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The local meteoric relationship for ^{18}O and ^{2}H in precipitations and isotopic compositions of water resources in northeast Amara area (South of Iraq)

Abstract

This paper focuses on determining the Amara meteoric water line for the study area (AMWL) is defined or the first time, based on samples of precipitation collected Amara city - southeast of Iraq. For an adequate management of available water resources in semi-arid and arid regions, it is important to compare isotopic data of surface water and groundwater with the local meteoric relationship for δ18O and δD in precipitations. Isotope values of precipitation indicate a local meteoric water line (Amara MWL δ2H = 7.51 $\delta^{18}O$ + 10.82; R2=0.94) situated between the Mediterranean MWL and Global MWL. Both the slope and 2H intercept for AMWL are deviated from the global meteoric water line - GMWL ($\delta^{2}H$ = 8.13 18O + 10) and Mediterranean MWL (δ 2H = 8.13 18O + 22). The slightly variation in isotopic compositions of the Missan rain (from -4 to +3.2‰ and from -20 to -14‰ for ^{18}O and ^{2}H, respectively) is because of slightly seasonal changes in precipitations in this area. The 18O and 2H isotopes of local water resources show that the rainwater is affected by the Arabian Gulf Arabian Sea potential moisture sources.

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Introduction

The study area is located in arid or semi-arid climatic regions. It suffers from a systematic water shortage that is exacerbated by rapid urbanization, industrialization, growing agricultural demand, and environmental degradation. Therefore, the study of isotopes will be useful in gaining a better understanding of the hydro geological processes of the surface water-aquifer interface, and the study of aquifers in this area has been initiated to provide the necessary information to allow the sustainable development of water resources in the region.[1] In order to better understand the conditions of groundwater variability from the recharge to the exploitation zones, stable isotopes of oxygen (^{18}O) and hydrogen (δD) have been used.[2,3] The natural isotopes (stable & unstable) contributes in many applications of hydrological, hydrogeological and geochemical sciences, which give evidence about of water sources, quality, and ages of water, in addition to recharge and movement of groundwater.[4] The first studies on isotopes techniques in water were involved of precipitation and seawater. The first study was about survey on variations in concentration rate of ^{18}O, after that followed by a study about variation ^{2}H rate in natural waters, the variations of ^{18}O in global precipitation scale, involving a discussion in great detail on the meteorological patterns.[5,6] Many hydrological studies use the stable isotopes (^{18}O, ^{2}H) to determine the origin, recharge mechanisms and hydraulic connection of water molecules in groundwater. The climate of the study area is hot and semi-arid. The 22-year (1995-2015) average rainfall in the Missanarea is 33.2 mm and average temperature is 26 °C. According to the FAO Penman – Monteith method for Ali-Al Gharbi station occurs with a high value from May to September with the maximum value occurring in Jun (450 mm day^{-1}).[7]

Several studies have discussed the hydrogeology and hydrochemistryof the study area in the Al-Teeb and Ali Al-Gharbi areas (southeastern part) its surroundings, Missan province.[8-13] However, none of them covered the entire aquifer in terms of its stable isotope composition. Consequently, this investigation has been undertaken to fill these informational gaps. The aims of this present research were to (1) develop the Amarahmeteoric relationship for ^{18}O and ^{2}H in precipitations in order to obtain Amarah meteoric water line (AMWL), (2) compare AMWL 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 Amarah area with that of local meteoric eater.

Study area

The study area is district that is called Ali Al-Gharbi and located in the northeastern of Missan province,the area of study about (760 km^{2}), (Figure1).The topography elevation ranges from (0–160m) is derived from the Digital Elevation Model produced by (USGS), (Figure 2). The surface is relatively flat in the central part of the area and bounded by Hemrin hills in the north-eastern near of the Iran. The surface elevations from north- east to south- west of the study area for district of Ali Al-Gharbi are decrease. The geological characteristics of study area are by the Rocks of uppermost Miocene and Pliocene are slope towards the Mesopotamian plain from the foothills along the Iraqi-Iranian border on the east. The rocks are buried under the Mesopotamian plain by thick layer deposits of Pleistocene and Holocene age.[14] The study area is composed of different types of Quaternary deposits Pleistocene sequence. The quaternary sediment constitutes about 100% in study area, these sediments are gravel, sand, silt and clay.[15] The sediments characterized of Quaternary are finer grained and unconsolidated than the underlying Mukdadiya and Bai Hassan Formations.[16-18] Many deposits such as Alluvial fan, depression fill, sheet runoff deposits, and Aeolian deposits are the major units in the study area.[19] The tectonic setting of study area was the largest part is within of eastern most unit the stable shelf (Mesopotamian Zone). The study area bounded in the north -east by the high folded zone that represented in the Hemrin hills.[20,21]

