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Application of Stable Isotope Technique in Estimating of Groundwater Mixing in Al-Najaf – Ain- A l-Tamur Area

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Abstract: ***Hydrochemistry and stable isotopic technique were used in studying the groundwater mixing in Al-Najaf-Ain-Al-Tamur area. Twenty one shallow and deep wells were chosen for hydrochemical and isotopic (^{2}H and ^{18}O)analyses in addition to spring, Razzaza Lake and rainwater. Diagram between $\delta^{18}O$,and δD was plotted then the result showed that groundwater samples separated into two groups; one for Dammam aquifer which underwent less evaporation or may be fed with rain water that is enriched with stable isotopes, the other group belongs to Dibdibba aquifer including Razaza lake which have been underwent more evaporation.***

Keywords: Isotope, Hydrochemistry, Razzaza Lake, Dibdibba, Dammam, Aquifer, Iraq

1. Introduction

The studied area is located within Al-Najaf- Karbala-Ain Al-Tamur. The study area extends from Razzaza Lake in the north bounded from the east by the Modern village project, from the west by Ain Al-tamur oasis, and from the south by Al-Najaf governorate, between the longitudes(43 30 to 44 12) and latitudes (32 36 to 32 23) ,The elevation ranges from (28-120m) above sea level fig(1).

The important geological formations in the study area of Tertiary sediment from older to younger, Dammam , Euphrates, Nfayil, Fatha, Injana, Dibdibba in addition to Quarternary deposits**.**Karbala city and its suburbs are located on the edged interim between the stable platform (Al-Salman sub-zone) and the unstable platform (Mesopotamian sub-zone). The use of isotopic composition in hydrology gives answers for where water goes, its sources, resident time in watershed, its pathways and environmental situation. Stable isotopes of water (^{2}H and ^{18}O) have been used globally since 1950 (Epstein and Mayeda 1953; Graig1961; Dansgaard 1964).The isotopic technique is an important tool in hydrological investigation and in water resources management. Stable isotopic technique (deuterium and oxygen-18)was used to examine the intermixing between the different aquifer in Al-Najaf-Ain-Al-Tamur area.

