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The Study of Stable Isotopes (^{18}O, ^{2}H & ^{13}C) in Kardeh River and Dam Reservoir, North-Eastern Iran

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Abstract—Among various water resources, the surface water has a dominant role in providing water supply in the arid and semi-arid region of Iran. Andarokh-Kardeh basin is located in 50 km from Mashhad city - the second biggest city of Iran (NE of Iran), draining by Kardeh river which provides a significant portion of potable and irrigation water needs for Mashhad. The stable isotopes (^{18}O, ^{2}H, ^{13}C-DIC, and ^{13}C-DOC), as reliable and precious water fingerprints, have been measured in Kardeh river (Kharket, Mareshk, Jong, All and Kardeh stations) and in Kardeh dam reservoirs (at five different sites S1 to S5) during March to June 2011 and June 2012. On $\delta^{18}O$ vs. $\delta^{2}H$ diagram, the river samples were plotted between Global and Eastern Mediterranean Meteoric Water lines (GMWL and EMMWL) which demonstrate that various moisture sources are providing humidity for precipitation events in this area. The enriched $\delta^{18}O$ and $\delta^{2}H$ values (-6.5 ‰ and -44.5 ‰ VSMOW) of Kardeh dam reservoir are compared to Kardeh river (-8.6‰and-54.4‰), and its deviation from Mashhad meteoric water line (MMWL- $\delta^{2}H=7.16\delta^{18}O+11.22$) is due to evaporation from the open surface water body. The enriched value of $\delta^{13}C$-DIC and high amount of DIC values (-7.9 ‰ VPDB and 57.23 ppm) in the river and Kardeh dam reservoir (-7.3 ‰ VPDB and 55.53 ppm) is due to dissolution of Mozdooran Carbonate Formation lithology (Jm1 to Jm3 units) (contains enriched $\delta^{13}C$ DIC values of 9.2‰ to 27.7‰ VPDB) in the region. Because of the domination of C3 vegetations in Andarokh_Kardeh basin, the $\delta^{13}C$-DOC isotope of the river (-28.4‰ VPDB) and dam reservoir (-32.3‰ VPDB) demonstrate depleted values. Higher DOC concentration in dam reservoir (2.57 ppm) compared to the river (0.72 ppm) is due to more biological activities and organic matters in dam reservoir.

***Keywords*—**Dam reservoir, Iran, Kardeh river, Khorasan razavi, Stable isotopes.

I. Introduction

IN the recent decades, the world faces important challenges to provide water supply for growing societies. As water resources' quality and quantity reduce globally due to population growth, anthropogenic pollution, and recent droughts, very accurate water management programs should be developed to control water shortage crisis. Iran as an arid and semi-arid region faces crucial water shortage crisis due to rapid population growth and long hydrological droughts. Among the various water resources in Iran, surface water (rivers and dam reservoirs) plays crucial role to provide water needs in almost every part of the country. The study site is located in Andarokh-Kardeh basin, north of Mashhad the second biggest city of Iran. This basin is draining by Kardeh river, on which the Kardeh dam was constructed. Kardeh dam reservoir provides significant part of drinking water supply for Mashhad. The climate of this region is continental and most of its precipitation occurs from September to June with average of 260 mm and average potential evaporation of 1835 mm per year. Andarokh-Kardeh is a part of Kopeh-Dagh basin in north-eastern Iran. The outcropped geological formations in the area are Mozdooran limestone Formation (Jmz1, Jmz2, and Jmz3), Shourijeh (Ksh) shale and limestone Formation, Ngr Formation marly sandstone and gypsum and Quaternary and Plio-Quaternary sediments (Fig. 1). Kardeh thrust fault (Ktf), with north-western south-eastern orientation and six main series of joints, demonstrates active tectonic which progressively developed drainage system in this basin.

