SURFACE WATER-GROUNDWATER INTERACTION IN DIWANIYA, SOUTHERN IRAQ USING ISOTOPIC AND CHEMICAL TECHNIQUES

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ABSTRACT

The stable isotopes of ^2H , ^{18}O , and ^3H reinforced by hydrochemical data, were used to identify the interaction between groundwater and Shatt Al-Diwaniya water and estimate the age of groundwater in the research area. For achieving these two goals, twenty-two samples of water were collected at the suggested area through a sampling campaign for twelve shallow wells, three from Shatt Al-Diwaniya, six rainfall samples, and one sample of sewer water. Three additional samples were collected for comparison from outside of the study area. The results of stable isotopes and hydrochemical composition indicated that there is a similarity between shallow groundwater samples and Shatt Al-Diwaniya water. The surface water interacts with groundwater for all boreholes, except for the borehole in the Al-Jameih District (WR2), which showed similar results spring water as comparing with SW1 and SW2 spring water samples. The isotopic composition of Shatt Al-Diwaniya (^2H and ^{18}O) is close to the local, and meteoric global water line, this indicates that the rainfall makes a significant contribution to the water of Shatt-Al-Diwaniya. There is a convergence with the values of isotopes of wastewater and groundwater, which indicates that the formation of shallow groundwater is a mixture of Shatt Al-Diwaniya water and the recharge (wastewater and rainfall). The results of ^3H concentration remaining in shallow groundwater showed that the age of the groundwater ranges from 1.8 to 6.3 years, this indicates that recharge of shallow groundwater is modern.

Keywords: Groundwater; Hydrochemistry; Interaction; Isotopes; Shatt Al-Diwaniya

INTRODUCTION

Shatt Al-Diwaniya is a small river that passes through Al-Diwaniya city and divides the city into two parts, where it is the main source for recharging groundwater within the city (FCSDIP, 1992).

The importance of Shatt Al-Diwaniya increased especially after the expansion and re-establishment of the principal regulator, which its new discharge has become 96.2 m³/s instead of the old discharge of 60 m³/s (Al-Jaberi et al., 2016; Awadh et al., 2016; Al-Kilabi, 2018 and Al-Naely et al., 2018). As a result of the new flow that caused the water level to rise in the river (DWRD, 2019). It is necessary to study the interaction of groundwater with Shatt Al-Diwaniya water, identify other significant nutrition sources that affect the shallow groundwater within the city (Awadh et al., 2020). The surveyed areas are characterized by very shallow groundwater systems, which have many negative impacts on the socio-economic side and civil construction activities. Groundwater contains chemical compounds that affect the foundations of buildings, in addition to its effects on the public health (Awadh, 2018 and Awadh et al., 2015). Shallow groundwater systems are another problem in the area being studied, such as soil salinity and soil erosion (Al-Jabbari and Al-Enezy, 2014), which affect foundations by weakening soil stability and reducing their ability to bearing. For determining the interaction between surface water and groundwater, many methods have been developed by researchers to determine these trends (Armanuos et al., 2020). They have been greatly developed in recent years and have enhanced our understanding of processes and dynamics (Fleckenstein et al., 2010). Numerical models are widely used to test theories and develop new conceptual models for interactions between groundwater and surface water (GW-SW) (Al-Hadithi, 2018).

Water isotopes of oxygen, hydrogen, and tritium are commonly used as tools to understand hydrogeological processes, for example, rainfall, groundwater recharge, groundwater interactions, and basin hydrology (Al-Paruany et al., 2017 and Yeh et al., 2014). Stable isotopes have an important role in assessing and managing water, protecting its source, and managing tasks to study different types of water. Stable isotopes (¹⁸O and ²H) are one of the available methods for measuring the interaction between different feeding sources of water (Al-Bassam, 2018). A change in isotopes ratio of ²H/¹H and oxygen ¹⁸O/¹⁶O in water, which is known as $\delta^{18}\text{O}$ and $\delta^2\text{H}$, gives an idea of the water source and its quality (Mahmud et al., 2017). The relationship between $\delta^{18}\text{O}$ and $\delta^2\text{H}$ was determined globally through a stable isotope map of rainwater, as it was globally determined by the rain line equation (GMWL)

$$\delta^2H = 8 + \delta^{18}O + 10 \quad (\text{Craig, 1961}) \quad (1)$$

Which expresses samples of rainwater from different regions of the world that derived from an additional variable: excess deuterium (d-excess)

$$d - excess = \delta^2H - 8 * \delta^{18}O \quad (\text{Dansgaard, 1964}) \quad (2)$$