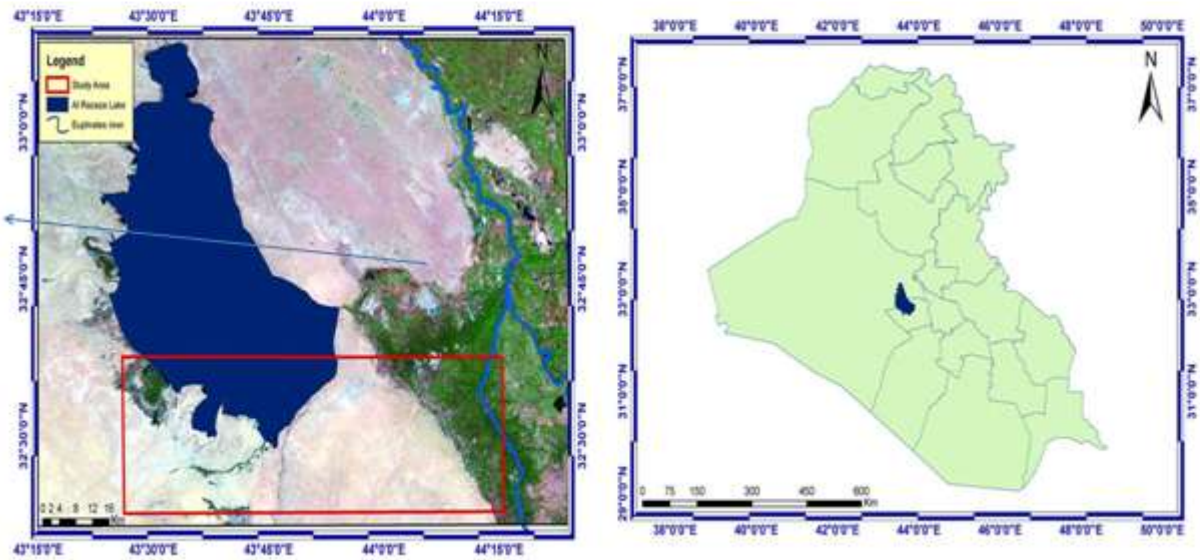


Figure 1: Location map of study area

General features of the study area

The outcrop formation in the study area are configured from the oldest to the youngest by Dammam, Euphrates, Injana to Dibdibba formations in addition to the Quaternary deposits (Pleistocene and Holocene) which appear south and southwest of Razzaza Lake represented by gypcrete , Aeolian deposits , sabkha sediments and valleys fill sediment in the region. All the studied area covered by gypcrete deposits except an area a rounded by Razzaza Lake and Tar-Alsayd, where Dibdibba, Injana and Al-Nfayil formations are outcrop (Al-Shamari, 2014). The study area is located on the edged interim between the stable platform (Al-Salman sub-zone) and the unstable platform (Mesopotamian sub-zone). The unstable platform represents the eastern and northeastern extension of the stable platform, where the thickness of the sedimentary cover is relatively thin and the surface slope is irregular. The reason for instability is the presence of subsurface faults that sometimes extends to the surface (Buday and Jassim 1984).

The study area is considered tectonically stable and the sedimentary cover range from (7-8km) it characterized by two type of fault. The first one trends from NE-SW(Rhaimady-Hilla),(khanaquin-Baqubakarbala) fault.The second type trends from NW-SE represented by (Heet-Abu Jir zone fault).

From field observations and according to (Al-Khateeb and Hassan, 2005),The study area could be divided into several geomorphologic parts: Najaf - Karbala plateau, Al –Razzaza depression, Rock cliff, Slope sediments, and Mesas and Buttes

Groundwater recharge of the study area from many natural sources includes precipitation, stream flow and seasonal rivers. The only water source is the groundwater that discharged from wells and the seasonal surface water that comes from outside the study area through the streams like Ubayadh valley (AL-Shamari, 2014).

The geologic formations in the study area are classified into two hydrogeological units (unconfined and confined aquifer).The unconfined aquifer in the study area located at the right side of Tar AL-Sayyed cliff within Karbala-Najaf plateau is composed of (Dibdibba and Injana formations) they are considered as the first upper aquifers. These formations are separated by unconformable surface some times. Euphrates Formation represents unconfined aquifer; this formation is not considered as main aquifer because of its high-salinity and low productivity and its content of sulfates, and sometime behaves as an isolated bed that separated from Dammam Formation below (Al-Suhail, 1996). The confined aquifer Dammam carbonate is one of the most important aquifers in southwest Iraq. It is divided into two aquifer types: unconfined and confined. Its karst porosity, associated with cracks, which increase the aquifer storage properties and the specific yield. Highest permeability occurs in depressions where strong water circulation occurs (Jassim and Goff, 2006).

2. Materials and methodology

Twenty-One samples were collected from the wells within the study area for hydrochemistry and ^{2}H and ^{18}O analysis. Two samples is taken from each location ,one for hydrochemistry analysis kept in 500 ml polyethylene bottle ,the other in 100ml polyethylene bottles for isotope analysis. The bottle was washed by distilled water;all sample bottles were filled completely, capped, labeled, and sealed.

Sample containers were put into cool-box and transported to analytical laboratory.Date of sampling, and coordinates, Physiochemical properties such as (pH, T◦C, EC, TDS, and Salinity) measured and recorded in-situ(Table 1).The distribution of the selected wells in the area is shown in table 1 and in Fig. 2.

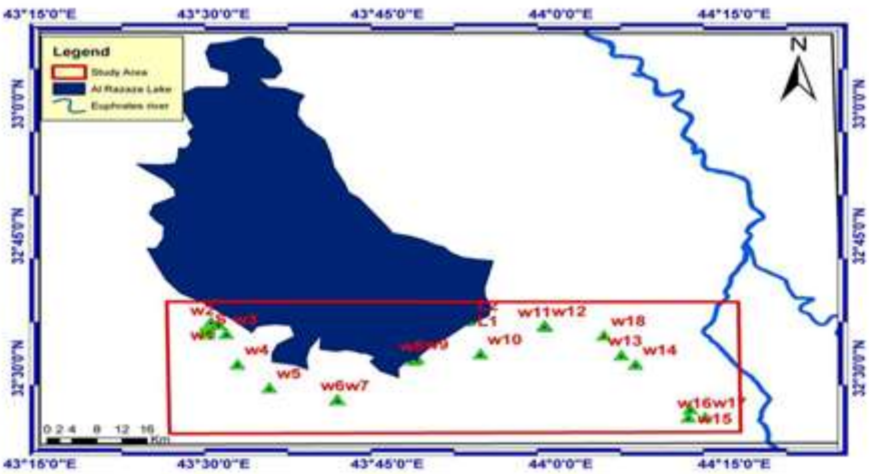


Figure 2: Sampling map

Table 1: Locations groundwater sampling stations, elevation, total depth, and water table level within the period of study area

