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DETERMINATION OF GROUNDWATER AND SURFACE WATER INTERACTION IN BAGHDAD CITY USING ISOTOPES TECHNIQUE

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ABSTRACT

The stable isotopes of deuterium (^{2}H) and (^{18}O) together with radioactive values of tritium, enhanced by hydrochemical data were used in the current study to identify the interaction between groundwater and Tigris river water in the city of Baghdad. To achieve this objective, 3 samples of surface water, 3 rainwater samples and 12 samples of groundwater were collected and analysed for ^{2}H, ^{18}O stable isotopes, tritium and hydrochemical analysis. The hydrochemical parameters of both groundwater and surface water samples show similarity in the wells located in the area of Al-Mansour (WK4), Shulah (WK6), Adamia (WR3) Zafarania (WR1) and Diala (WR4), indicating interaction between surface and groundwater in these areas. Moreover, the stable isotopes results show that the difference between the values in groundwater and surface water samples is small and they are close to each other, which also indicates that the surface water in the study area interact with some groundwater, as shown in samples from wells at Al Dora (WK1), Saidia (WK2), Karadha Mariam (WK3), Rahmania (WK7), Zafrania (WR1) and Diala (WR4). The interaction between surface and groundwater in these areas is confirmed by the results of the environmental isotopes (H), where the values are very close in the samples collected from these sites. The present study also showed that the composition of the hydrogen and oxygen isotopes from river water matched with the local meteoric water in the Tigris river basin. This indicates that rainfall has a major contribution to the river water. Therefore, the groundwater might be a mixture of river water and rainwater and the composition of isotopes is controlled by the mixing rates of surface water, internal flow and groundwater components.

تحديد اختلاط المياه الجوفية والمياه السطحية في مدينة بغداد باستخدام تقنية النظائر

مفيد سعدي الحديثي

المستخلص

استخدمت النظائر المستقرة للديوتيريوم (^{2}H و ^{18}O) والنظير المشع للهيدروجين المعززة بالبيانات الهيدروكيميائية في الدراسة الحالية لتحديد التفاعل بين المياه الجوفية ومياه دجلة في مدينة بغداد. لتحقيق هذا الهدف تم جمع 3 عينات من المياه السطحية و 3 عينات من مياه الأمطار و 12 عينة من المياه الجوفية لتحليل النظائر المستقرة (^{2}H و ^{18}O) والتريتيوم

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والتحليل الهيدروكيميائي. أظهرت قيم المحددات الهيدروكيميائية لكل من عينات المياه الجوفية والمياه السطحية التشابه في الآبار الواقعة في منطقة المنصور (WK4) والشعلة (WK6) والأعظمية (WR3) والزعفرانية (WR1) وديالى (WR4). وهذا يدل على وجود اختلاط بين المياه السطحية والجوفية في هذه المناطق. واستنادا إلى النظائر المستقرة من الديوتريوم (^{2}H و ^{18}O) للمياه الجوفية والسطحية، وجد أن الفرق بين قيم هذه النظائرفي عينات المياه صغيرة وقريبة من بعضها البعض. وهذا يدل أيضا على أن المياه السطحية في منطقة الدراسة تسهم في تغذية بعض خزانات المياه الجوفية كما هو الحال في منطقة الدورة (WK1) وسعيده (WK2) وكرادة مريم (WK3) والرحمانية (WK7) والزعفرانية (WR1) وديالى (WR4) وتؤكد نتائج نظائر التريتيوم (^{3}H) الاستنتاج بأن هناك اختلاط بين المياه السطحية والجوفية في هذه المناطق حيث كانت القيم قريبة جدا في هذه المواقع. أظهرت هذه الدراسة أيضا أن قيم نظائر الهيدروجين والأوكسجين في مياه النهر متطابقة مع مياه الامطار المحلية لحوض نهر دجلة مما يشير الى أن هطول الأمطار يسهم بشكل رئيسي في تغذية مياه النهر. عليه فان المياه الجوفية قد تكون خليطا من مياه الأنهار ومياه الأمطار ويتم التحكم في مكونات النظائر من خلال معدلات خلط المياه السطحية والتدفق الداخلي ومكونات المياه الجوفية.