Equation 2 reflects the effect of evaporation from water sources (Clark and Fritz, 1997 and IAEA, 2007). Analogue applications of the Water Behaviour Study (Mook, 1982), contain stable and radioactive isotopes as traceable followers to measure the concentration of stable isotopes (^2H and ^{18}O) in rainwater and track the concentration of these two isotopes during precipitation when water or carbon dioxide is transferred from one stage to another. Another change in isotope concentration, which is called isotope fractionation (Al-Paruany, 2013), gives an idea of the geochemical or hydrological processes that make a difference in stable isotopes (^{18}O and ^2H) in rainwater depending on longitude, latitude, climate and time of the year (GCGN, 2012). In this study, show authors touched using the same technique in different regions of Iraq. (Hussien, 2010) studied the groundwater recharge within the groundwater Mullusa carbonate aquifer- Dhabaa - western Iraq uses the application of environmental isotope technology (^2H , ^{18}O , and ^3H) (Awadh and Al-Ankaz, 2016). The study shows that the groundwater source is rainwater and runoff through Hauran Valley, also the age of the formation of this water inside the reservoir. (Al-Shamma'a and Al-Mutawki, 2014) determined the age of groundwater from tritium computed (^3H).

By selecting four samples from the wells water and spring water in Al-Shanafiyah area (Southwest Iraq). The results indicate that the approximate age of groundwater is modern water mixed with old water before the 1950s. (Ali et al., 2015) studied the interaction between sources of water in the arid region, western Iraq, using stable isotopic techniques and chemical analysis of water (Al-Hamdani et al., 2016). They emphasized that the high temperature leads to an increase in the values of stable isotopes. They found, through the study, that there is a similarity in the isotopes of the Euphrates River water and Haditha reservoir with groundwater taken from wells nearby, the indication gives that there is a mixture between them. Alabadi and Alshamma'a (2015) described the applications of water isotopes to indicate the hydrologic activities, recharge areas, flow pathways, in addition to the common interactions between different water sources in the study area (Altun Kopri Basin, NE Kirkuk). The results show that the groundwater samples are characterized that their ^{18}O and ^2H content increases with the depth of wells. Noting that there are two sets of groundwater samples during the periods dry and wet, the first group samples are highest then GMWL, and the second group samples are below the GMWL. Mahmud et al. (2017) used measurements of isotopes (^2H and ^{18}O) to identify areas of interaction between the different sources of water, which are located between Shanafiyah – Samawah, south Iraq. The results indicate to

lack of interaction between the groundwater and river, with no interaction between Sawa lake and groundwater. Al-Hadithi (2018) studied the interaction between groundwater-surface waters in Baghdad using the stable isotopes as a comparison with the isotope of groundwater, rainwater, and the Tigris river proved that the groundwater is a mixture of the Tigris river water and rainwater (Hammood et al., 2019). In Fallujah- Anbar area, the study on isotope technology was conducted to determine flow direction, recharge areas, and the relative age of groundwater. The results showed that isotopes (oxygen and hydrogen) in the groundwater samples are similar to the isotopes of surface water represented by the Euphrates river. Also, the researchers showed that there are interactions between the Euphrates water and groundwater in the study site (AL-Dulaimi and Al-Shamma'a, 2018).

On the other hand, Al-Diwaniya City suffers from a huge problem, which is the high levels of groundwater that led to the presence of water near the surface and fluctuated with depth 0.5 - 1 m, during most of the days of the year. The problem of high groundwater levels within the city is concentrated on the foundations of the buildings and the soil's instability, which is caused by continuous recharge from different sources (Shatt Al-Diwaniya, rainwater and sewage infiltration due to the lack of efficiency or absence of sewage systems). Also, the lack of a sufficient understanding of the general movement of groundwater and its trends within Al- Diwaniya city. Therefore, this study aims to use modern technologies (stable environmental isotopes and hydrochemistry) to determine the interaction between surface water - groundwater, with an indication of the main reasons for the rise of shallow groundwater in the area. With the development of treatments for reducing groundwater levels within the city. The objectives of this study are investigating the impact of Shatt Al-Diwaniya level on the groundwater level in the area and by technical methods (environmental isotopes and hydrochemical composition). Estimating the age of shallow groundwater in the study area, using the radioactive hydrogen isotope (tritium) and studying the chemical and physical properties of groundwater and find the quality of this water using Piper trilinear diagram.