Aquifer system in study area is subdivided into two aquifers: shallow aquifer (unconfined), deep aquifer (confined). These aquifers are separated by less permeable layers the hydraulic characteristics of which are unknown. The hydraulic connection between aquifer units is possible. Unconfined aquifer is shallow in nature. The sediments are sand (fine, medium) with little layer of silt and clay represents the main component of this unit and some of wells contain a gravel. Many dug wells in the study area penetrate this unit of aquifer and extract water, these Dug wells are with irregular diameters. Most of rainfall recharge goes to this part of aquifer, water quality is change depended on surface salt washing process. Confined aquifer is deep and found only in the eastern part of the area. This aquifer is limited extent in the study area and consists mainly of mixture of gravel and sand (sandy gravel), gravel and clay (clayey gravel) with significant amount of silt and in some parts of the aquifer. Hydraulic conductivities values quaternary deposits in the study area are acquired from previous studies such as.[19] but no mention of the method used to get these values is given. The value of hydraulic conductivity for quaternary deposits between (0.5–5.3)m/day. These values are less than other deposits, this may be because of components of Quaternary sediments that are sand and gravel with layers of silt and clay, which decrease the values of hydraulic conductivities in aquifer.

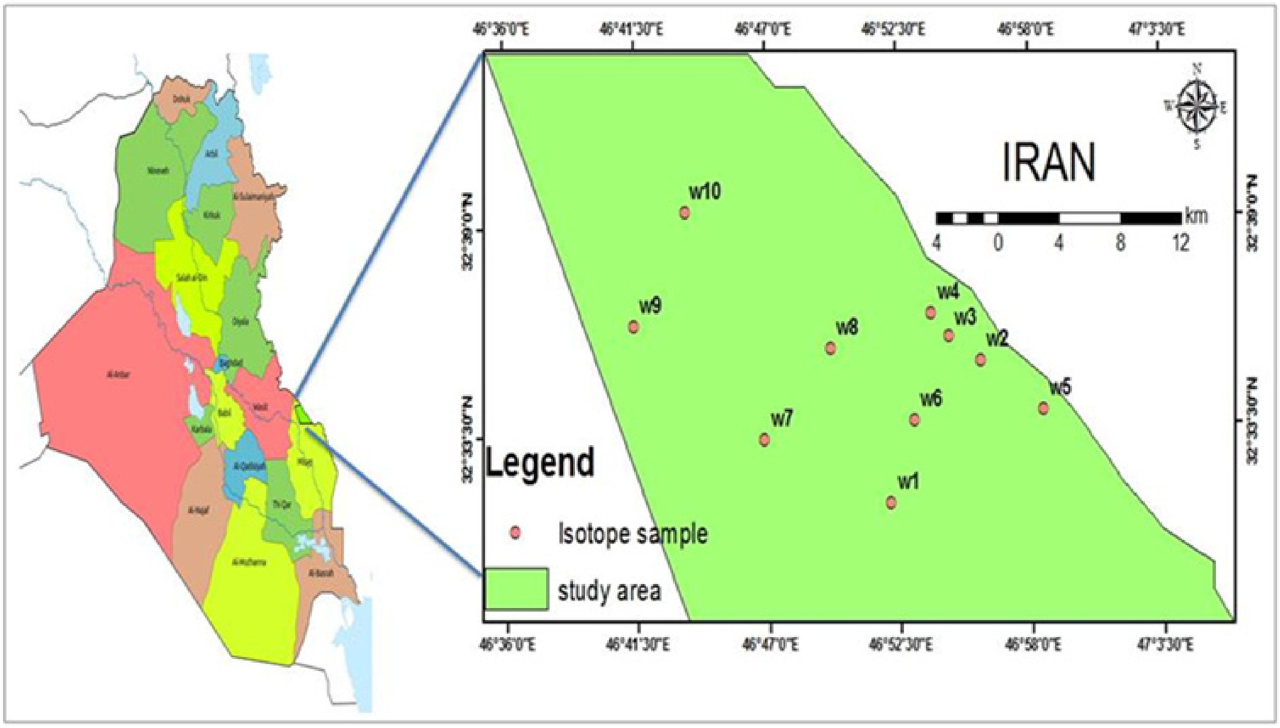

Figure 1 Location map of study area.

