations in determining chemical composition of the groundwater, the dominant groundwater type in Ravansar area is bicarbonate (Fig. 2). However, due to the evaporative minerals in the eastern part of the aquifer, in terms of Mg$^{2+}$ and SO$_4$$^-$$^-$ major cations and anions, the groundwater in HO, BA and SHB samples are more concentrated relative to the other samples. The huge decrease in the rate of groundwater recharge in Ravansar spring during the dry season leads to higher concentration of dissolved minerals in groundwater rather than those of wet season. Since carbonate formations dominate the mountainous area outcrops and because of the marl bedrock in the alluvial aquifer, calcite and dolomite dominate the groundwater composition in Ravansar area. In terms of saturation indexes, the groundwater in wet season is only oversaturated in respect to calcite, while in dry season, the saturation indexes of both calcite and dolomite are positive indicating higher residence time as well as the lower amount of recharge in the area. Generally, there is an increase in SI$_{\text{Gypsum}}$ eastward, which indicates the extent of evaporation beds in the eastern part of the plain.
Isotopic composition of precipitations and groundwater

The huge variation in isotopic compositions of monthly precipitations (from $-53.81$ to $44.41$ and from $-8.34$ to $7.54\text{‰ VSMOW}$ for $\delta^{18}\text{O}$ and $\delta^{2}\text{H}$, respectively) is because of the strong variations in temperature and rainfall amount in the study area. The relationship between the isotopic composition of monthly precipitations and their corresponding atmospheric parameters implies that there is a negative correlation between the isotopic values with the precipitation amount, while this correlation about the temperature is positive (Fig. 3). The isotopically enriched October-2015 precipitation (with negative d-excess) is believed to be under the influence of high temperature and low amount of rainfall, whereas, the isotopically depleted November-2015 precipitation is due to the high amount of rainfall. The relatively high correlation between d-excess and temperature ($R^2 = 0.51$) is attributed to the seasonal effects and thermodynamic conditions in the atmosphere (Mustafa et al. 2015).

The local meteoric water line equation for Ravansar ($\text{RMWL} - \delta^{3}\text{H} = 5.8 \delta^{18}\text{O} + 2.7$) was deviated from the Global and Eastern Mediterranean meteoric water lines (GMWL and EMMWL) in both slope and $^{3}\text{H}$ intercept.
(Fig. 4), which suggests the effect of the local conditions on the isotopic content of rains. All samples taken in dry season show an enrichment in $\delta^{18}O$ values which reveals the effect of water-rock interaction on $\delta^{18}O$ composition of groundwater. In terms of locating around the RMWL, four groups of groundwater samples can be identified including: Bistoon, Radiolarite, Deep wells (> 120 m depths) and Semi deep wells (up to 120 m depths) (Fig. 4). The karst samples (Bistoon and Radiolarites) were plotted above the RMWL, indicate recharging from high land precipitations. Being isotopically more enriched than Bistoon samples, the Radiolarite water samples show the effect of evaporation caused by low permeability of Radiolarite formation to the groundwater recharge.

![Fig. 4. The Ravansar meteoric water line (RMWL) and the distribution of groundwater samples around it.](image)

**Conclusion**

The developed Ravansar meteoric water line (RMWL - $\delta^2H = 5.8 \delta^{18}O + 2.7$) was deviated from GMWL and EMMWL in both slope and intercept. In addition to the local meteorological characteristics, the isotopic composition of precipitation in Ravansar changes seasonally mostly under the influence of temperature and rainfall amount. The groundwater chemical composition is mainly subjected to the expansion of carbonated formations in the area as well as the seasonal changes in groundwater recharge. Due to the higher permeability, groundwater samples of Bistoun are isotopically more depleted than those of Radiolarites. The dipper groundwater samples are isotopically more depleted than the semi-deep ones, which suggests that these groundwaters have been recharged from higher elevations during the rainy years in the area.

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**References**