INTRODUCTION

Water scientists have conducted research in the development of technical tools to measure and predict the presence of surface and groundwater connection. Although progress was made in this area but the methods of measurement are very difficult and require extensive technical knowledge (Naiman *et al*., 1995). Generally all surface-water features including streams, lakes, reservoirs, wetlands, and estuaries interact with groundwater which takes many forms. In many cases a body of surface water recovers water from aquifers and in other cases surface water is a source of groundwater recharge and causes changes in the groundwater quality. As a result, withdraw from watercourses can lead to depletion of groundwater or vice versa, and groundwater can also be pumped into streams, lakes and wetlands. Thus, pollution of surface water can affect the quality of groundwater or vice versa. Effective land and water management requires a clear understanding of the links between groundwater and surface water, and this applies to any particular hydrological situation (Thomas *et al*., 1998). Methods to assess these patterns such as the use of natural tracers (e.g. heat) and integrated surface – subsurface numerical models were refined and enhanced considerably in recent years and have improved our understanding of processes and dynamics. Numerical models are increasingly used to explore hypotheses and to develop new conceptual models of groundwater-surface water (GW – SW) interactions (Jan *et al*., 2010). Oxygen, hydrogen and tritium isotopes of water are broadly used as tracers to understand hydrogeological processes such as precipitation, groundwater recharge, groundwater-surface water interactions, and basin hydrology (Hisn *et al*., 2014; Vandenschrick, 2002; Singh *et al*., 2013 and Gat, 1996). Understanding of the underlying flow system and distinction between sources, stable hydrogen and oxygen isotope ratios of water can give similar information with reduced sampling and physical measurement (Hunt *et al*., 1998; Maloszewski *et al*., 1990; Hunt *et al*., 2001; Clarck and Fritz, 1997 and Coplen *et al*., 1999). The aim of the present study is to use tritium isotopes of oxygen and hydrogen, and hydrochemical parameters in investigating the possible interaction between groundwater and the Tigris River water in Baghdad city. The results provide useful information about hydrological processes of interaction between precipitation water, river water, and groundwater.

STUDY AREA

Baghdad is located in the central part of Iraq, between latitude 33° 10' to 33° 29' N, longitudes 44° 09' to 44° 33' E. The elevation of the catchment area ranges from 33 m to 37 m above sea level covering an area of about 5159 Km^2 (Fig.1). The Tigris River, divides Baghdad City into two sides, Al-Karkh side and Al-Rusafa side. The Karkh side lies southwest of the river, while the Rusafa side lies northeast of the river. 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 (Jassim and Goff, 2006). The Tigris River is the major source of water supply for domestic, agricultural and industrial uses in the study area.

The climate throughout the area of study is hot and, dry in summer season and cool, moist in winter season. The mean annual values of precipitation, temperature and evaporation rates are 9.9 mm, 23.07 °C and 266.81 mm respectively, while the relative humidity has a negative trend compared to temperature and evaporation. Hydrogeologically, a good sand aquifer has been observed at a depth range of 8 – 20 m in the studied area (Al-Paruany, 2013).