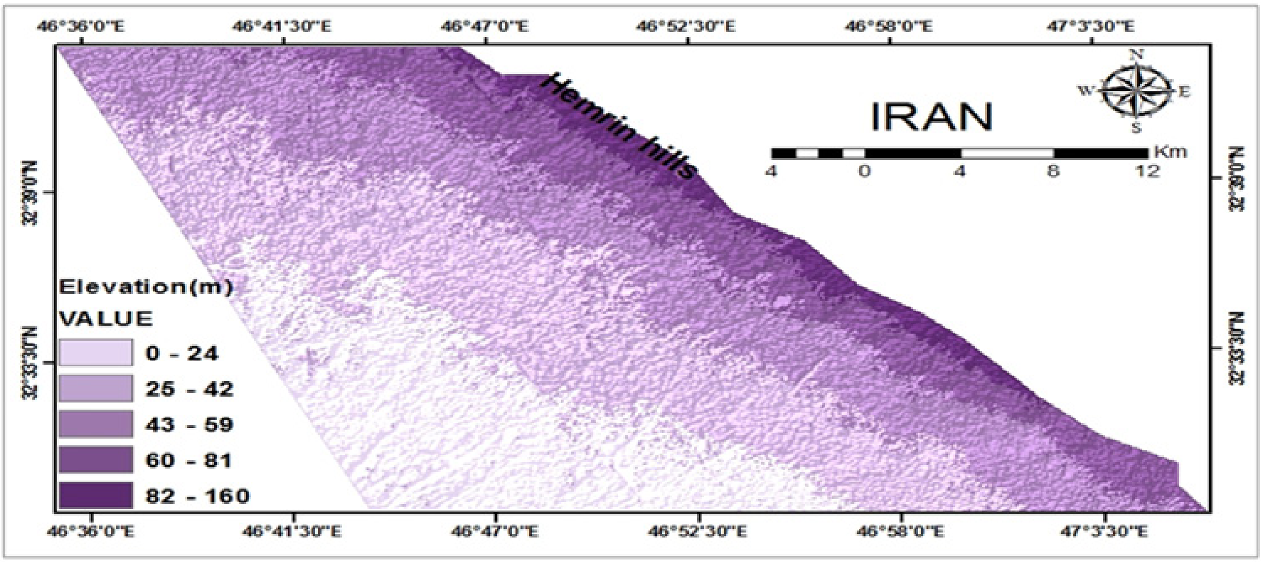

Figure 2 Topography of study area.

Material and method

Stable isotopes of the molecule ($^{2}H/^{1}H$ and $^{18}O/^{16}O$)

Stable isotopes are a powerful research tool in geology and environmental science.[22,23] The interest of stable isotopes in groundwater is that the two isotopes should display identical chemical behavior in the environment. Slight variations in isotopic abundance are caused by small differences in reactivity of the different isotopes. Express stable isotope ratios using d values in ‰ (per mil or ppt) relative to a standard

$$^{18}O = \frac{^{18}O/^{16}O_{sample} - ^{18}O/^{16}O_{std}}{^{18}O/^{16}O_{std}} \quad (1)$$

According general equation, where (R) refers to the rate isotope, Sample /Standard. the rate form sample to another are small, using the above rate would be unsuitable because we need to comparing values with third or fourth decimal, there for Instead by delta (δ), this delta is now universally using and an adopted and also the comparison had become more easily.