Lack of comprehensive quality and quantity assessment is the most crucial problem facing sustainable water resources management. Stable isotopes are precious tools in hydrological investigations and assessments, and are critical in supporting effective water management programs. Stable isotopes have been used in numerous surface water studies worldwide [1]-[4] and in Iran [5]-[7]. The objective of the present survey is to study ^{18}O, ^{2}H and d-excess values along Kardeh river in several stations (Kharket, Mareshk, Jong, All and Kardeh) and dam reservoir sites (S1 to S5) (Fig. 1), to determine the spatial variation and altitude effect on ^{18}O, ^{2}H and d-excess values along Kardeh river and dam reservoir and also to show the evaporation intensity in these stations. In addition, ^{13}C isotopes and DIC and DOC concentration have been studied in dam reservoir and (Kharket, All and Kardeh) stations along Kardeh river to study carbon cycle in the region.

II. Materials and Methods

In this survey, 31 samples were collected for stable isotopes (^{18}O and ^{2}H) and eight samples for DIC, DOC, and ^{13}C isotopes during March to June 2011 and June 2012. Water samples were collected for ^{18}O and ^{2}H isotope analysis in 25 ml plastic bottles, andfor ^{13}C isotope and DIC/DOC concentrations, samples were collected in 40 ml amber Trace Clean EPA vials. All the analysis has been done using Delta plus Xp isotope ratio mass spectrometer (Thermo Finigan, Germany) in G.G Hatch stable isotope laboratory at Ottawa University in Canada. The results of ^{18}O, ^{2}H, and ^{13}C stable isotopes analysis were expressed relative to Vienna Standard Mean Ocean Water (VSMOW) with uncertainty of ±0.1‰ and ±1‰ for ^{18}O and ^{2}H, respectively, and ± 0.2‰ Vienna Pee Dee Belemnite (VPDB) for ^{13}C.

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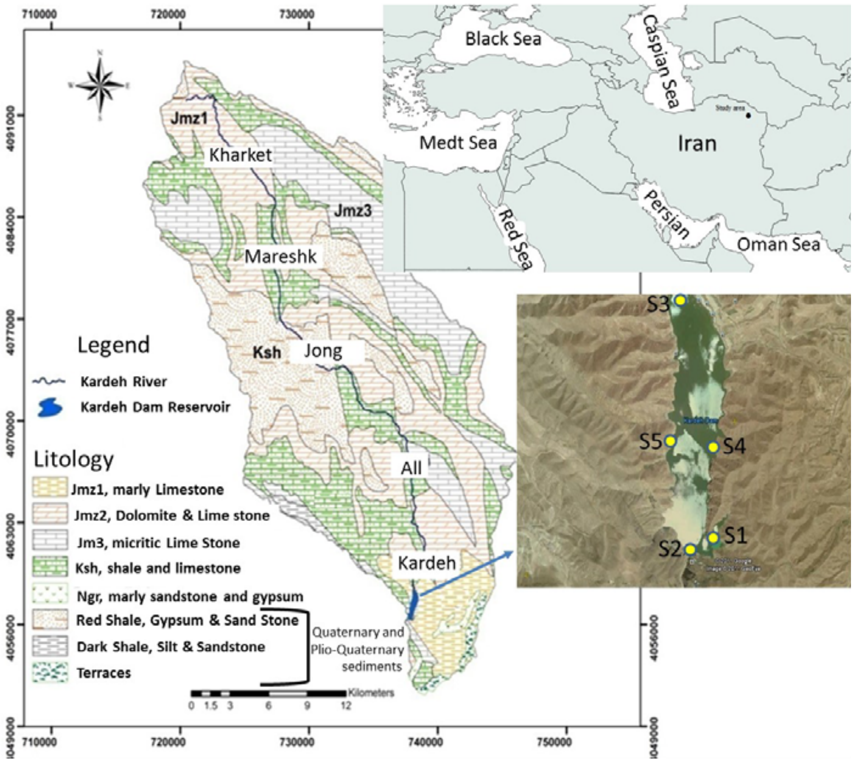
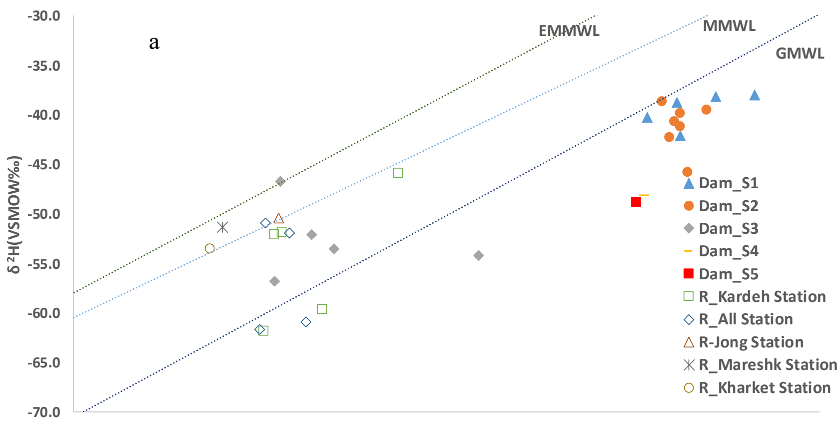