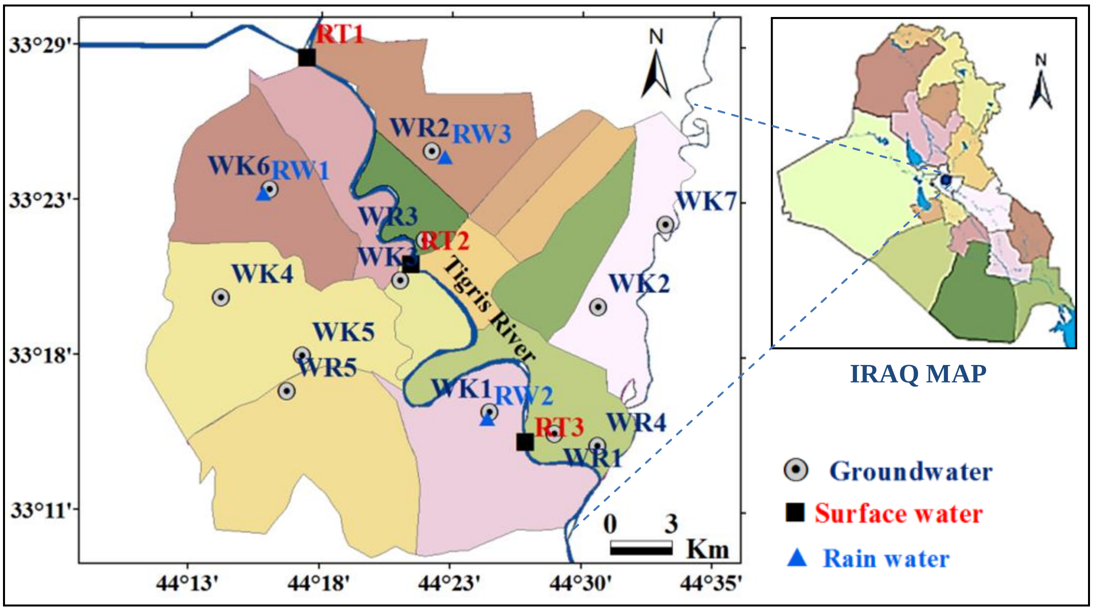

Fig.1: Location map of the study area showing code of sampling sites

METHODOLOGY

Groundwater, precipitation and river water samples have been collected and analysed for oxygen, hydrogen, tritium and hydrochemical composition. The samples were taken during January – February periods, 2014, in accordance to International Atomic Energy Agency (IAEA) guidelines (IAEA, 1983). Twelve groundwater samples were collected from 12 active wells, three samples were taken from the Tigris river at high discharge (February), and three samples were taken from rainfall during January – February 2014. Details of sampling locations are shown in Table 1. Temperature, pH value and electrical conductivity of each sample were measured in situ using an EC/pH meter. All samples were analyzed for major ions and cations composition. Major cations were determined using Ion chromatography. HCO_3^- was measured by the diluted vitriol-methylic titration method using 0.0112MH_2SO_4. Stable isotopes were analyzed using the Liquid Water Isotopes Analyzer (LWIS). The isotopic composition is presented as the δ-notation (‰) related to the international Vienna Standard Mean Ocean Water (VSMOW) standard. The precisions (2σ) for $\delta^{18}O$ and δD were 0.1‰ and 1.5‰, respectively. Tritium was analyzed using Liquid Scintillation Counter (LSC). The water quality and isotope composition were measured at the Center of water Research in the Ministry of Science and Technology (MOST). All data were transferred to the Geographic Information System (GIS) platform to generate water quality and stable isotope database including spatial distribution maps using inverse distance weight (IDW) interpolation methods in the ArcGIS 9.3 software.

Table 1: Sampling locations

Location	Sample code	Sample type	Latitude	Longitude	Elevation (masl)	Depth (m)	Water level (mbgs)
Al-Dora	WK1	GW*	33 16 58.9	44 26 37.6	35	14	20
Saidia	WK2	GW	33 16 12.4	44 27 43.7	34	27	28
Karadha M.	WK3	GW	33 18 50.1	44 22 20.2	32	26	28
Al-Mansour	WK4	GW	33 19 12.4	44 24 52	33	11	12
Yarmouk	WK5	GW	33 16 11.9	44 21 11.4	35	13	13
Shulah	WK6	GW	33 22 17	44 17 27.0	38	22	22
Rahmania	WK7	GW	33 21 11.1	44 21 15.1	36	20	20
Zafrania	WR1	GW	33 14 9.7	44 28 07.7	33	15	15
Shabe	WR2	GW	33 23 34	44 25 7.2	34	13	13
Adamia	WR3	GW	33 21 40	44 23 18.6	34	14	14
Diala	WR4	GW	33 12 17	44 30 52	33	21	21
M.O.S.T	WR5	GW	33 16 43.6	44 24 09.3	34.5	18	18
Tigris river	RT1	SW**	33 25 01.3	44 20 40.6	36		
Karadha M.	RT2	SW	33 21 25.4	44 22 58.0	34.8		
Dora	RT3	SW	33 17 19.3	44 27 09.3	32		
Al-Gazalia	RW1	RW***	33 22 32.2	44 17 35.0	36.8		
Dora	RW2	RW	33 17 23.1	44 27 11.0	36		
Shabe	RW3	RW	33 23 29.4	44 23 24.7	38		

Groundwater*; Surface water**; Rain water***; masl = meter above sea level; mbgs = meter below ground surface.

RESULTS AND DISCUSSION

- **Hydrochemistry**

The detailed results of hydrochemistry of groundwater, surface water and rain water samples of studied area are presented in Table 2 and illustrated in Figs.2, 3 and 4. In the current work, water chemistry is used as supporting evidence to the interaction between surface water and groundwater rather than a detailed investigation.