These are expressed in per (‰) recorded according to the general formula:

$$\delta\,(‰) = \frac{R_{sample}}{R_{standard} - 1} \times 1000 \quad (2)$$

Where the (R sample) ratio in the samples, (R standard): ratio in the standard. For stable isotopes (18O, 2H) of waters, the standard adopted is Vienna- Standard Mean Ocean Water (V-SMOW).[2,24-26] δ (‰) is indicate to ratio of sample and a standard, when the sample is enriched in heavy isotopes, the values (δ) will be positives, while if the sample is depleted in heavy isotopes, the values (δ) will be negative.[27] When δ2H is plotted as a function of δ18O for water found in continental precipitation, an experimental linear relationship is found that can be described by theequation.[28]

$$\delta^{2}H = 8\,\delta\,^{18}O + 10 \quad (3)$$

Where the $\delta^{2}H$= hydrogen isotope composition, $\delta^{18}O$ = oxygen isotopecom position. This is known as the Global Meteoric Water Line (GMWL) or evenCraig line (Figure 3). Continental precipitation samples will tend to group close to this line, precipitation falling in areas with lower temperature or at higher latitudes will tend to have lower $\delta^{2}H$ and $\delta^{18}O$ values. Deviations from the meteoric water line can be interpreted as being caused byprecipitation that occurred during warmer or colder climate than at present or by geochemical changes that occurred when the water was underground.[29] The δ values are higher (more positive) in the summer and lower (more negative) in winter. In the present study, the isotopes (^{2}H, ^{18}O) content in water of studied area was evaluated by collected (6) samples for rainwater. All samples were analyzed at the laboratories of isotopes in Ministry of science and technology (Iraq).

Results and discussion

Several studies have been conducted in Iraq and the neighboring countries concerning establishing the local meteoric lines in these countries. In[30,31] showed that Erbil-Hajji Omaran meteoric line in the northern part of Iraq has the following equation:

$$\delta 2H = 8\,\delta^{18}O + 20 \quad (4)$$

Kattan,[32] showed that Syrian meteoric line has the following equation:

$$\delta^{2}H = 8.2\,\delta^{18}O + 19.37 \quad (5)$$

whereas the common regional meteoric line for both Jordan and Syria have the following expression. [33]

$$\delta^{2}H = 7.8\,\delta^{18}O + 19.25 \quad (6)$$

SLIM, SAAD[34] developed the following equation as a representative for Lebanon Meteoric Water Line

$$\delta^{2}H = 7.18\,\delta\,^{18}O + 15.98 \quad (7)$$

For Kuwait, the following equation was suggested byKendall and Alsharhan.[35]

$$\delta^{2}H = 8.0\,\delta^{18}O + 15 \quad (8)$$

whereas, in the United Arab Emirates, the local meteoric water line equation as suggested by[36] is of the following form:

$$\delta^{2}H = 8\,\delta^{18}O + 17 \quad (9)$$

The East Mediterranean Water Line (EMWL), has the following equation.[37]

$$\delta^{2}H = 8\,\delta^{18}O + 22 \quad (10)$$

According to the present results (Figure 3), AMWL lies between EMWLand GMWL.

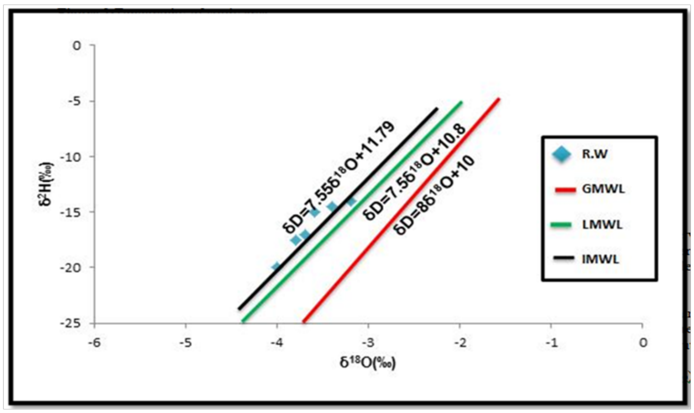

Figure 3 Relation between the δD and δ18O for precipitation samples of study area during the observation periods December 2015 and January, February 2016.

