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The Use of Isotopic Techniques to Determine the Sources of Groundwater Recharge and Interaction with Surface Water in Southern Baghdad –Iraq

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Abstract
Isotope Hydrology has become a widely used technique for managing the global water crisis. The study of the Isotopic content of Groundwater and surface water and the study of chemical analysis is an important source of water sustainability. The study area is located south of Baghdad- Iraq three regions (Al-Dora, Al- Rustumiya and Al-Tuwaitha). Many samples were taken in the study area (15) samples Groundwater (well) and surface water (Rivers Tigris and Diyala). The results of the isotopic study indicated that there is a clear interaction in the values of the two stable isotopes between groundwater and surface water (Tigris and Diyala Rivers). In the wells (-41.5,-42.95 ‰) for deuterium (2H) (-6.77, -7.15 ‰) Oxygen-18 (18O) and the Tigris and Diyala rivers (-40 , - 39.47 - -7.34,-7.2 ‰) respectively ((2H), ((18O)) in the study area. Depending on these variables, indicates isotopic signatures similar between groundwater and surface water in the study area, helped in this the geological structures of the city of Baghdad (the sedimentation of the sedimentary plain). Through the results of isotope Tritium (H-3), (indicator to know the age of water and Recharge of water) we showed a clear convergence between the concentrations of tritium in the surface water of the rivers (Tigris and Diyala) (4.8 ± 0.064) TU and the wells (4.5 ±0.045) TU in the region, which indicates that the supply of water from wells is modern and continuous, and confirms the overlap between surface water and groundwater in the study area. It also indicated the high values of electrical conductivity in wells samples because most of the wells in the study area are shallow, where salt concentrations are high due to increased evaporation and are not suitable for drinking.

Keywords: Groundwater, Surface Water, Stable Isotopes, Tritium, Isotope Hydrology

1. Introduction

The assessment of surface and ground water is one of the main tasks in the planning and rational management of water resources around the world because it is considered one of the main sources for drinking water and agriculture, and the scarcity of fresh water is one of the major threats facing humanity today. Iraq, as one of the arid to semi-arid countries, is severely affected by water shortage [1]. Efforts must be intensified to protect the existing water resources, develop new sources of sustainable water supply, and improve the management of water resources [2]. Groundwater is recharged by (rain, snow and surface water intrusion into the soil), and recharge rates depend on the geology and weather conditions of the area, In addition to the abundance of vegetation cover on the Earth's surface [3]. This groundwater finds its way to the surface of the earth, where it rises naturally in the form of springs or a person may dig a well to reach it. The movement of Groundwater down to recharge and then pull it up again is a natural filtration process for it, which makes Groundwater under natural conditions one of the safest water sources for human use on earth, and even one of the best sources for producing agricultural crops [4]. Hydrological studies indicate the high levels of groundwater in the sedimentary plain region, as their levels do not exceed a few meters and may reach less than one meter, while their depth increases as they move away from riverbeds [5, 6]. The application of environmental isotopes techniques (both stable and radioactive) plays an important role in the assessment, management, and protection of water resources. Stable environmental isotopes are a powerful tool to study the sources of water bodies, allowing a better appraisal of their capacity and more rational exploitation. They also can be used in (correlation between aquifers, inter relationships between surface and groundwater, sources of pollution and salinization of groundwater ,evaluate the sources and potential risk of contamination and to investigate the transport and fate of those contaminants, origin of groundwater, efficacy of natural and artificial recharge, the exchange of water movement between lakes and adjacent groundwater aquifers, sources of recharge, and estimation of recharge (or depletion) in aquifer quantities [7]. Therefore, if there is a real problem to be studied, the priority in choosing an environmental impact instrument to study this problem is whether it is in the form of a stable or radioactive isotope [8]. In general, in open areas, stable isotope selection is most appropriate because the stable isotope composition of water is modified by physical and chemical atmospheric processes to make it have a characteristic signature of isotopes from rain and water supplying the area in order to know the origin of groundwater for example at that location [9].

Here it must be noted that it is necessary to know the distinguishing properties of the isotopes of rain water on the one hand, and the distinguishing properties of the isotopes of sea and ocean waters on the other [10]. One of the most important of these properties is to determine the relationship between the isotope oxygen-18 (18O) and deuterium (2H), as this relationship is called the Global Meteorite Water Line (GMWL) [11]. Tritium is the heavy isotope of the hydrogen atom and is a radioactive isotope of beta particles that is used as a tracer for groundwater movement [12]. And measuring the ages of modern water, with a half-life of (12.5) years, to find out the source of nutrition for one of the water layers [13]. We can determine the age of the water by it - meaning when was the last time that water touched the atmosphere. Based on this, we can find out how long the water took to reach its source of nutrition in that water layer, and thus we can calculate safe amounts of water withdrawal from that layer [14]. There are many research and studies in which the use of isotopic techniques in determining water quality and points .Interference between ground and surface waters including Nada et al. (2018): Using isotopic techniques to identify areas of overlap between Ground and surface waters in Al-Shanafiya area in southern Iraq, Al-Barwani (2013) studied hydro chemical and isotopic resources Water between Haditha Dam and Al-Baghdadi Dam. Ajna (2014) studied an isotopic and geochemical study of water resources in the Samawah region [15]. This study aims to use Isotope techniques (deuterium, tritium, and oxygen-18) to determine groundwater recharge sources and interference areas. The potential between it and the surface waters (Tigris and Diyala rivers) in the areas south of Baghdad (Al-Dora, Al-Tuwaitha, Al-Rustumiya), In addition to providing a database for the quality of ground and surface water (Tigris and Diyala rivers) in the region.