Well No.	Well name	Static level	Wells depth(m)	Elevation (m)	Latitude	Longitude
Dammam Aquifer						
W1	Gharazah well	flowing	115	40	32°35' 19.28"	43° 29' 48.83"
W2	Al khudar well	flowing	120	42	32°34' 59.31"	43° 30' 27.90"
W3	Ain tamurr well	86	110	44	32°33 '58"	43° 31' 05"
W4	farm well	12	120	57	32°30 29"	43° 32' 05"
W5	Gas station well	20.5	77.5	64	32°27' 49"	43° 34' 49.8"
W6	Quarry	20.91	90	44	32°26' 25"	43° 40' 41.7"
W7	Quarry inter	7.2	90	37	32°26' 25"	43°40' 45.00"
W8	Qataruh1	flowing	120	30	32°30' 56"	43° 47' 17"
W9	Qataruh2	3.52	120	20	32°31' 07"	43° 47' 36"

W10	Modern village	6	120	76	32°31' 40"	43° 53' 04"
S	AL-Zarga spring	-	-	55	32°33' 59.40	43° 29' 26.55"
Dibdibba Aquifer						
W11	green belt1	17.8	50	60	32°34' 46"	43° 58' 40.00"
W12	green belt2	19.2	54	50	32°34' 52"	43° 58' 36.5"
W13	Mashrue al-dawajin1	26	42	20	32°31' 31"	44° 05' 14.42"
W14	Mashrue al-dawajin2	26.2	42	30	32°30' 28"	44° 06' 28.00"
W15	ya hussein road1	25	42	30	32°25' 24"	44° 11' 12.9"
W16	ya hussein road2	13	24	20	32°24' 27.22"	44° 11 42.91"
W17	khan al-rubua	14	24	20	32°24' 30"	44° 12' 29"
W18	departmen of growndwater	4.9	32	20	32°33' 46"	44° 03' 44.00"
W19	green blet	9.75	52	40.2	32°32' 26.7"	44° 02' 40.20"
W20	khan al-nas	6	42	27.1	32°28' 12.4"	44° 08' 54.5"
W21	Alttahrir quarry	18.5	54	38.5	32°19' 44.2"	44° 12' 23.3"
Al –Razzaza Lake						
L1	Al –Razzaza	13.3	-	20	32°35' 27"	43° 52' 08.00"
L2	Al –Razzaza	13.3	-	20	32°35' 33.8"	43° 52' 06.78"

Samples preparation and analysis

Samples were prepared for hydrochemistry and stable isotopes analysis, both have been analyzed in the laboratories of the Ministry of Science and Technology, Iraq. The stable isotopes (^{2}H and ^{18}O) analysis by using isotopes ratio mass spectrophotometer (IRMS).Two methods were used to calculate the accuracy of analysis for all samples in this study. The first U % (percentage of analysis accuracy), the second is T % (percentage of difference between calculated and measured salts). Results of analysis for all selected samples were within the acceptable limits (less than 5 %), which indicate that all the results are ready to used for interpretation of the hydrochemical process.