The concentrations of TDS in Baghdad city (Karakh and Rassafa) varied from 561 to 2877 mg/l in Al-Karakh side and from 786 to 2228 mg/l in Al-Rassafa side. The concentration of TDS in the Tigris River varied from 471 to 598 mg/l, while the concentration of TDS in rainwater samples is between (95 – 98 mg/l). It is clear that there is significant variation in the chemical parameters values between groundwater, surface water and rain water, especially in the sulfate (SO_4^{-2}) and chlorite, (Cl^-) values which reach in some locations high concentrations of up to 1320 mg/l and 1067 mg/l, respectively. The variation in the concentration of cations and anions in the study area depends mainly on the geological features, climate and human activities. Human activity, driven by economic development, population growth, and urbanization, contributes significantly to changes in the quality of river water, mainly related to urban development and intensification of agriculture, particularly the discharge of untreated sewage. Thus, river water chemistry can reflect changes in watersheds, making rivers good indicators of land use (Meybeck and Helmer, 1989). In the present study the hydrochemical parameters of surface water samples show the temporal variation and gradually increasing from north to south of the river, in the direction of the river flow. On the other hand, the results show that there is a rational similarity between the chemical parameters of the three types of water in the wells located in the area of Al-Mansour (WK4), Shulah (WK6), Adamia (WR3) Zafrania (WR1) and Diala (WR4). This indicates that there is an interaction between surface and groundwater in these sites.

Table 2: Hydrochemistry and isotopic composition of groundwater, surface water and rain water samples

Sample code	$\delta^{18}O$ ‰	δD ‰	^{3}H TU	pH	TDS mg/l	EC (µs/cm)	Ca^{+2} mg/l	Mg^{2+} mg/l	K^{+} mg/l	Na^{+} mg/l	HCO_3^- mg/l	Cl^- mg/l	SO_4^{2-} mg/l
WK1	-5.6	-38	6.2	7.3	2298	3800	260	100	4.2	375	203	880	476
WK2	-6.6	-37	5.7	6.9	2573	5320	335	176	4.1	300	370	1067	321
WK3	-7	-41	6	7.4	1578	3100	110	124	3	198	600	277	266
WK4	-4	-31	1.2	7.2	2877	11000	343	187	6	280	195	656	1210
WK5	-4.8	-29	1.1	7.3	970	1840	133	55	5	98	250	119	310
WK6	-4.5	-26	1	7.3	2042	2300	188	102	5	305	320	322	800
WK7	-6.9	-39	5.9	7.8	561	1210	52	33	3	63	176	89	145
WR1	-6	-40	6	7.7	786	1000	91	35	4.8	98	301	89	168
WR2	-4	-26	1.3	7.2	1210	1990	154	75	7.5	115	350	169	340
WR3	-4	-28	1.2	7.4	2228	4260	460	84	7.1	107	140	110	1320
WR4	-6.3	-38	6.3	7.3	1528	2420	171	78	7.4	176	232	214	650
WR5	-3	-23	1.2	6.8	1901	3210	174	60	6.3	321	356	214	770
RT1	-7.7	-40	6.1	8.1	471	1032	60	17	4	72	105	70	143
RT2	-7.1	-38.5	6.1	8	531	1033	65	23	5	65	130	88	155
RT3	-7.2	-39	6.2	7.8	598	1011	73	31	8	75	143	98	170
RW1	-7.82	-43.3	5.6	6.5	96	176	18	4	0.2	4.5	30	11	29
RW2	-6	-41.8	5.3	6.5	98	174	19	4	0.4	4.6	29	11	30
RW3	-7	-42	5.5	6.9	95	179	18	3.9	0.3	4.3	29	12	28