Fig. 1 Andarokh_Kardeh geology map and sampling locations

III. Discussion

The local Mashhad Meteoric Water Line (MMWL - $\delta^2H = 7.17\delta^{18}O + 11.22$ [10]) is plotted between Global (GMWL - $\delta^2H = 8.13\ \delta^{18}O + 10.8‰$ [8]) and Eastern Mediterranean (EMMWL - $\delta^2H = 8\delta\ ^{18}O + 22‰$ [9]) meteoric water lines. The river water samples were sparsely plotted around MMWL and between Global and Eastern Mediterranean meteoric water lines, indicating that various humidity sources providing moisture for this region precipitation.

Caspian Sea, Black sea, Mediterranean Sea, Red Sea and Persian Gulf - with different temperature and relative humidity characteristics provide moisture for north-eastern Iran precipitation during year. River stations mostly were plotted on MMWL, and their isotopic values are relatively smaller and more depleted than those of precipitation due to recharge from high elevation precipitations with very low evaporation effect, while some river samples deviate MMWL line due to evaporation. Kardeh dam reservoir samples shows more enriched values and deviates from MMWL due to evaporation from dam reservoir. Studying d-excess and electrical conductivity (EC) vs $\delta^{18}O$ demonstrate that the river water samples have d-excess from 6.6‰ to 20.7 ‰ due to various sources providing moisture for precipitation. The evaporation from dam surface results in $\delta^{18}O$ enrichment and low d-excess (Fig. 2 (b)). In EC vs $\delta^{18}O$ diagram (Fig. 2 (c)), Kardeh dam reservoir samples demonstrate higher EC compare to river water samples due to evaporation effect.