STUDY AREA

The city of Diwaniya is located in the southern part of Iraq, about 180 km south of Baghdad, located on a branch of the Euphrates river called Shatt Al-Diwaniya. The city extends between latitudes N 31° 57 18 to 32° 01 30 and longitude E 44° 52 13.70 to 44° 58 29.16 (Fig. 1). The land elevation within the city is about 21 m.a.s.l, the total study area is about 45 km², and the river passes through

the city by a length of 12 km. It is one of the major and important water sources in Al-Diwaniyah, its width ranging between 20-25 meters and a depth of about 3 m. Shatt Al-Diwaniya water is used for agriculture, industry, human consumption and other different uses (DWRD, 2019).

Fig. 1. A map of the study area showing the location of wells and sample selection sites

Twelve sites in the city of Diwaniyah were selected for sampling to study groundwater (wells). The groundwater inside the city of Diwaniyah has high levels. It is near to ground level (DWRD, 2019), where the water of Shat Al-Diwaniya, rainwater and wastewater are the main sources of groundwater recharge. The climate of the study area is characterized by being hot and dry in summer, cold and rainy in winter because the stable isotope technique changed with changing temperature, evaporation, relative humidity and the amount of precipitation that feed shallow groundwater (Sayl et al., 2016). The average annual values of rainfall, temperature, and evaporation are 103.36 mm, 22.76° C and 3311.7 mm, respectively, while relative humidity has a negative trend compared to temperature and evaporation (Al-Hadithi, 2018).

Climate

The climate is the most important factor affecting the quality of surface water, groundwater and the hydrological cycle in the study area (Qutbudin et al., 2019). The prevailing climate is the continental climate, characterized by the area of study, the summer is hot and dry, and the winter is cool with little rainfall. It is characterized by high rates of air temperature and high-temperature differences between daytime and night as well as between winter and summer. It is also characterized by varying relative humidity. The year is divided into two influential seasons. A long warm dry summer, a short cold rainy winter cold season and sunny weather often year-round.

Temperature

The temperature rates in the study area are high in the summer, beginning in April, with the mean value of 24.74 °C at Al-Diwaniya station, then it reaches its highest values in the months of June, July and August. These rates take the mean values of 35.15, 36.62, and 34.76 °C respectively, for the previous months. The high temperature in the study area due to the angle of sunlight fall over the Tropic of Cancer (June 21), also the increased amount of radiation gained. However, these rates begin to decrease in the winter to reach their lowest levels in January (7.30 °C) at Al-Diwaniya station (Table 1).

Table 1. Mean average monthly temperature (°C) for interval 1980-2019, (Iraqi Meteorological Organization and Seismicity, 2019)

Months												
Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
7.30	10.83	17.03	24.74	30.71	35.15	36.62	34.76	29.68	23.33	14.15	8.86	22.76

Rainfall

In the study area, rainfall extends from October to May, the rate reaches in October and November 3.84 and 18.04 mm at Al-Diwaniya station. This rate increases in December, January and February to 14.11, 22.56, and 14.35 mm, respectively (Table 2). The rainfall stopped in the summer because of the reduction of atmospheric depressions in the study site. Rainfall is an important factor in recharge water of the river and groundwater in the area. The total annual rate of rainfall is 103.36 mm.

Table 2. Average monthly rainfall for interval 1980-2019 (IMOS, 2019)

Months												
Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
22.56	14.35	11.22	14.31	4.34	0	0	0	0.59	3.84	18.04	14.11	103.36

Characteristics of Shatt Al-Diwaniya Flow

Shatt Al-Diwaniya is considered the most important canal that passes through the study area, knowing that the study area is residential areas for citizens and not agricultural lands. The agricultural lands are located after the study area and need to launch high flow to deliver water to these lands and Al- Muthanna Governorate. When this water is released, the levels inside the city become high and may reach the highest level of about 20.34 m with a hydraulic slope of about 0.075 m/km. Shatt al-Diwaniya is an extension of Shatt Al-Hillah, branched out from the upstream of Al-Hindiya barrage and continues to run to the study area with a total length of 146 km. The course soil is formed from fine sand and the level of the river bed at the beginning of the study area (17.13) m. There is one station for measuring the flow of Shatt Al-Diwaniya (Sadr Al- Daghara Station), in the limit with Babylon governorate.