Study Area:- The study area is located in the south and southeast of Baghdad (Iraq) and includes Al-Dora, Al-Rustumiya, Al-Tuwayitha areas between latitudes (33.16 - 33.13) N and longitude (44.31–44.33) E, elevation of the catchment area ranges from 30 m to 35 m above sea level (Fig.1). It is characterized that residential and agricultural. The Tigris and Diyala rivers pass through them. The geology of the study area is relatively simple and is dominated by Quaternary sediments (Holocene –Pleistocene age). The sediments consist of recent alluvial sediments, flood plain deposits, valley- and depression-fills, that the water-bearing layers are sand and gravel layers, and as for the clay layers, they are Low permeability layers separate between the water-bearing layers [16]. The climate throughout the study area is hot and dry in summer season is cool and wet in winter. The average annual values of rainfall, temperature, and evaporation rates are 9.9 mm, 23.07 °C, 266.81 mm, respectively, Precipitation incidents occurs only in winter (December-April) while it rarely rains in other months , Hydrogeological, a good sand aquifer has been observed at a depth range of 8 – 20 m in the studied area [17].

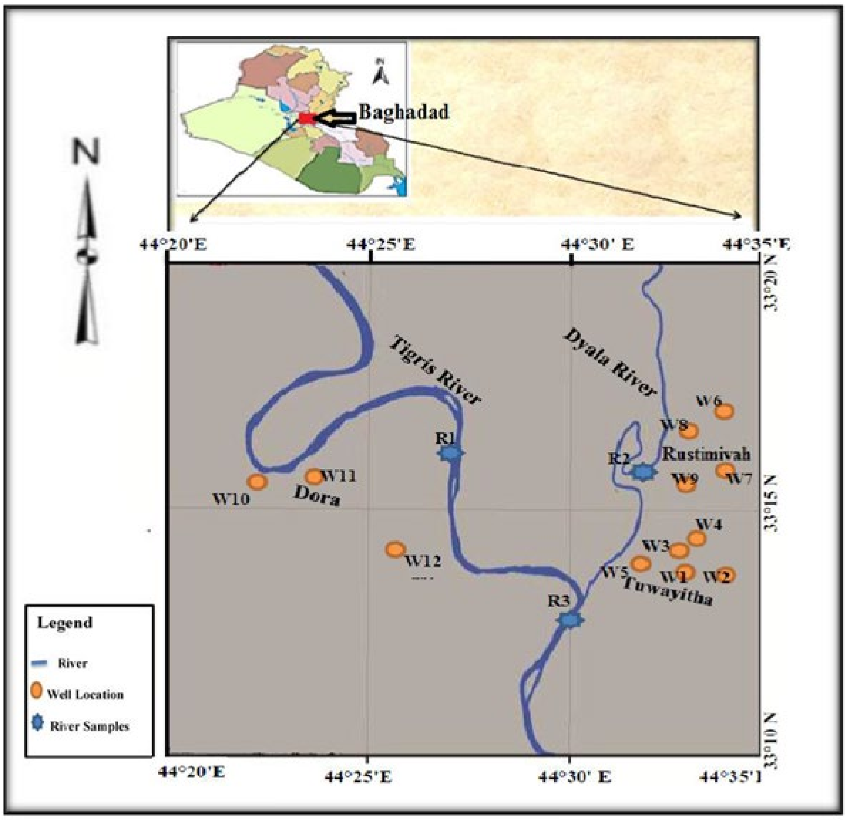

Figure 1: Location of the Study Area

2. Materials and Methods

Samples were collected for the period 2019-2020 (15) samples Groundwater and Surface water (Rive) analyzed for oxygen, hydrogen, and Tritium and |Hydrochemical composition. water distributed in the study area, 3 samples from Dora area and 4 samples from Rustumiya area and 5 samples from Al-Tuwaitha area, in addition to 3 samples from surface water Tigris river (two samples) and Diyala (one sample). During two seasons, autumn (September 2019), spring (March 2020) Details of sampling locations are shown in (Table1). Temperature, pH value and electrical conductivity of each sample were measured in situ using an Ec/pH meter. Table no. (1), Samples were taken under the instructions of the International Atomic Energy Agency (IAEA, 2007) one liter from each well for isotopic analysis of samples in addition to chemical and physical properties (pH, Ec). All bottles were marked with their coding, sampling date, and coordinates. Electrical conductivity was measured (pH, Ec) locally. As for the collected samples, they were placed in a cold box to be sent to the laboratory for measurement and analysis Stable isotopes (2H and 18O) were measured using liquid water isotope analyzer instrument Model DLT-100 from LGR Company-USA and reported as (2H and 18O) in ‰ (per mil) relative to a VSMOW and Tritium was analyzed using Liquid Scintillation Counter (LSC). Measurements were conducted in the Iraqi Ministry of Science and Technology, Environment and Water Directorate for accuracy purposes, they are as shown:

(V SMOW2): a water sample was taken from the ocean water sample standard reference for all water on the surface of the ground.(SLAP2) Standard Light Antarctic Precipitation: a water sample taken from the molten snow from the Antarctica area. (GISP) Greenland snow Sheet Precipitation: a water sample was determined isotopic composition of several international laboratories [18].

Location	Sample type	Symbol	Latitude	Longitude
Al-Tuwaitha	Well	W1	33°13'23.7"N	44°33'03.9"E
Al-Tuwaitha	Well	W2	33°13'30.09"N	44°34'10.67"E
Al-Tuwaitha	Well	W3	33°13'57.4"N	44°33'52.7"E
Al-Tuwaitha	Well	W4	33°14'28.94"N	44°33'68.9"E
Al-Tuwaitha	Well	W5	33°13'38.7"N	44°32'03.9"E
Al- Rustumiya	Well	W6	33°16'33.04"N	44°33'58.12"E
Al- Rustumiya	Well	W7	33°15'33.94"N	44°33'26.66"E
Al- Rustumiya	Well	W8	33°16'8.50"N	44°33'16.64"E
Al- Rustumiya	Well	W9	33°15'29.33"N	44°32'42.17"E
Al-Dora	Well	W10	33°15'33.29" N	44°22'04.49" E
Al-Dora	Well	W11	33°15'33.29" N	44°24'04.49" E
Al-Dora	Well	W12	33°13'22.5" N,	44°26'30.63" E
Tigris river	Surface water	R1	33°15'37.88"N	44°27'3.00"E
Diyala river	Surface water	R2	33°15'27.48"N	44°31'24.88"E
Tigris river	Surface water	R3	33°12'51.03"N	44°29'56.21"E

Table 1. Location of sampling points in the study area

3. Results and Discussion

The stable isotopes of water deuterium ^{2}H, oxygen ^{18}O and the radioactive isotope Tritium 3H were used in the current study to determine the interaction between groundwater and surface water, in particular, the relationship between rivers (Tigris, Diyala), and groundwater in areas south of Baghdad (Al-Dora, Al-Tuwaitha, Al-Rustumiya).

The study area was divided into three regions, where the rates of stable isotope values (^{2}H and ^{18}O) ranged. In Al-Tuwaitha region show that values range from (-42.16 to -40.88) ‰ for ^{2}H, (-7.15 to -6.97) ‰ for ^{18}O, while the values range In the Al-Rustumiya region (-30.57 to --28.7) ‰ for ^{2}H, (-4.69 to -4.66) ‰for ^{18}O, and values range in the Dora (-39.13 to -38.64) ‰ for ^{2}H, (-7.56 to -6.82) ‰ for ^{18}O, in September 2019. While the isotopic values in the March 2020, (-42.95 to -41.42) ‰ for ^{2}H, (-7.62 to -6.96) ‰ for ^{18}O, (-31.52 to -29.34) ‰ for ^{2}H, (-5.48 to -4.96) ‰ for 18O and (-40.78 to -40.3) ‰ for ^{2}H, (-7.14 to -6.99) ‰ for ^{18}O In Al-Tuwaitha, Al-Rustumiya and Al- Dora Respectively. The results of the stable isotope values of surface water represented by In the Tigris River, (-39.47) ‰ for ^{2}H and -7.2 for ^{18}O September 2019 While in the March 2020, (-40) ‰ for ^{2}H, (-7.34) ‰ for ^{18}O In addition to the Diyala River, (-23.91, -24.91) ‰ for ^{2}H and (-4.87,-5.19) for ^{18}O for two seasons September 2019 and March 2020 Respectively; (Table 2). From the above results, a spatial and temporal changes showed a slight variation in the values of stable isotopes (deuterium and oxygen-18) where there was a slight increase in 2019 and This can be attributed to The samples were collected in September The end of the summer season (Dry), which is characterized by high temperatures, which leads to a rise in isotope values due to the evaporation process While the opposite happens in the winter (Wet) because of the impact of rain water.