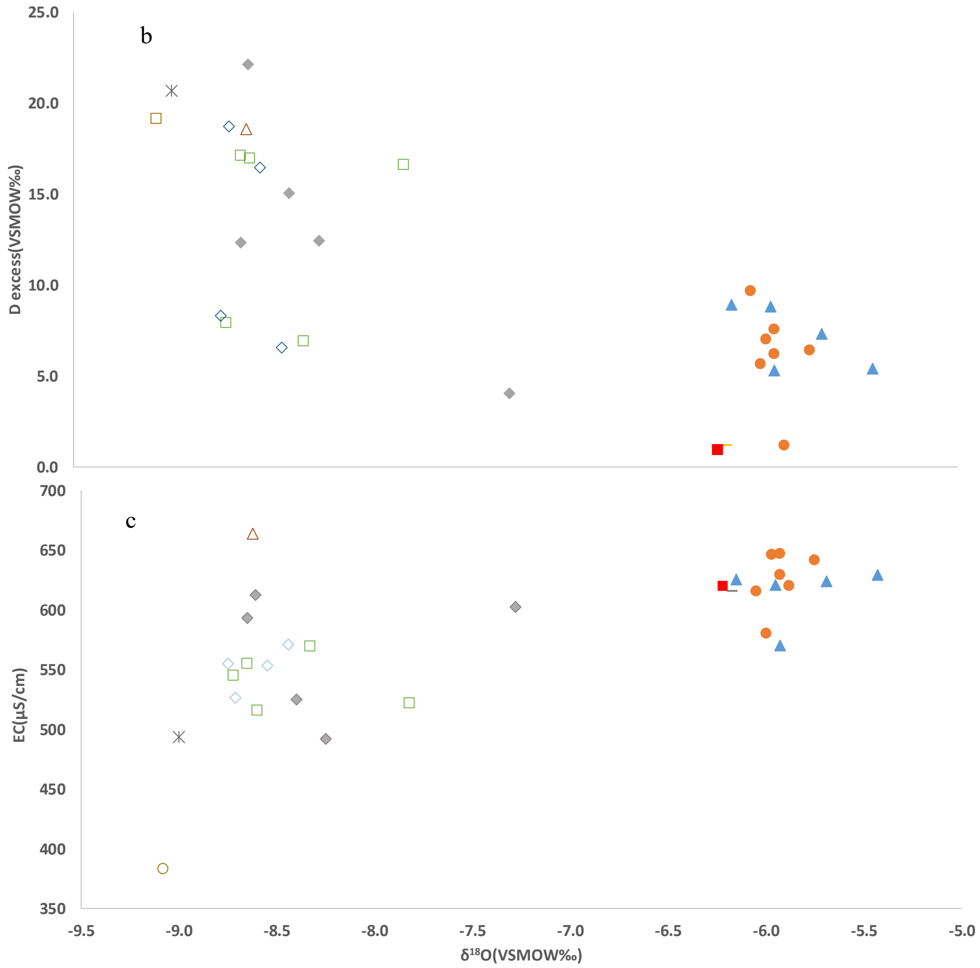
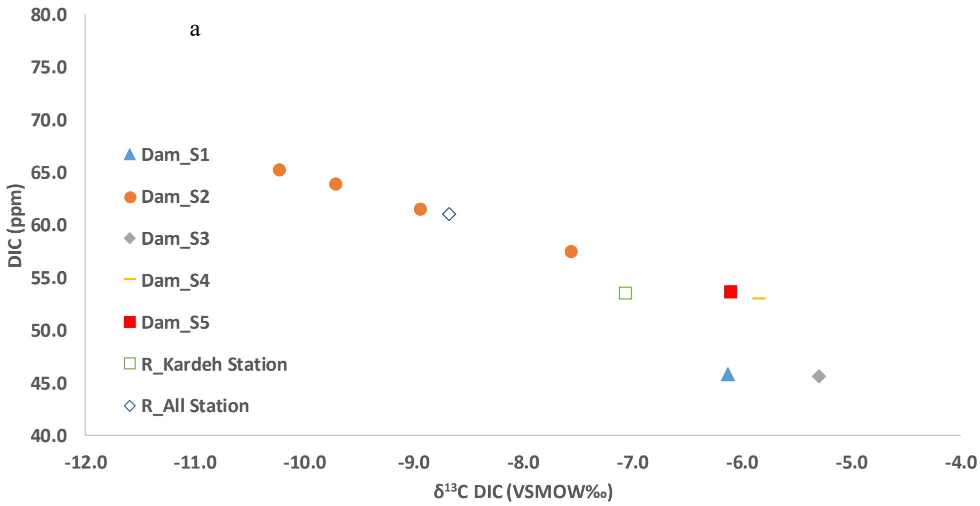