METHODOLOGY

For achieving the goal of the paper, the following methodology was applied:

- The distributed wells over the study area were drilled with ten holes to know the specification of the soil layers in the study area. The natural land level of these wells was determined by measuring groundwater levels and surface water twice a month to determine the interaction between groundwater and surface water.
- Twelve samples of groundwater, six samples of rainwater, three samples of Shatt Al-Diwaniya water, and one sample of sewage water were taken, according to the International Atomic Energy Agency (IAEA, 1983) guidelines. The purpose of the samples is isotope analysis, and determination of ^{18}O and ^2H isotopes using the device Liquide Water Isotope Analyzer from Los Gatos Research Company, Model (DLT100), in the Environmental Isotopes Laboratory, Ministry of Science and Technology (Table3).
- The relationship between $\delta^{18}\text{O}$ and $\delta^2\text{H}$, the interaction of surface water, groundwater and rainwater. In addition to evaporation indicators and other required information in the study.
- Also, the ground and surface water samples were tested to determine the chemical properties (pH, EC, TDS, Cl^- , SO_4^{2-} , HCO_3^{1-} , HCO_3^{1-} , K^{1+} , Na^{1+} , Mg^{2+} , and Ca^{2+}) to

enhance and define the interaction between surface and groundwater in the area and to evaluate the quality of this water (Awadh and Nejbert, 2016).

- Four samples were taken for analysis of ^3H , indicating the relative age of shallow groundwater within the study area.

Table 3. Sampling sites, symbols, and some details related to boreholes

Location	Sample Code	Sample Type	Latitude	Longitude	Well depth (m)	Site elevation (m.a.s.l.)	Shallow Groundwater Level
Al-Furat District	WL1	GW*	32° 1.202'	44° 54.300'	9	20.65	19.54
Al- Thubat District	WL2	GW	32° 0.158'	44° 55.201'	7	21.71	20.16
Al-Motkaden D.	WL3	GW	31° 59.905'	44° 55.194'	6	21.55	20.59
Al-Asri District	WL5	GW	31° 59.308'	44° 56.001'	6	21.51	20.9
Al-Askan District	WL7	GW	31° 58.444'	44° 57.122'	6	21.63	20.45
Al-Thaqlin District	WL8	GW	31° 58.224'	44° 57.969'	7	21.15	20.44
Al-Zahraa District	WL6	GW	31°59'25.95"	44° 57.722'	6	20.91	19.68
Al-Askari District	WL4	GW	32° 0.344'	44° 55.997'	6	19.71	18.31
Al-Jameih District	WR2	GW	31° 59.487'	44° 52.755'	6	20.47	19.8
Ramadan District	WR3	GW	31° 58.919'	44° 53.815'	10	20.9	20.13
Um Al-Khail /1 D.	WR4	GW	31° 59.593'	44° 54.215'	12	21.5	20.79
Um Al- Khail /3 D.	WR1	GW	32° 0.347'	44° 53.694'	10	20.44	19.46
Diwaniya River/1	RD1	SW**	32° 0'58.93"	44°53'45.66"	-	-	-
Diwaniya River/2	RD2	SW	31°59'3.54"	44°55'16.89"	-	-	-
Diwaniya River/3	RD3	SW	31°57'38.30"	44°56'53.05"	-	-	-
Al-Furat District	RW3	RW***	32° 1.202'	44° 54.300'	-	-	-
Al-Asri District	RW5	RW	31° 59.308'	44° 56.001'	-	-	-
Al-Askan District	RW6	RW	31° 58.444'	44° 57.122'	-	-	-
Um Al- Khail /3 D.	RW1	RW	32° 0.347'	44° 53.694'	-	-	-
Al-Askari District	RW4	RW	32° 0.344'	44° 55.997'	-	-	-
Al-Jzaeer District	RW2	RW	31°59'20.57"	44°54'2.96"	-	-	-

Groundwater*; Surface water**; Rainwater***; m. a. s. l = meter above sea level

RESULTS AND DISCUSSION

Hydrochemistry

The effect of Shatt al-Diwaniya on the groundwater was examined using the chemical analysis of selected groundwater samples from boreholes and compared with Shatt Al-Diwaniya and rainwater. The samples were collected using tightly covered bottles and kept in the laboratory at a temperature of 4 °C. The samples were tested using the methods shown in Table 4. The results of chemical analysis are appeared as in Tables 5 and 6. For determining the quality of groundwater in

Al-Diwaniya city, and the extent of interaction with other water sources (surface and rain). The values of the concentrations were calculated by the unit equivalent per millions (epm). Fig. 2 shows the spatial distribution of EC results, values in the ground water range from 2.80 to 53.60 dS/m, the average value in the Shatt al-Diwaniya water samples is 1.013 dS/m.