3. Results and Discussion

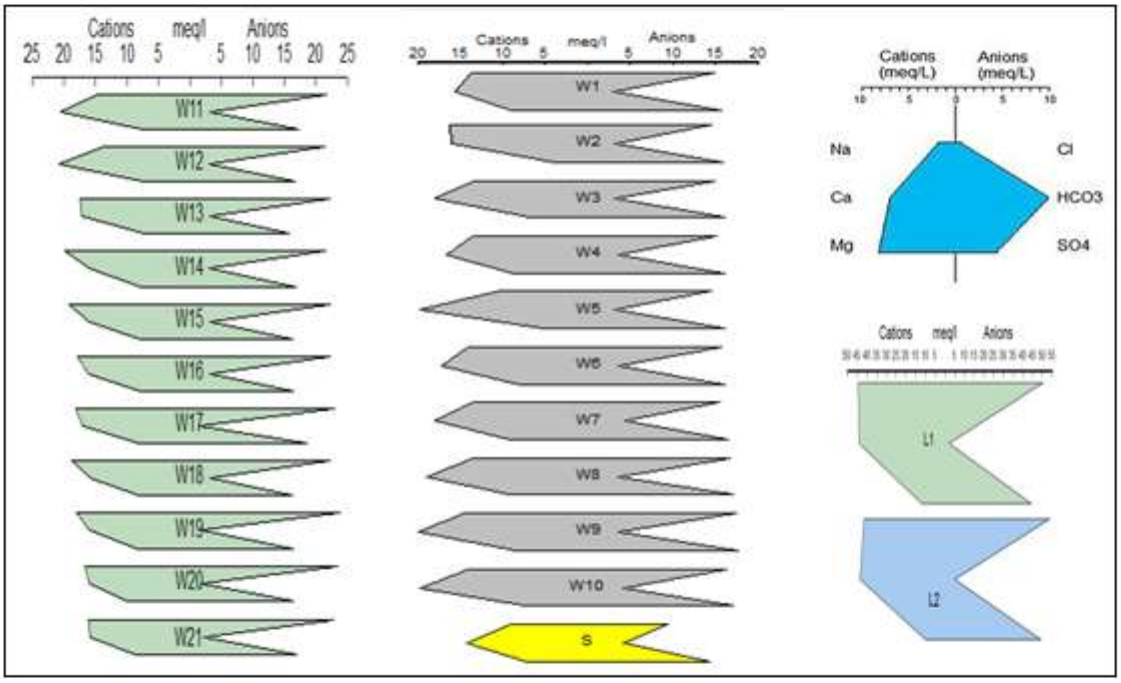
1) Hydrochemistry

Figure (3) shows the chemical composition of groundwater for Dibdibba and Dammam aquifer in addition to Razzaza lake in the study area.

The dominant cations and anions in groundwater for Dammam aquifer are mainly of in Order (Ca > Na > Mg and ,SO4>Cl) and the water type Ca-sulfate, while in Dabdiba some wells in order (Ca>Na >Mg >Cl >So4) and the water type Ca- chloride, The other well it(Na >Ca >Mg > Cl >So4) and their type Na –chloride. The Razzaza lake (L1, L2,) have formula (Ca >Na>So4->Cl-) and the type Ca-chloride .

The Rain water (R1, R2,R3,R4,R5) have cations of the order (Ca >Na>Cl->SO4) and their type Ca sulfate.

The chemical composition of the main samples of groundwater characterizes as Ca-SO4 in Dammam aquifer, inDibdibba aquifer characterizes as Ca-Cl in some of well and the other as Na-Cl, like Razzaza Lake. According to Stiff diagrams and Piper diagrams (Fig.3) water samples in Dammam aquifer, rain water, and Razzaza Lake fall in (class e) which represents (Earth alkaline water with increase portion of alkali). While Dibdibba aquifer, some of these samples fall in (class e) and some of samples developed to (class g) which represents (Alkaline water with prevailing sulphate and chloride).