Fig. 2 Kardeh river and dam reservoir samples on δ^2H vs $\delta^{18}O$, (a) d-excess vs $\delta^{18}O$ (b) and EC vs $\delta^{18}O$ (c) diagrams



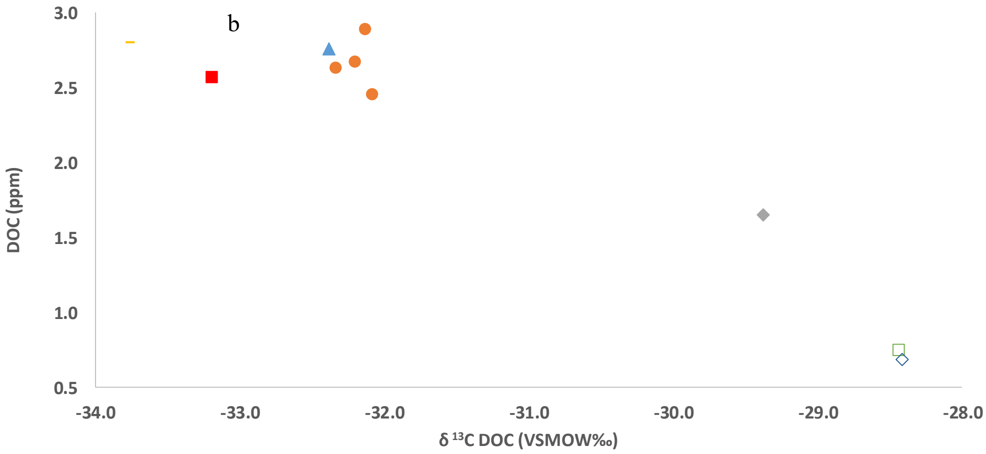


Fig. 3 Kardeh river and dam reservoir samples on δ^{13}C-DIC vs DIC (a) and δ^{13}C-DOC vs DOC (b) diagrams

In carbon cycle, where carbon is exchanged among the different reactions in biological, hydrological, geological and atmosphere in the earth, the stable ^{13}C isotope can be used as a precious tool to detect the origin and evaluation of carbon cycle. Studying δ^{13}C-DIC and DIC in both river and dam reservoir samples demonstrate enriched value of δ^{13}C-DIC and high DIC concentration which is due to dissolution of Mozdooran carbonate Formation lithology (Jm1 to Jm3 units) (Fig. 1) (with δ^{13}C values of 9.2‰ to 27.7‰ [11]). The weak depletion of δ^{13}C-DIC and increasing in DIC in Kardeh dam reservoir (Dam_S2) is due to bacterial degradation of organic matters and methanogenesis (Fig. 3 (a)). Studying δ^{13}C-DOC isotope content of river and dam reservoir samples show depleted values from -28.4‰ to -33.2‰ due to domination of C3 vegetation (-23‰ to -35‰ [12]) in the region. The higher amount of DOC in Kardeh dam reservoir compare to river stations is due to more biological activities (Phytoplankton and bacteria's) producing organic matter in Kardeh dam reservoir (Fig. 3 (b)).

IV. Conclusion

Studying stable isotope (^{18}O, ^{2}H,$^{13}C_{DIC}$ and $^{13}C_{DOC}$) in Kardeh river and dam reservoir demonstrate the river stations samples plots between GMWL and EMMWL due to various humidity sources providing humidity for precipitation events in the region. Kardeh dam reservoir samples have more enriched values and deviate from local meteoric water lines due to evaporation effect. The δ^{13}C-DIC and DIC have more enriched value and higher concentration due to dissolution of Mozdooran Formation lithology (Jm1 to Jm3 units) contain enriched δ^{13}C-DIC values. δ^{13}C-DOC isotope content in river stations and dam reservoir demonstrate depleted value due to domination of C3 vegetations in the region. The more biological activity and organic matter in dam reservoir results in higher DOC concentration in dam reservoir compare to river stations.

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