Table 4. Chemical, physical elements and methods of samples examination

Parameter	Method of Analysis
EC and PH	Field electrode meter
Total Dissolved Solid (TDS)	Evaporation and drying method
Sodium (Na^{1+}) and Potassium (K^{1+})	Flame photometer
Calcium (Ca^{2+}) and Magnesium (Mg^{2+})	Titration with EDTA (Ethylene Diamine Tetrcitic Acid)
Chloride (Cl^{-})	Titration with 0.02N AgNO_3 using K diochromate indicator
Bicarbonate (HCO_3^{-})	Titration with (0.02N) H_2SO_4 and phenoephtaline indicator
Sulphate (SO_4^{2-})	A gravimetric method by using wavelength (430nm)

Table 5. Physical parameters of groundwater, Shatt Al-Diwaniya water and rainwater specimen in the investigation zone, (November-2019)

Sample Name	Sample Code	the concentration of hydrogen ions(pH)	Electrical conductivity (EC), dS/m	Total dissolve solids (TDS), mg/L
Shatt al-Diwaniya	RD2	7.41	1.013	638
Rain	RW1	7.16	0.29	173
Al- Furat	WL1	7.89	15.6	9960
Al-Thubat	WL2	7.62	5.15	3260
Al-Zahraa	WL6	8.09	26.7	17226
Al- Askan	WL7	7.96	22.8	14503
Um Al-Khail-3	WR1	8.23	48.2	28750
Ramadan	WR3	7.75	5.7	3622
Motkaden	WL3	7.12	53.6	34304
AL- Jameih	WR2	6.6	2.8	1792
AL- Asri	WL5	7.1	5.94	3801.6
Um AL-Khail-1	WR4	7.2	5	3200
Thaqlin	WL8	7.07	8.9	5696
AL-Askari	WL4	7	18.29	11705.6

This result indicates that the infiltrated water into the soil interacts with the soil, and leads to dissolving salts, in the dry conditions that prevail in the study area and evaporation. As noted from the chemical results in Fig. 3, the shallow groundwater in the study area is dominated by ions of

Cl¹⁻ and SO₄²⁻. Most water boreholes in Diwaniya city are salty, salinity increases with the depth of the well, in addition to pollution, because the soil has weak permeability, and that there are no deep groundwater reservoirs (GCGN, 2012). The reason for the salinity increasing due to the effect of neighbouring lands and the nature of salinity in its layers, the salinity of the water seepage into the groundwater through permeable soil layers, dissolving the salts present in the soil during the filtering of water through it.

Table 6. Chemical parameters of groundwater, Shatt Al-Diwaniya water and rainwater specimen in the investigation zone, (November-2019)

Sample Name	Sample	Na ⁺	Mg ²⁺	Ca ²⁺	K ⁺	So ₄ ²⁻	Hco ³⁻	Cl ¹⁻	Unit
Shatt al-Diwaniya	RD2	89	35	77	3	159	65	191	mg/l
		3.85	2.85	3.84	0.077	3.31	1.064	5.4	Epm
Rainfall	RW1	25	11.4	19	1.5	46	12.8	54	mg/l
		1.09	0.94	0.95	0.04	0.96	0.21	1.52	Epm
Al- Furat	WL1	1457	583	1391	71	2805	620	2875	mg/l
		63.3	47.94	69.41	1.82	58.39	10.15	81.03	Epm
Al-Thubat	WL2	449	217	390	28	898	345	966	mg/l
		19.51	17.85	19.46	0.72	18.69	5.65	27.23	Epm
Al-Zahraa	WL6	2116	1360	2299	91	4172	1505	5675	mg/l
		91.92	111.8	114.7	2.33	86.84	24.63	160	Epm
Al- Askan	WL7	2036	806	1910	82	4065	1320	4283	mg/l
		88.45	66.28	95.31	2.098	84.62	21.61	120.7	Epm
Um Al-Khail-3	WR1	4001	1597	3890	95	7870	2188	8609	mg/l
		173.8	131.3	194.1	2.43	163.82	35.81	242.6	Epm
Ramadan	WR3	468	261	447	31	988	375	1050	mg/l
		20.33	21.46	22.31	0.79	20.57	6.14	29.59	Epm

Hydrochemical Classification Using Piper Diagram

After obtaining the chemical results of the different water sources (groundwater, surface water and rainfall) inside Al-Diwaniya city. It is necessary to classify these samples according to the results and to know the extent of the interaction between the different water sources. In the current study the Piper diagram (Piper, 1944), was used, as it is one of the most used diagrams to understand the relationship between the hydrochemical properties of water samples by representing the percentage of cations and anions in three separate charts. The chemical properties of the water samples collected from the study area were determined in the Piper diagram, using the latest techniques in the graph such as Rockwork 17 program (Fig. 4).

Fig. 2. Distribution of electrical conductivity (EC) within the field of study

Fig. 3. The cations and anions of groundwater samples in the study area

From Piper's interpretation of the system, the following hydrochemical aspects can be noted:

1-For Cations, 100% of samples are no dominant type.

2- For Anions, 100 % of samples are chloride type.