Well. no	pH	Ec(ms/cm)	δD ‰	SD	δ18O ‰	SD	d-excess	Date
W1	8.28	2.65	-41.5	0.94	-6.77	0.22	12.7	September 2019 (Dry)
W2	7.66	2.26	-41.74	0.52	-6.87	0.05	13.2	
W3	7.18	2.25	-42.06	0.26	-7.13	0.09	15.0	
W4	6.86	2.72	-42.16	0.75	-7.15	0.14	15.0	
W5	7.22	2.89	-40.88	0.11	-6.97	0.21	14.9	
W6	7	4.98	-30.57	0.75	-4.69	0.08	7.0	
W7	6.8	6.55	-28.42	0.26	-4.35	0.15	6.4	
W8	7.12	5.71	-29.54	0.24	-4.5	0.12	6.5	
W9	7.56	5.15	-28.7	0.4	-4.66	0.11	7.0	
W10	6.8	3.2	-39.13	0.44	-7.56	0.03	13.4	
W11	6.9	3.01	-38.88	0.82	-6.82	0.13	15.7	
W12	6.9	2.2	-38.64	1.77	-7.07	0.13	17.9	
R1	7.6	0.733	-39.47	0.77	-7.2	0.08	18.1	
R2	6.91	0.755	-23.91	0.39	-4.87	0.02	15.1	
R3	7.3	0.733	-39.5	0.54	-6.54	0.32	12.8	
W1	8.06	2.65	-41.68	1.35	-7.22	0.25	12.9	March 2020
W2	7.65	2.26	-42.1	1.1	-6.96	0.11	10.5	
W3	7.75	2.25	-42.64	1.56	-7.62	0.23	15	
W4	7.3	2.72	-41.42	0.12	-7.38	0.13	14.4	
W5	7.81	2.89	-42.95	0.73	-7.15	0.08	11.1	
W6	7.07	4.98	-31.52	0.07	-5.48	0.15	9.9	
W7	7.23	5.55	-29.78	1.03	-5.22	0.13	9.7	
W8	7.06	5.71	-29.34	0.29	-4.96	0.09	8.2	
W9	7	5.15	-31.5	0.58	-5.37	0.14	9.2	
W10	6.8	2.8	-40.59	1.28	-6.99	0.03	12.3	
W11	6.9	2.4	-40.3	1.3	-7.12	0.13	13.6	
W12	6.82	2.3	-40.78	0.26	-7.14	0.13	13.2	
R1	7.65	0.720	-40	0.19	-7.34	0.09	15.	
R2	6.945	0.73	-24.91	0.71	-5.19	0.05	12.9	
R3		0.743	-38.5	0.9	-6.14	0.52	10	
VSOMW2			0		0			STANDARD SOLUTION
SLAP2			-427.5		-55.5			
GISP			-189.8		-24.85			

Table 2. Isotopic Values & Parameters (pH, Ec) of Water Samples in the Study Area

Figures (2a, 2b). Shows that's all the samples of study area placed along both the global meteoric water lines (Reference for determining water sources depending on the region, the differences in the amount of rainfall, and changes in degrees Heat, evaporation, and all influence in the relationship between deuterium isotopic and -18. oxygen This leads to its difference from the global rain line on the local scale) (Craig, 1961) and local meteoric water lines (Al-Paruany, 2013) which indicates the similarity between there groundwater and surface water (Tigris River , Diyala River), indicating that the rainfall is the recharge source of water resources in the study area but the difference in its distribution is related to the amount of evaporation and its relationship to the evaporation line of the region, which depends mainly on the depth of water in these wells. While some samples below the local meteoric water line (LMWL) (water samples in the Al- Rustumiya region in the dry season in September (2019), indicating that experienced evaporation.

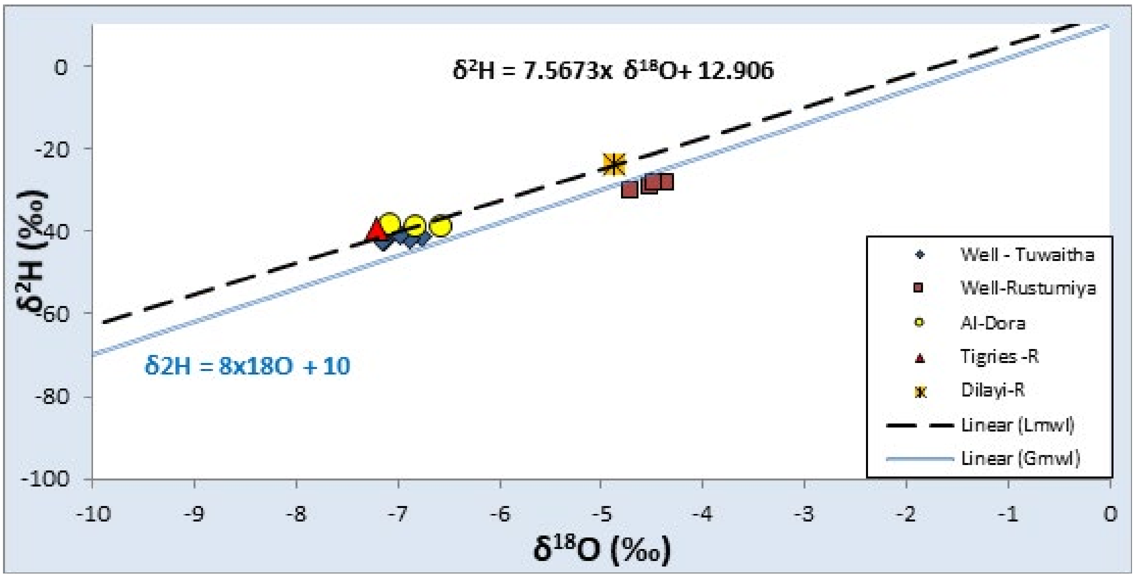

Figure 2a: Relationship between δ2H and δ18O and Meteoric water line (GMWL and LMWL) in groundwater, surface water of the study area during September 2019