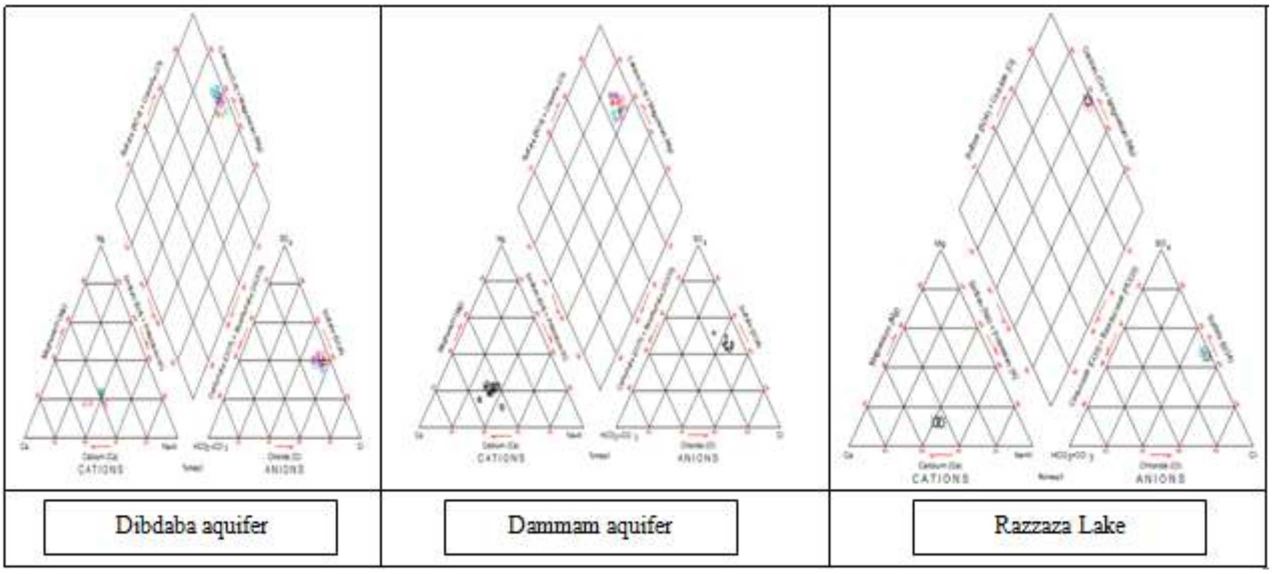


Figure 3: Stiff and Piper diagram for groundwater in study area

2) Stable isotopic composition

The isotopic composition of groundwater table (2) collected from Dammam Aquifer ranges between (-31.13‰ to -17.64 ‰) for ^{2}H with average (23.04)‰ while it ranges between (-3.18‰ to -1.63 ‰) for ^{18}O with average (2.30) ‰. These values are more depleted when they compare with the isotopic composition of the Razaza Lake water which ranges between (-2.83‰ to -10.62 ‰) for ^{2}H with avargee (11.73) ‰ and between (-1.01‰ to -1‰) for ^{18}O with average of (1.005) ‰. It is a logical result since the Razaza usually has been affected by evaporation which caused it to be more enriched and to be close to the groundwater of Dibdiba aquifer as appear in Table(2). On the other hand, the isotopic composition of the groundwater selected from Dibdibba Aquifer ranges between (-19.31‰ to -2.88‰) for ^{2}H with average (10.27)‰ while it ranges between (-1.34‰ to0.18‰) for ^{18}O with average (0.349)‰. In the current study the stable isotopes (δ^{2}H, δ^{18}O) were evaluated by collected 10 samples of groundwater from Dammam aquifer and 10 samples from Dibdibba aquifer and 5 samples of rain water and 2 from Razzaz lake.

Table 2: Isotope composition of δ^{18}O and δD, TDS and Cl^- in water samples in the study area

Sample No.	δ^{2}H	SD	δ^{18}O	SD	d-excess
Dammam aquifer					
W1	-22.56	0.5	-2.04	0.07	- 6.24
W2	-20.88	1.75	-2.22	0.23	- 3.12
W3	-19.32	0.99	-2.31	0.12	- 0.84
W4	-18.57	0.63	-2.1	0.18	- 1.77
W5	-17.64	1.49	-2.47	0.08	+ 2.12
W6	-21.2	0.86	-1.63	0.21	- 8.16
W7	-24.02	0.58	-1.83	0.05	- 9.38
W8	-24.85	1.09	-1.9	0.05	- 9.65
W9	-31.13	0.52	-2.56	0.08	- 10.65
W10	-23.18	0.82	-3.18	0.09	+ 2.26
S	-27.4	1.27	-2.91	0.08	- 4.12
Dibdibba aquifer					
W11	-8.2	1.06	-0.8	0.22	-13.1
W12	-9.1	1.51	-0.7	0.07	-16.72
W13	-19.31	1.28	-0.34	0.06	- 16.59
W14	-13.41	0.2	0.08	0.16	- 14.05
W15	-15.04	1	-0.71	0.14	- 9.36
W16	0	-	0	0	0
W17	-9.39	0.84	0.17	0.15	- 10.75
W18	-14.32	1.78	-1.34	0.12	- 3.6
W19	-3.34	1.95	0.18	0.13	- 4.78
W20	-2.88	1.65	0.05	0.17	- 3.28
W21	-7.71	1.27	-0.08	0.10	- 7.07
Rain water					
R1	-21.66	0.95	-4.79	0.2	+ 16.66
R2	31.71	0.17	3.18	0.28	+ 6.27
R3	7.91	1.42	-1.46	0.18	+ 19.59
R4	26.74	0.53	1.13	0.29	+ 17.7
R5	4.89	1.02	-1.6	0.25	+ 17.69
Razzaza Lake					
L1	-12.83	1.00	-1.01	0.21	- 4.75
L2	-10.62	1.83	-1	0.07	- 2.62