Amara meteoric water line (AMWL)

Six rain water samples are collected during three month, December, 2015 and January, February 2016. The results for all isotopes are expressed in δ record as per mil deviation from internationally accepted standard V-SMOW (Vienna standard mean ocean water). The values of stable isotopes ($\delta^{18}O$, $\delta^{2}H$ and d-excess calculations) are summarized in Table 1. The range of $\delta^{2}H$ is (-20.0‰ to -14.0‰), with a mean value of (-16.33‰), whereas the range of δ18O was (-4.12‰ to -3.2‰), with mean value of (-3.61‰). No Significant difference in the stable isotopic composition values of the rainfall samples was noticed. The changes of $\delta^{18}O$ and $\delta^{2}H$ in rainwater throughout Iraq is due to rainfall intensity (amount effect) and is attributed to passage of air mass from the Mediterranean Sea.[33] The results are reported in negative numbers because they are showing how much less ^{18}O

isotopes are present compared to the ocean water. The low negative numbers indicate heavier water with a higher concentration of ^{18}O, whereas the high negative numbers signify lighter water where more of the ^{18}O has been precipitated out.

Table 1 Stable Isotope results from selected samples for rainwater.

Rainfall samples	Date	δ^2H (‰)	$\delta^{18}O$ (‰)	d-excess
R1	14\12\2015	-20	-4	12
R2	23\12\2015	-17.5	-3.8	12.9
R3	30\12\2015	-17	-3.7	12.6
R4	07\01\2016	-15	-3.6	13.8
R5	20\01\2016	-14.5	-3.4	12.7
R6	10\02\2016	-14	-3.2	11.6
	average	-16.33	-3.61	12.6

In Amara for district of Ali al Gharbi, $\delta^{18}O$ and δ^2H relationship for all the samples data during the observation periods of December, 2015 and January, February 2016, may define initial Amarah meteoric water line (AMWL) which fits with the relation below a regression line coefficient $R^2 = 0.94$ as shown in Figure 3.

$$\delta D = 7.51\ \delta^{18}O + 10.82 \qquad (11)$$

The equation defines the Local (AMARA) Meteoric Water Line (LMWL). The slope of the line (7.51) is slightly different from the slope of GMWL (8) and interception (10.82), because of the varying climate conditions. The Slope (7.51) shows that no significant evaporation occurred during precipitation (Scholl, 2011). The slope of the regression line for the relationship between ($\delta^{18}O$ - δ^2H) in rainwater is <8, Figure 3, which is the climate characteristic is a semi-arid (Geyh et al., 1998). The slope of the linear MMWL (in blue colour) is the Mediterranean Water Line, AMWL (in green colour) is the Amara Meteoric Water Line, and GMWL (in red colour) is the Global Meteoric Water Line regression is less than the GMWL and ($\delta^{18}O$ and δ^2H) relationship provides a good characterization of air mass origi.[38] The value of d-excess shows variation due to the differences in the amount of rainfall, relative humidity, and mixing of air masses from Arab Gulf. On the other hand, the increase of d-excess is attributed to the moisture origin from Arabian gulf, as well as the significant influence of Mediterranean air masses.

The ^2H and ^{18O} isotopes of groundwater in alluvial aquifer (average of -12.54 and -3.01‰) and in discharge water from springs (average of -13.7 and -3.8‰) show minimal evaporativeenrichment. The isotopic compositions of runoff for rainfall events (average of -10.4 and - 2.7‰) show greater evaporativeenrichment. In general groundwater samples gave a different isotope than surface watersamples, due to the different physical processes that occur, which will affect their isotope values.[2] Surface water is subjected to higher evaporation, due to direct solarradiation, which results in a shallower slope compared to ground waters on ^2H vs. ^{18}O diagramed.

Conclusion

Study area (Ali Al-Gharbi) approximately 760km^2 covering the north east of Missan Province of Iraq. The topographic map elevation (DEM) is between (0-160)m, high elevation is Hemrin hills. The sediments of study area are quaternary deposits. Confined part located in eastern part of study area and most of sediment of this aquifer is gavel, while unconfined part located in western part of study area and most of sediments are sand with silt. Based on measured ^2H and ^{18}O values of rain events during 2015 and 2016, the AMARA meteoric water line (AMWL) is derived as $^2H=7.51\ \delta^{18}O+10.82$, which shows some deviation in both the slope and ^2H intercept from the global meteoric water line ($^2H=8.1\times^{18}O+10.8$) and also from other available local meteoric water line in Iraq. Due to evaporation and different physical processes, the isotopic compositions of local water resources show some discrepancy from that of precipitation. Amara meteoric water line (AMWL) are near to GMWL and away from MMWL, this indicates climate of study area is affected by Arab Gulf climate.

Acknowledgments

None.

Conflicts of interest

The authors declares that there is no conflict of interest.

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