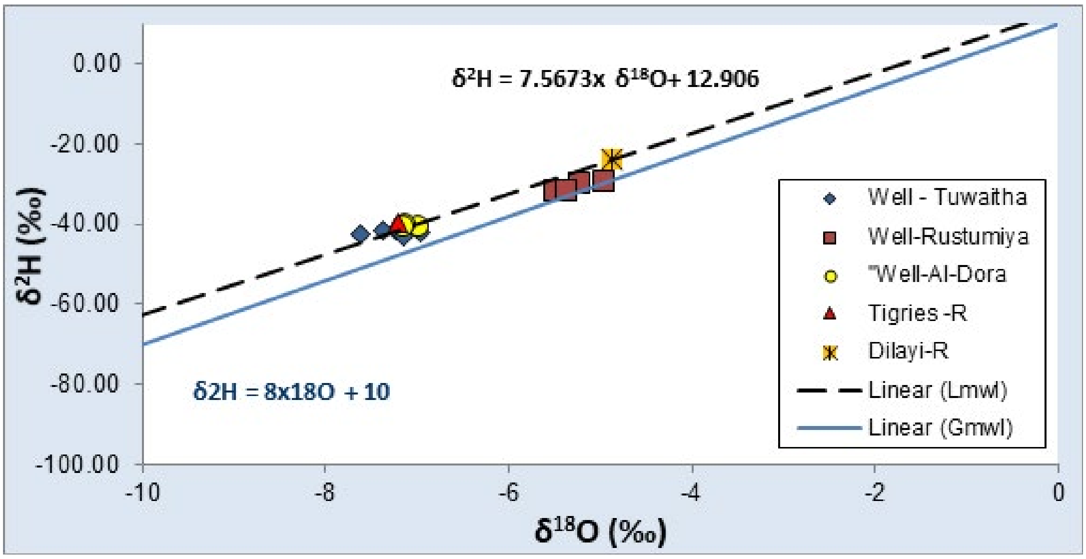

Figure 2b: Relationship between δ2H and δ18O and Meteoric water line (GMWL and LMWL) in groundwater, surface water of the study area during March 2020