3) Stable isotopes and local meteoric water line (LMWL)

The Iraqi Meteoric Water Line or (LMWL) ($\delta^{2}H = 8.32\ \delta^{18}O + 15.53$) wasplotted from the relationship between δ^{18}O and δ^{2}H as seenin Fig(4). the LMWL obtained in current study is comparable with those obtained in the neighboring countries**.** The regression line of groundwater from the both aquifers (Dammam and Dibdibba) with the relationship:$\delta^{2}H = 5.49\ \delta^{18}O + 8.85$ it appears that water of the two aquifers as well as Razaza Lake water lie on the same regression line which indicates the same source of rainwater(source of feeding) but they have underwent different degrees of evaporation, due to their difference in depth and their influence by evaporation within infiltration as well as resident time effects, in this case.The δ^{2}H and δ^{18}O diagram fig (4) shows that groundwater seem to be separated into two groups; one for Dammam aquifer which underwent less evaporation or may be fed with rain water that is enriched with stable isotopes, the other group belongs to Dibdibba aquifer including Razaza lake which have been underwent more evaporation

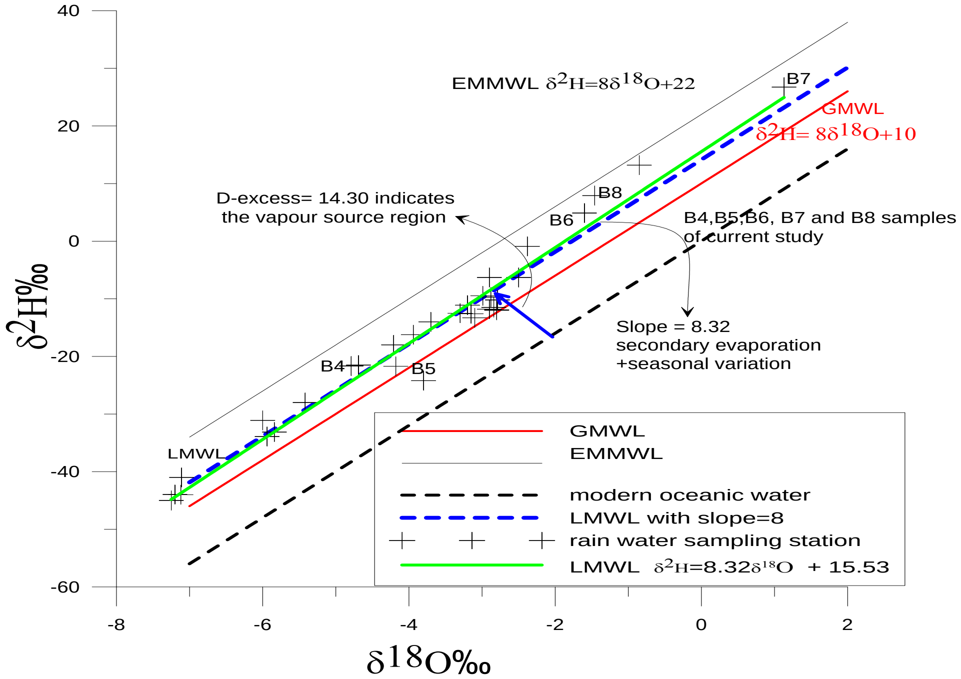


Figure 4: The LMWL with the GMWL and Eastern Mediterranean Meteoric Water Line (EMMWL)

4) Use isotopic techniques to determine the origin of groundwater salinity

Salinization in brackish water or highly saline water can be detected by plot the relation between ^{18}O and chloride content (Fig 5). Groundwater, in the two aquifers is enriched with ^{18}O due to evaporation process that happened during the different stages of hydrological cycles of water. If water evaporates the lighter Oxygen-16 isotope evaporates in the atmosphere and the heavier Oxygen-18 isotope accumulates in the remaining water causing enrichment of water with heavy stable isotopes. That is exactly what has happened with groundwater in the two aquifers (Dammam and Dibdibba).Stable isotope can be used to identify the mechanism of groundwater salinization (IAEA, 2009).To define the mechanism of salinity in groundwater in study area a diagram plotted between $\delta^{18}O$‰ and TDS (mg/l) as seen in figure (6). The figure shows that there is no clear relationship between the two parameters which indicates that the essential salinity in groundwater caused due to dissolution and rock-water interaction then enrichment of stable isotopes have occurred but it is not accompanied with a significant increasing of TDS. Groundwater in Dibdibba aquifer underwent more evaporation. The salinity of Razaza Lake water is due to the dissolution and highly suffering of evaporation with no enough recharge of new fresh water. Again the previous diagrams (figure 5 and6)show two groups of groundwater with no clear mixing occur between them.