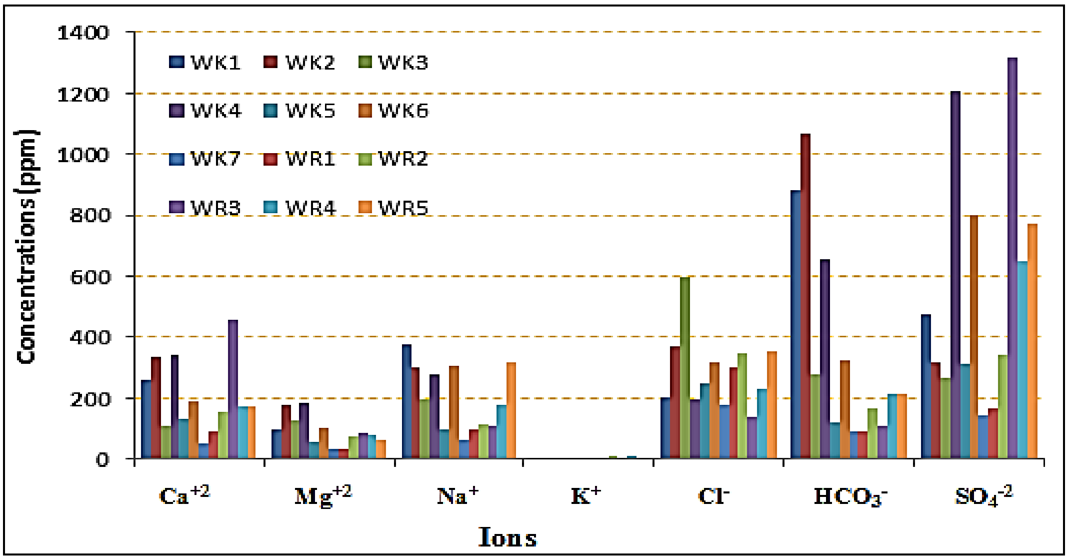

Fig.2: Cation and anion concentrations in the groundwater samples

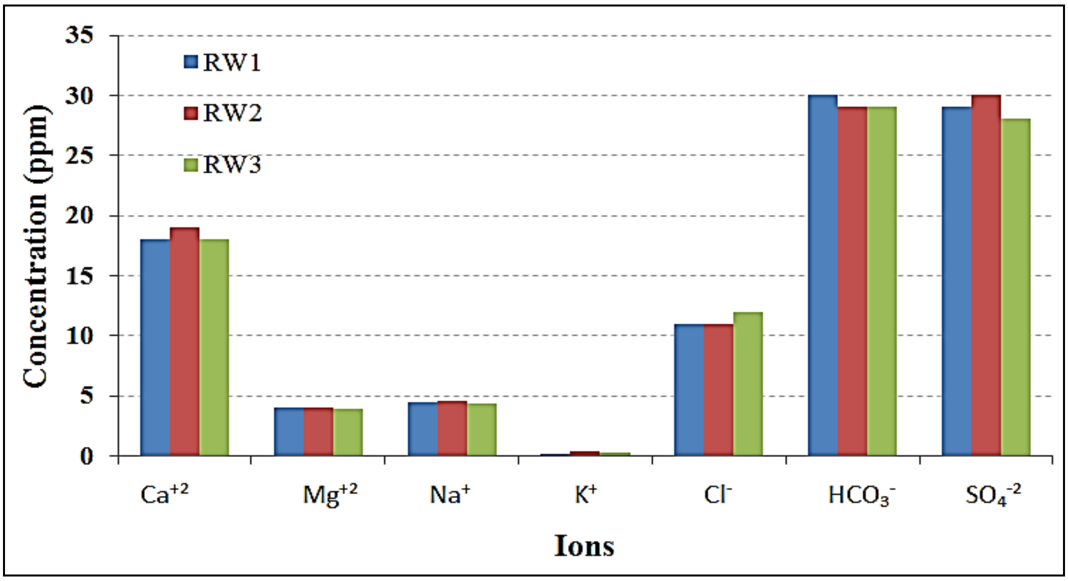

Fig.3: Cation and anion concentrations in the Rain water samples

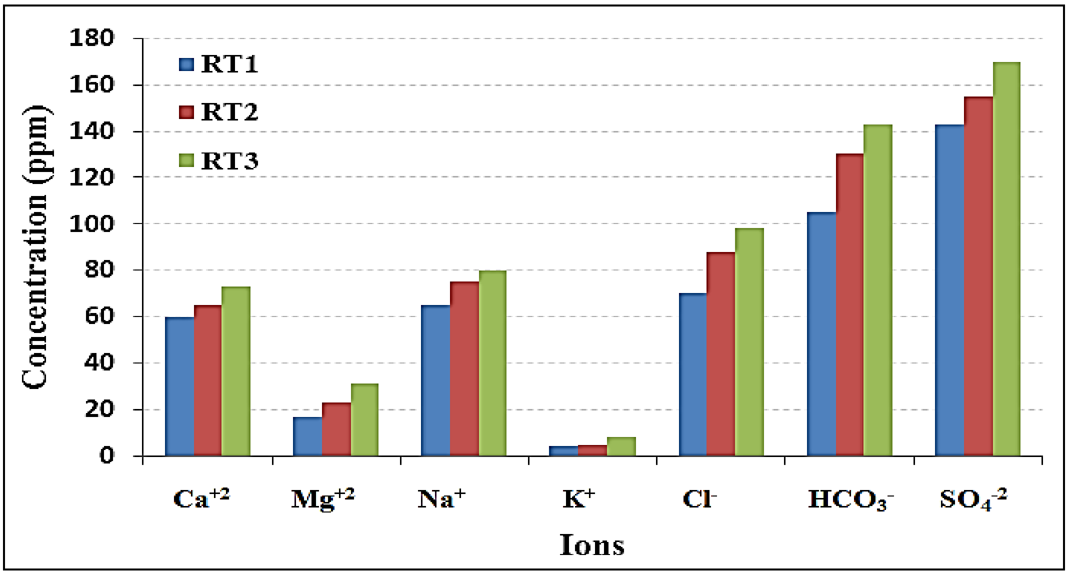

Fig.4: Cation and Anion concentration in the surface water samples

- **Hydrochemical classification**

Schoeller, 1972; Sulin, 1946; and Piper, 1944 suggested the main common methods used for hydrochemical classification. All methods are planned to determine water quality, source, origin and balance between different water sources. Piper, 1944 diagram, which was used in the current study, is the best graphical method that leads to plot further water analysis on the same diagram as well as it can be used to classify water and to identify the mixing of water types. In the current study, a piper diagram was prepared by AqQA Software to estimate the chemical types of the groundwater in the Baghdad city, at Al-Karkh