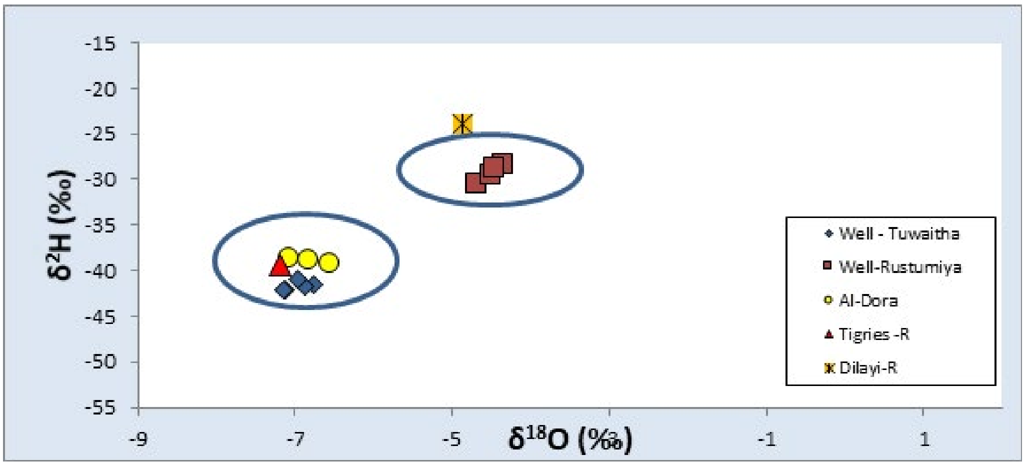

Figure 3a: Type of water in the study area according to isotopic values 2019

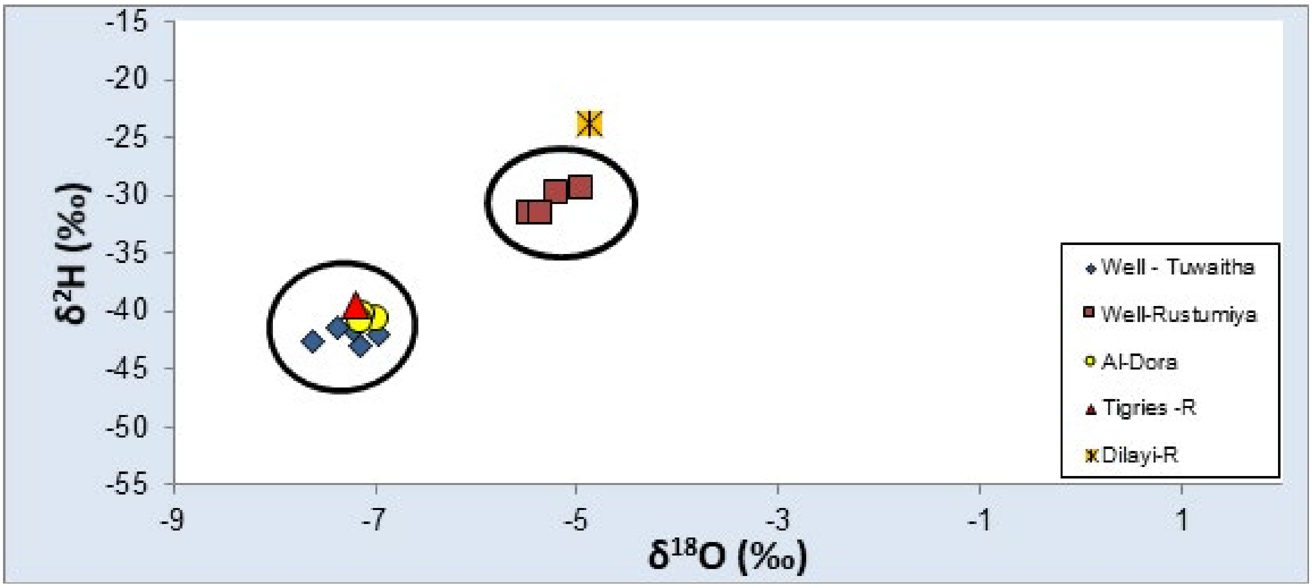

Figure 3b: Type of water in the study area according to isotopic values 2020

The values range d-excess 18.1- 6.4 (is an indicator that shows the effect of evaporation on the chemical and physical properties of water. With the following equation:

d- **excess = δ2H - 8*δ18O** (Clark and Fritz, 1997).

Figures (4a, 4b) show the relationship between the excess of deuterium and oxygen-18 for the water samples in the study area. The average excess of deuterium for the groundwater samples in the Al-Dora and Al-Tuwaitha areas shows a clear convergence. This reflects that the evaporation process is little and the continuous feeding of groundwater from surface water (River Tigris), while in the groundwater samples in the Al-Rustumiya area, the excess of deuterium was less. The reason is attributed to the exposure of groundwater to a state of evaporation or related to air masses, which led to a decrease in the average excess of deuterium.