3- It turns out from the top of the diagram, 100% samples are the type ($\text{Ca}^{2+}\text{-Cl}^{-}$), this indicates that the location of samples are within the area (6) in which the non-carbon hardness (secondary pollutant) exceeded 50% (Walton, 1970).

Fig. 4. The Piper diagram of Al-Diwaniya city

Isotopes Composition

The isotopes technique of water (^{18}O , ^2H , and ^3H) also resulted in detecting the interaction between the different water sources and the groundwater age. In particular, the relationship between Shatt Al-Diwaniya and groundwater in Al-Diwaniya city. Modelling of a group of boreholes was conducted, and samples were taken from stations along the Shatt Al- Diwaniya. Modelling of a group of wells was conducted, and samples were taken from stations along the Shatt Al- Diwaniya, in addition to samples of rainwater for stations distributed in the study area, for isotopic evaluation.

Modelling was carried out using 50 ml glass bottles to measure the isotopes. The samples were kept at a temperature of 4 °C until the laboratory analysis was carried out. Three types of standard solutions were used for precision purposes, (Table 7). These solutions are:

1. VSMOW2 (Vienna Standard Mean Ocean Water 2): this sample was taken from any ocean's water as a standard reference sample for all the water on the surface of the earth.
2. SLAP2 (Standard Light Antarctic Precipitation): water sample taken from molten ice from the Antarctic region.
3. GISP (Greenland Ice Sheet Precipitation): which is a water sample that has been structurally isotoping determined in several international laboratories.

Table 7. Content for stable isotopes (^{18}O and ^2H) for global standard solutions

Standard Known Values	$\delta^{18}\text{O}$	$\delta^2\text{H}$
VSMOW2	0	0
SLAP2	-427.5	-55.5
GISP	-189.8	-24.85

Deuterium-Excess (D)

A regular feature demonstrates the air masses original. The researcher suggested Dansgaard for the first time to use the value of d-excess to describe the excess of deuterium in the world's rainfall (Dansgaard, 1964). Any rainwater sample is calculated according to equation 2, on a global basis. The average rate (d-excess) in the rain is about 10‰, but its value changes according to changes in humidity, wind speed, and temperature (Clark and Fritz, 1997). The value of the deuterium excess indicates the evaporation effect on the physical and chemical elements of water. That is, if the water evaporates, the deuterium excess rate will decrease (Table 8). Figs. 5 and 6 show a slight variation in values of stable isotopes in shallow groundwater and Shatt Al-Diwaniya water. This indicates that the water for exporters has the same structural fingerprinting of isotopes, unlike the location (WR2). Figs. 7 and 8 show the spatial distribution of stable isotopes where the Al-Jameih District (WR2) appears in a manner that differs from the general study area for the presence of recharge of shallow groundwater from deep water. It was observed that the isotopic of the sewer water sample resembles the isotopic fingerprinting of Shatt Al-Diwaniya water, this indicates that the main source of this water is Shatt Al-Diwaniya (Table 8).

Table 8. Isotopic of groundwater, Shatt Al-Diwaniya water, and rainwater samples (January-2020)

Sample No.	Sample Code	$\delta^2\text{H}$ Reportable Value (per mil)	$\delta^2\text{H}$ Standard deviation (per mil)	$\delta^{18}\text{O}$ Reportable Value (per mil)	$\delta^{18}\text{O}$ Standard deviation (per mil)	d-excess
1	WL1	-34.75	2.75	-5.17	0.45	6.61
2	WL2	-34.42	0.78	-5.49	0.3	9.5
3	WL3	-32.57	1.07	-4.99	0.52	7.35
4	WL4	-36.02	0.93	-5.02	0.2	4.14
5	WL5	-36.14	1.33	-5.62	0.21	8.82
6	WL6	-28.84	0.33	-4.24	0.14	5.08
7	WL7	-32.37	1.07	-4.7	0.19	5.23
8	WL8	-36.16	0.72	-5.09	0.22	4.56
9	WR1	-32.83	1.63	-3.89	0.33	-1.71
10	WR2	-19.36	0.77	-1.95	0.27	-3.76
11	WR3	-31.97	1.14	-4.21	0.16	1.71
12	WR4	-30.69	1.19	-5.09	0.19	10.03
13	RW1	17.42	0.91	0.04	0.17	7.1
14	RW2	19.1	1.56	0.49	0.23	15.18
15	RW3	20.07	1.57	0.19	0.35	18.55
16	RW4	10.51	2.23	-1.03	0.24	18.75
17	RW5	7.97	1.05	-0.98	0.29	15.81
18	RW6	15.92	0.57	-0.42	0.15	19.28
19	RD1	-29.2	1.35	-4.43	0.21	6.24
20	RD2	-30.29	0.45	-4.46	0.16	5.39
21	RD3	-30.44	0.32	-4.4	0.2	4.76
20	SEW	-30.52	1.17	-5.07	0.18	10.04
23	RF	-44.52	0.71	-6.55	0.19	7.88
24	SW1	-19.67	0.62	-2.49	0.37	0.25
25	SW2	-19.52	0.69	-2.22	0.32	-1.76