and Al-Rusafa sides. Back and Hanshaw, 1965 have suggested subdivisions of the tri-linear diagram to understand and recognize the composition of water in various classes depending on the domain in which water type occurs in the diagram segments (Fig.5). It can be noted that 83% of the groundwater samples fall in the No Dominant Cation Type Zone, 8% of groundwater samples fall in the zone of Calcium Type and the same percent falls in the zone of Sodium and Potassium Type (Fig.5). Sixty six percent of surface and rain water samples fall in the No Dominant Cation Type Zone and 34% of groundwater samples fall in zone of Calcium Type. Hydrochemical formula of groundwater samples in Al-Karkh side was Ca^{2+} – SO_4^{2-} water type while in Al-Rassafa side mixed Ca^{+2} – Na^{+} – Cl^{-} – SO_4^{2-} water type (Fig.5).

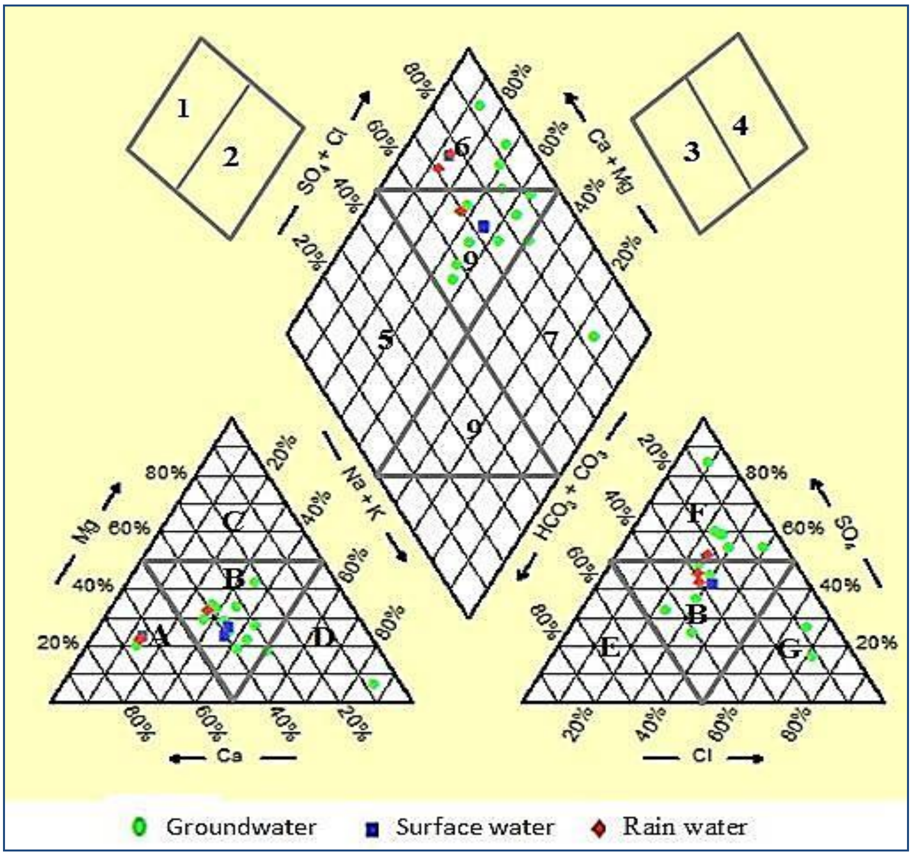

Fig.5: Piper diagram showing the chemical composition of groundwater, surface water and rainfall samples