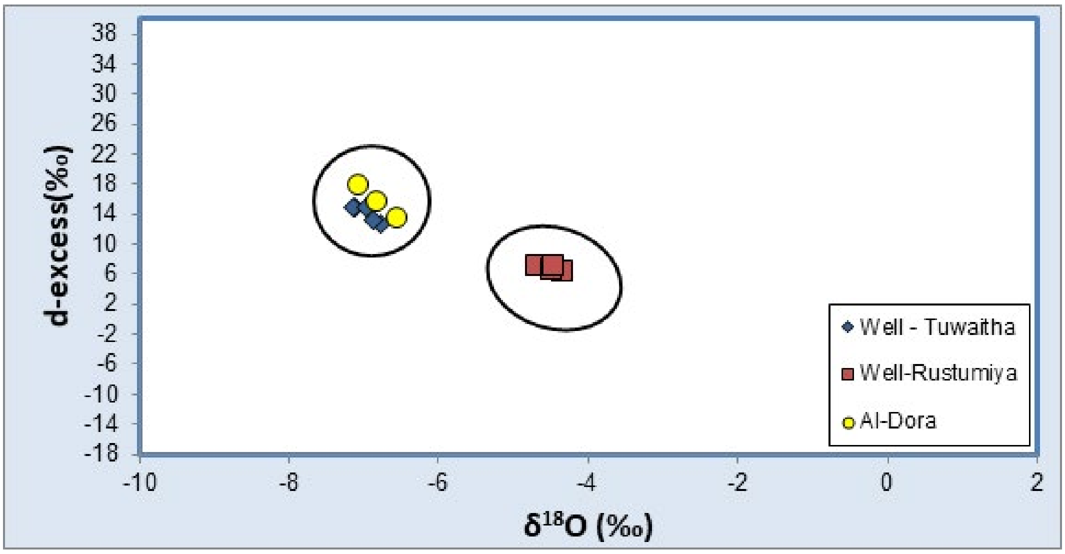

Figure 4a: The relationship between δ18O d-excess in the study area.2019

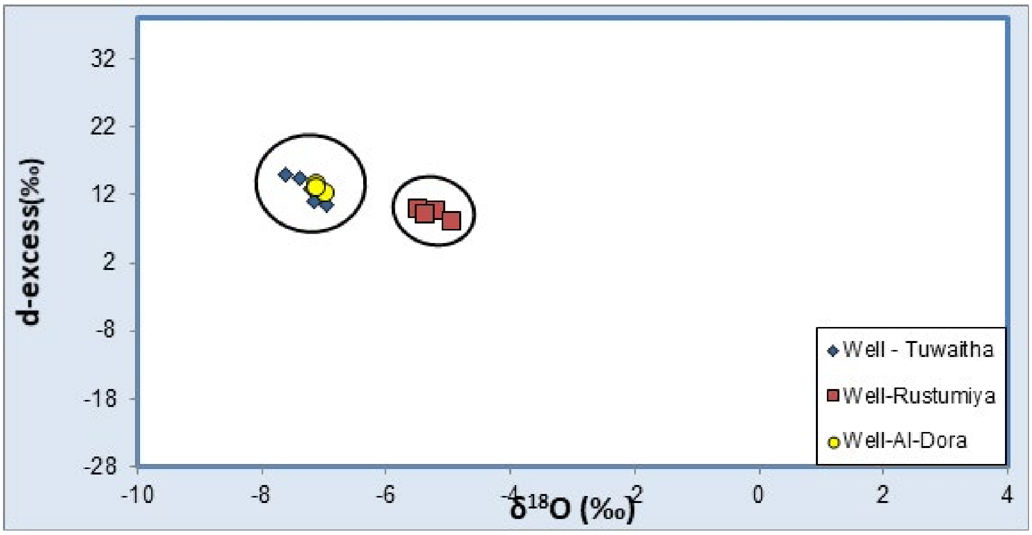

Figure 4b: The relationship between δ18O and d-excess in the study area.2020

There are several sources of salinity in the water, some of these sources are natural while others are industrial The results of the study showed an increase in electrical conductivity values in well water samples compared with surface water, where it reached The highest value of electrical conductivity was in the Al-Rustumiya region (6.55ms/cm), while the conductivity values were in the Al-Tuwaitha region. And the cycle (4.9 ms/cm) and (3.2 ms/cm), respectively, and this indicates that the groundwater in the study areas is saline. It is not suitable for drinking because it significantly exceeds the permissible limits worldwide (WHO, 2011/ 0.6 mS/cm) as well as Local (IQS.2009/2ms/cm).

Stable isotopes can determine successfully the mechanisms of groundwater salinization (the origin of salinity and brackish water or highly saline water can be detected of salinity and due to leaching and/ or dissolution or mixing from the two cases) could be defined by plotting the relation between ^{18}O and Ec content. This concept is based on the isotopic composition of groundwater under evaporation processes whereas salinization caused by the dissolution of salt is not accompanied by a change in isotopic composition. This Figures (5a, 5b)shows the relationship between ^{18}O and Ec, where it was found from the type of relationship that there is a stability of the isotopic values of the water in the study area with the values of Ec, which indicates that the salinity in groundwater due to the dissolution and highly suffering from evaporation and the groundwater in that area is affected by the operations of Irrigation and drainage .It is clear that the wet period had low values This can be attributed to the influences of evaporation, dissolution, isotopic depletion