WL and WR: (Groundwater sample), RW: (Rainwater sample), RD : (Shatt Diwaniya water sample), SEW (Sewer water sample), RF: (Euphrates River water sample is taken from the front of Al-Hindiya barrage), SW1&SW2: (Springwater sample in the Al-Shanafiya area, 50 km southwest of the study area)

Fig. 5. Stable isotopes ($\delta^2\text{H}$ and $\delta^{18}\text{O}$) in groundwater and Shatt Al-Diwaniya

Fig. 6. The relationship between $\delta^{18}\text{O}$ and $\delta^2\text{H}$ for groundwater and Shatt Al-Diwaniya

Fig. 7. Spatial distribution of $\delta^2\text{H}$ composition in groundwater samples

Fig. 8. Spatial distribution of $\delta^{18}\text{O}$ composition in groundwater samples

Fig. 9 shows that groundwater for all wells is fed from the Shatt Al-Diwaniyah water. The reason for that the values of stable isotopes of shallow groundwater (^2H) and (^{18}O) range is (- 28.84 to - 36.16) and (- 3.89 to - 5.68), respectively. That is similar to the stable isotopes of Shatt Al-Diwaniya water. Exception WR2 well located in Al-Jameih District, which has different water and same as the spring water. Shallow groundwater of WR2 is similar to spring water or deep groundwater, which was confirmed by testing two samples (SW1, SW2) of spring water in Al-Shanafiya area of Al-Diwaniyah, which their average values of ^2H , and ^{18}O is -19.60, and 2.36 respectively. It is similar to the values of the stable isotopes of the WR2 well (-19.36, and -1.95). The results of testing spring water samples are consistent with previous studies of the tested spring water in Al-Shanafiya area (Mahmud et al., 2017). The relationship between $\delta^{18}\text{O}$ and $\delta^2\text{H}$ indicates that most isotopic values are similar to the GMWL, which indicates the similarity between the water of Shatt Al-Diwaniya and groundwater, which have the same evaporation mechanism. GMWL = Global Meteoric Water Line, see equation 1.

$$\text{LMWL} = \text{Local Meteoric Water Line } (\delta^2\text{H} = 8 * \delta^{18}\text{O} + 13.68) \quad (3)$$

Fig. 9. Relationship between the $\delta^{18}\text{O}$ and $\delta^2\text{H}$ for groundwater, surface water

The values of d- excess which are less than 10, indicate the occurrence of the evaporation process. In this study, it is observed that the lowest value is at the WR2 well, which means that there is very high evaporation process, and the reason is that the water source is deep groundwater. Also, it is observed from Figs. 10 and 11 signs of evaporation of the rest of the wells, as well as Shatt Al-Diwaniya.

Fig. 10. The relationship between $\delta^{18}\text{O}$ and d- excess for groundwater and Shatt Al-Diwaniya samples

Fig. 11. The value of the d-excess in shallow groundwater samples (2020)

Stable isotopes are also used to find the origin of the concentration of salinity in water. There is a spatial variation with the values of electrical conductivity (EC) versus the stable isotope (^{18}O) (Fig. 9). Evaporation and human activities are considered the main reason for increasing the value of electrical conductivity in the study area. The increase in electrical conductivity can be referred to two reasons, firstly due to evaporation in Shatt Al-Diwaniya and groundwater and secondly due to the melting of the salts of the soil layers and their mixing with groundwater (Al-Dabbas et al., 2016). Stable isotopes did not increase or decrease with the change of the values of electrical

conductivity but are affected by differences in geographic meteorologies, such as high temperature, evaporation, humidity, and amount of rainfall.

Fig. 12. The EC concentration vs $\delta^{18}\text{O}$ in shallow groundwater and Shatt Al-Diwaniya water samples, 2020

Groundwater Age

Four samples were taken for measuring the isotope tritium (^3H) to estimate the shallow groundwater age in the investigation site. The tritium isotope probably predicts the source from which water came, how quickly groundwater is replenished, and how likely it is to be polluted. There is a classification for the isotope tritium (^3H) value in water through the groundwater age is estimated depending on I. Clark and Fritz classification (Clark and Fritz, 1997), as:

- < 0.8 TU represents sub-modern water (previous to 1950s).
- (0.8 to 4) TU represents a mix of sub-modern and modern water.
- (5 to 15) TU represents modern water (5 to 10 years).
- (15 to 30) TU represents some bomb tritium.
- > 30 TU: recharge occurred for the period (the 1960s to 1970s).
- > 50 TU: recharge occurred in the 1960s.