The concentrations of Ca^{+2} and Mg^{+2} exceed the Na^{+} concentration with 60% in both sides because of the geological nature of the area and the frequent use of water wells. Hydrochemical type of surface water in the study area was Ca^{+2} – HCO_3^{-} with dominating Ca^{+2} and HCO_3^{-} ions. The water type of rainwater samples was mixed Ca^{+2} – Na^{+} – HCO_3^{-} – SO_4^{2-} water type. Comparison between the hydrochemistry of the groundwater and surface water show that there is a correspondence in surface and groundwater quality at both sides of the river, where the anions are predominant, such as sulfates, chlorides and bicarbonates, in most locations close to the river. This may give a good indication of the interaction between surface and groundwater in these sites.

- **Isotopes composition**

Twelve samples were taken from groundwater in both side of Baghdad and three samples from the Tigris River in order to determine the interaction between surface water and groundwater. The change in isotopes composition of groundwater for O and H varied from -7.0‰ to -3.0‰ and from -41‰ to -23‰ for $\delta^{18}O$‰ and δD‰, respectively (Figs.6 and 7).

While the change in isotopes composition of the Tigris River for $\delta^{18}O$‰ and δD‰ varied from -7.7‰ to -7.1‰ and from -40‰ to -38.5‰, respectively. It has been observed that there are significant variations and inconsistencies in the isotopes composition values of groundwater depending on the proximity or distance of the wells to the river. It is clear that there is a convergence of values in some sites close to the river, especially in samples of Al-Dora (WK1), Saidia (WK2), Karadha Mariam (WK3), Rahmania (WK7), Zafrania (WR1) and Diala (WR4), as shown in the chart below (Fig.8). This is evidence that there is interaction between surface water and groundwater in these sites. The isotopic composition of river water is controlled by the mixing rates of the runoff, interflow, and groundwater components.