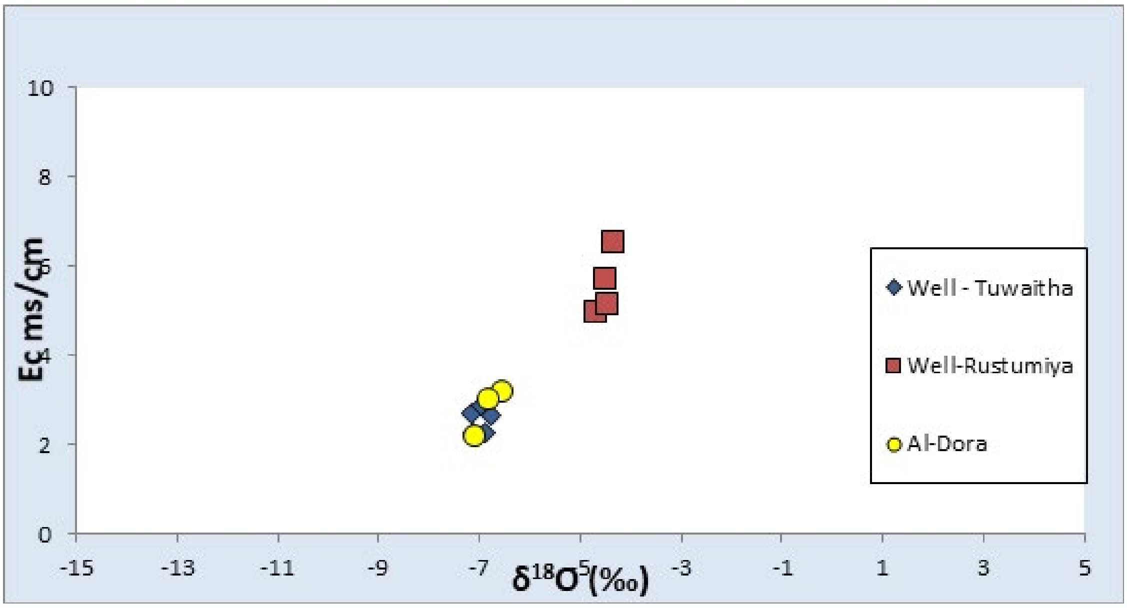

Figure 5a: Relationship between 18O and Ec in the study area

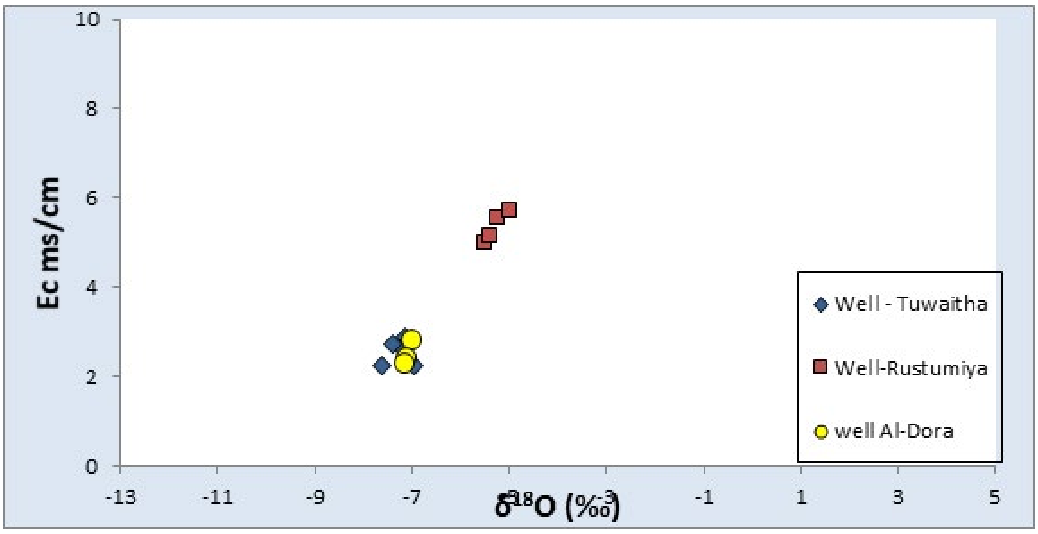

Figure 5b: Relationship between 18O and Ec in the study area

Tritium is an important indicator to know the age of water and the potential for interference between groundwater and surface water, The main source of tritium in surface and groundwater is tritium in rainwater (Ali,K.Ket al., 2015), The tritium content actual rainfall in Iraq (below 5 – 6 TU) (Al-Paruany, 2013). shown in Table (3).In 6 water samples selected from the study area as follows: 2 samples of river water The Tigris and Diyala, 3 samples of well water (Al-Dora, Al-Tuwaitha, Al-Rustumiya) in addition to one sample of rainfall.

The values of tritium for water samples collected from different stations along its course during the wet period (2020) , the data indicate a clear convergence between tritium concentrations in surface water (Tigris and Diyala rivers), and groundwater in the cycle Al Tuwaitha, Al Rustumiya and is lower than that of rainfall in Baghdad in the study area . This indicates the existence of modern recharge of well water from the waters of the Tigris and Diyala rivers. Figure (6).

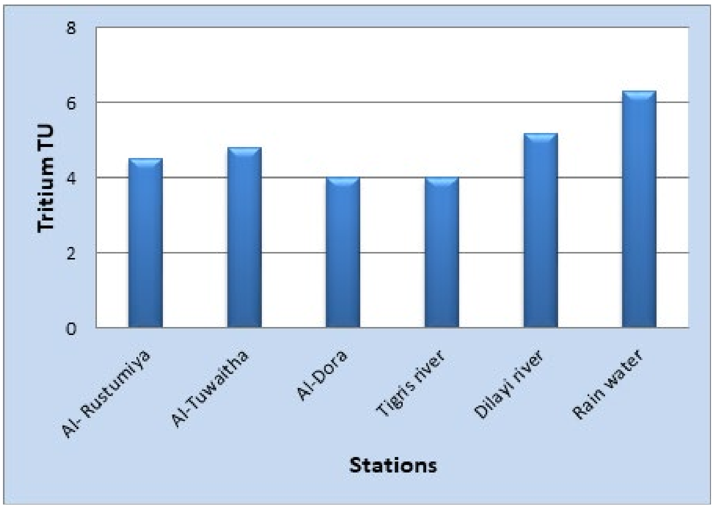

Figure 6: Tritium content in the study area

4. Conclusions

Isotopic compositions were used in the current study to identify the interaction between groundwater and surface water (Tigris and Diyala River) south of Baghdad City. Based on environmental isotopes, that there is a closeness in the values of the two stable isotope concentrations (18O and 2H) in well water and surface water. In the area of the study, indicates isotopic signatures similar between groundwater and surface water in the study area, helped in this the geological structures of the city of Baghdad (the sedimentation of the sedimentary plain). The depths of the wells few (4-12) m.

• EC values in the well water samples are high, and this proves that the groundwater in the study areas is not valid to drink.
• It was found that the concentrations of well water of tritium are relatively high, which indicates the modern feeding of these wells from rainwater and interaction between water river and Groundwater.

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