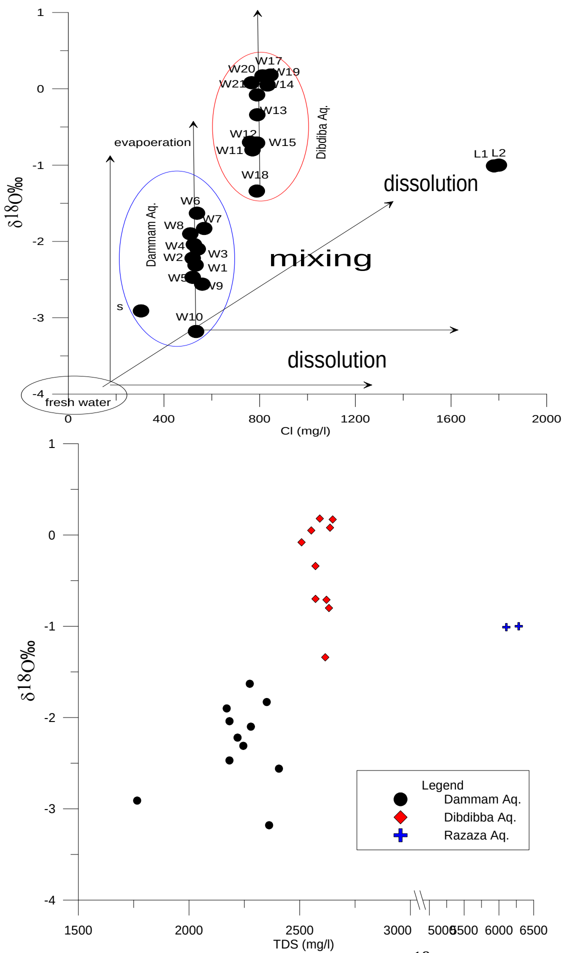


Figure 5 and 6: Relationship between δ^{18} O against Cl^- (meq/l)) (left) and between mean $\delta^{18}O$ with TDS (mg/l)(right) in all sample of water in current study

5) Deuterium-Excess (*d-excess)*

The d-excess value is an index showing the evaporation effect on the physical–chemical characteristics of water, that is, if the water evaporates, the d-excess decreases (Tsujimura et al. 2007).The value of *d* is estimated by (Craig ,1961) for large number of stations around the world. Deuterium-excess, defined for slope of 8, is calculated for any precipitation sample as: (in permil) = $\delta^2H - 8\ \delta^{18}O$.

The average of d-excess in groundwater in studied area shows variations. Figure shows the relationship between d-excess and $\delta\ ^{18}O$ of the water in the area. The figure clearly exhibits that there was negatively relationship between d-excess value and $\delta\ ^{18}O$. Again, the figure shows that two groups of water could be distinguished in groundwater: group Dammam aquifer which is influenced by lower evaporation and group of Dibdibba aquifer which is influenced by more evaporation rain water within precipitation and during infiltration. This result supports the above conclusion obtained from discussion of the distribution of the data points on $\delta\ ^2H$ and $\delta\ ^{18}O$ diagram (Fig7)

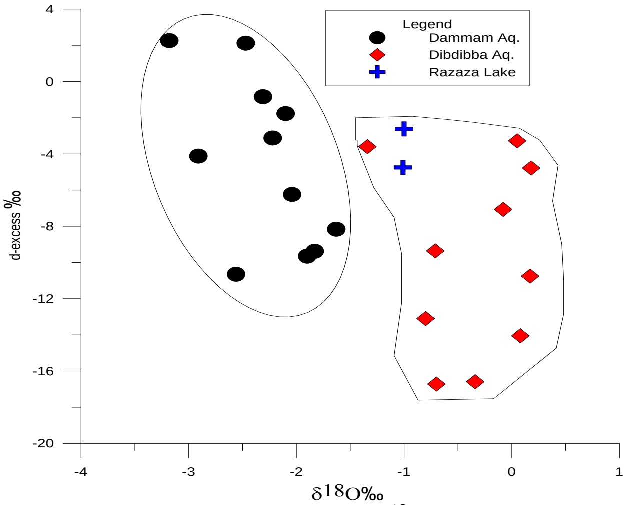


Figure 7: Relationship between $\delta\ ^{18}O$‰ and d-excess in water samples in current study