The calculation of the concentration of tritium percentage can be expressed by formula 4.

$$\frac{\text{sample tritium concentration} \times 100}{\text{natural concentration}} \quad (4)$$

The percentage values in the radioactive decay curve of tritium were observed in Fig. 13. Table 9 demonstrates the tritium concentration in the groundwater at various sites.

Fig. 13. Radioactive decay curve of ^3H (Mazor, 2004)

Table 9. The concentrations of ^3H in water samples at TU wells

Sample Name	Sample code	Concentration of ^3H (TU)
AL- Jameih	WR2	4.14
Um AL-Khail-1	WR4	4.68
AL- Asri	WL5	4.63
Al-Zahraa	WL6	3.72

Fig. 14. Tritium (^3H) in shallow groundwater in the investigation zone

The mean tritium content of the groundwater was 4.29 TU. It ranges from 3.72 - 4.68 TU (Table 9). According to Clark and Fritz (1997), the groundwater is classified as a mix of modern water and sub modern. Mazor (2004) used a modern analysis that can be applied when the tritium concentration in the rainfall has reached a normal state of about 5 TU. Al-Paruany (2013) explained that the ^3H concentrations had reached the normal state in Al-Diwaniya city, at a value of 5 TU in rainfall water (Al-Paruany, 2013). From Fig. 13 and formula 4, it is possible to estimate the shallow groundwater age in the investigation zone as in Table 10. The remaining tritium ratios (82.8%, 93.6%, 92.6%, and 74.40%) appeared, Fig. 14 shows the groundwater age (4.20, 1.60, 1.8, and 6.3) years in wells (WR2, WR4, WL5, and WL6), respectively, the groundwater ages indicate that the recharge is modern.

Table 10. Estimating the groundwater age in the investigation zone

Sample code	Concentration ^3H in (TU)	Formula 4.	Age of groundwater (year)
WR2	4.14	82.80%	4.2
WR4	4.68	93.60%	1.6
WL5	4.63	92.60%	1.8
WL6	3.72	74.40%	6.3

CONCLUSIONS

The following conclusions can be summarized:

- i. The levels of shallow groundwater in Al-Diwaniya city depend on several factors such as: the topography, type of the soil, Wastewater sources, land use nature, and rainfall amount in the area. Generally, groundwater levels of the city are higher than the water level in the Shatt Al-Diwaniya, then, groundwater movement is toward the river stream.
- ii. The stable isotopes supported by the hydrochemical study indicate that the Shat Al-Diwaniya is a source of indirect feed to all the wells by domestic consumption water. Exception well site (WR2), which appeared in this research that the water source is of deep groundwater origin, subjected from high evaporation in the study area.
- iii. The fingerprint of stable isotopes for groundwater is the same for Shatt Al-Diwaniya water, except for Al-Jameih district, isotopes showed similarities to deep groundwater isotopes. Wastewater comes originally from surface water because it has the same fingerprint as surface water, which indicates that the main recharge of groundwater is sewage in addition to rainfall leaking. The age of the groundwater showed that it is modern recharge water.

- iv. The total hardness of groundwater samples shows that they are very hard. TDS values show that all wells produce salty water. The WR2 well is characterized by a different specification where the water is medium to good because Al-Jameih district fed of groundwater deep.
- v. The hydrochemical study confirmed that there are interactions between groundwater and surface water in the selected region because all the results of the samples were located in the same zone, (sixth zone) within the Piper diagram. It was observed that all stable isotope results were near to the GMWL, meaning that the rainfall contributes effectively to feed the river and groundwater in the region, except for the site mentioned previously (RW2).

RECOMMENDATIONS

- i. The future proposal is a more detailed study to complete this study and support its results.
- ii. Monitoring over longer periods, especially in winter and summer, will help the exploration of the dynamics of groundwater during basic flow conditions and the impact of water leakage household consumption on shallow groundwater.
- iii. More future researches are required for Al- Jameih District, due to the different of stable isotopes in groundwater, in comparison with the well water in all study area.
- iv. Future research on groundwater monitoring and detection can be investigated using the feasibility of soft computing models such as artificial intelligence models (Afan et al., 2020; Yaseen et al., 2019 and Yaseen et al., 2020).

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