4. Conclusions

Isotopic composition may be used to assess and identify maxing relationship and support other techniques such as hydrochemistry studies. Depending on the isotopic content of all water sample and hydrochemistry results in this study, we can conclude that:

1) The hydrochemistry analysis of groundwater indicates that most of the wells have Ca-SO4 type, in Dammam aquifer while in Dibdibba aquifer some of their (Ca-Cl) while the other it Na-Cl. The hydrochemistry results also indicate that there is no mixing between groundwater of Dammam aquifer and that of Dibdibba aquifer.On the other hand there is mixing of groundwater of formations and units beneath Dammam aquifer which have caused increasing of sulfate in groundwater in addition to the relationship between Ca^{+2} and Mg^{+2}which indicates that they are derived from different formations, Dammam one of them in addition to units and formations below it.
2) The $\delta^{18}O$versus δD diagram indicates that ground water seem to be separated into two groups; one for Dammam aquifer which underwent less evaporation or may be fed with rain water that is enriched with stable isotopes, the other group belongs to Dibdibba aquifer including Razaza lake which have been underwent more evaporation. These result indicates that there is no mixing between the two aquifer although the study area is located within Abu Jir fault zone .
3) 3- The d-excess values versus $\delta^{18}O$relation in groundwater shows negatively relationship and this relationship shows that two groups of water could be distinguished in groundwater: group Dammam aquifer which is influenced by lower evaporation and group of Dibdibba aquifer which is influenced by more evaporation rain water within precipitation and during infiltration and no interaction between them.
4) 4-The $\delta^{18}O$ and TDS relation shows that there is no clear relationship between the two parameters which indicates that the essential salinity in groundwater caused due to dissolution and rock-water interaction then enrichment of stable isotopes have occurred due to evaporation process but it is not accompanied with a significant increasing of TDS.
5) The Iraqi Meteoric Water Line (IMWL) or LMWL was plotted from the relationship between $\delta^{18}O$ andδ^2H. The equation of the line is $\delta^2H= 8.32\ \delta^{18}O + 15.53$

Reference

[1] **Al-Khateeb, A. A. G. & Hassan, K. M.,(2005)** : Detailed Geologyical Survey for Mineral Exploration in Karbala-Najaf Area. GEOSURV. Baghdad. Iraq. Report No.2891. 59p.
[2] ***Al-Shamari , M. M, (2014)***: *Groundwater Evaluation for Dammam Formation in South Razzaza Lake ,M.Sc. thesis, collage of Scince, University of Baghdad ,Iraq, 138 p.*
[3] ***Al-Suhail, Q. A., (1996)***: *Evaluation of groundwater exploitation for Agriculture development of Bahr Al-Najaf Area, Western Desert, Ph.D. Thesis, College of Science, Baghdad University, (In Arabic). 132p.*
[4] ***Buday, T. and Jassim, S.Z.(1984):*** *The Regional Geology of Iraq. Vol.2:Tectonism, Magmatism and Metamorphism. S.E. Geol. Surv. Mine. Inves., Baghdad, p.: 352*
[5] ***Dansgaard, W., 1964***: *stable isotopes in precipitation, Tellus, 16 (436-468).*
[6] ***Graig, H. (1961):*** *Isotopic variations in natural waters, Science 133: 1702–1703*
[7] ***IAEA, 2009:*** *Global Network of isotopes in precipitation, the GNIP Database Accessible http:isohis.iaea.org.*
[8] ***Jassim , S.Z. and Goff, J.C. (2006):*** *Geology of Iraq . 1st ed. The Czech republic . Safina . p.: 188.*
[9] **Medley p., (2010)**: Barium sulphate method for consecutive determination of radium-226 and radium-228 on the same source. Internal Report 544, April, Supervising Scientist, Darwin. Australian Government, Department of Environment, water, Heritage and Arts Supervising Scientist.
[10] **Tsujimura, M., Numaguti, A., Tian, L., Hashimoto, S ., Sugimoto, A. and Nakawo, M. (2007)**: Behaviour of subsurface water revealed by stable isotope tensiometric observation in the Tibetan Plateau. *J. Meteorol. Soc. Japan*, 79(1B): 599–605