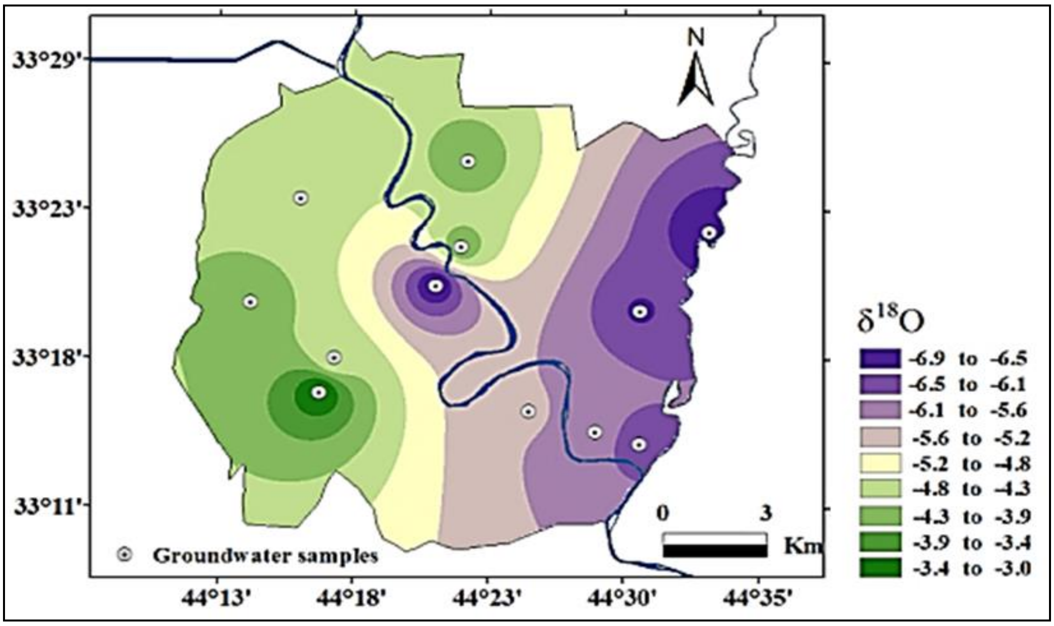

Fig.6: Spatial distribution of $\delta^{18}O$ composition in groundwater samples

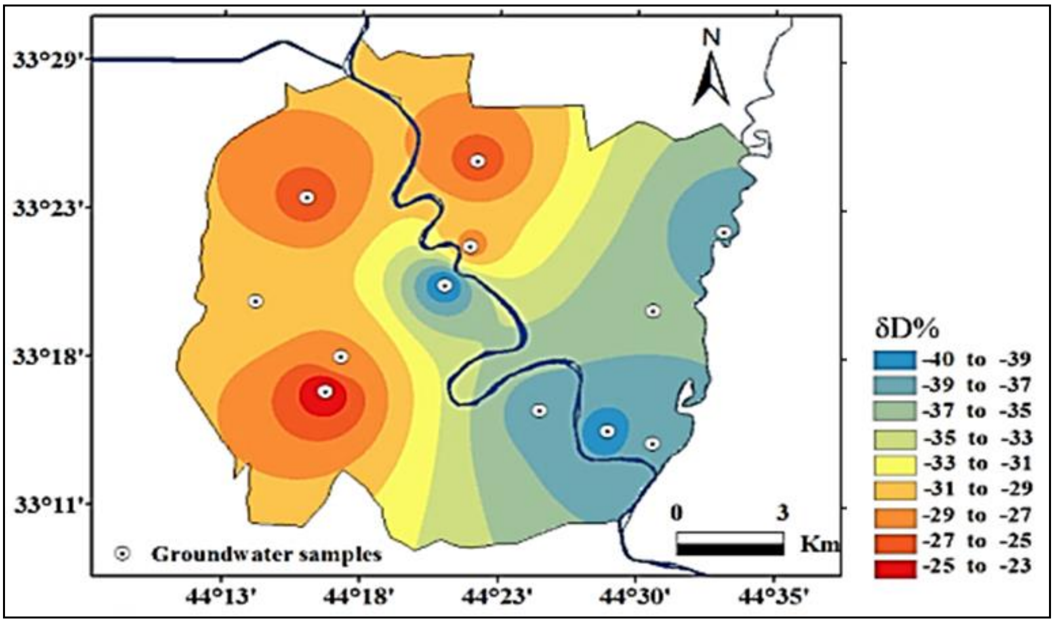

Fig.7: Spatial distribution of δD composition in groundwater samples

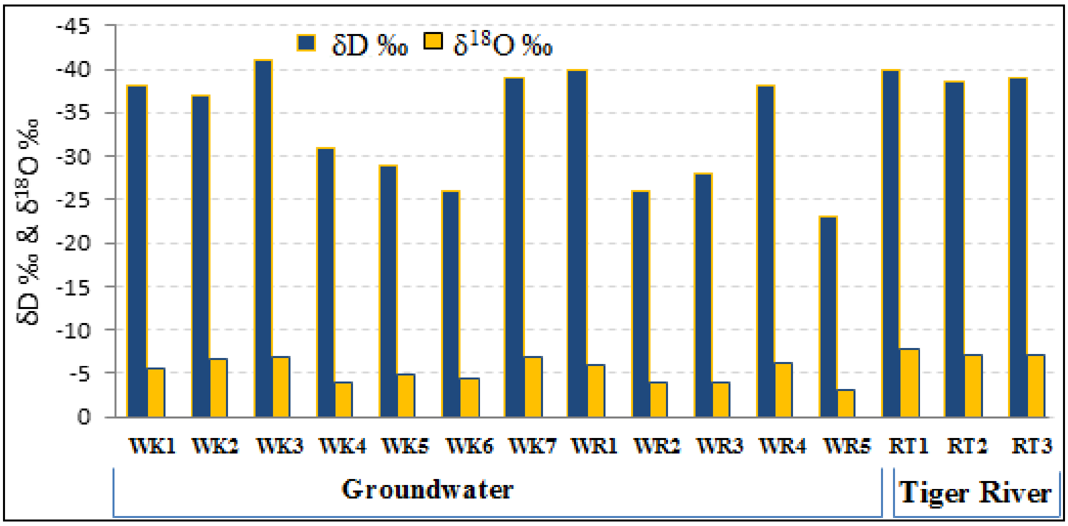

Fig.8: Stable isotopes in groundwater and Tigris River

Furthermore, the tritium values in the studied samples show variation between 1 – 6.3 TU in the groundwater, between 6.1 – 6.2 TU in the Tigris river, and 5.3 – 5.5 in the rainwater as displayed in Fig.9 and 10. The wide range of the tritium in groundwater refers to different residence times (groundwater ages), where the groundwater of high value refers to low residence lime.

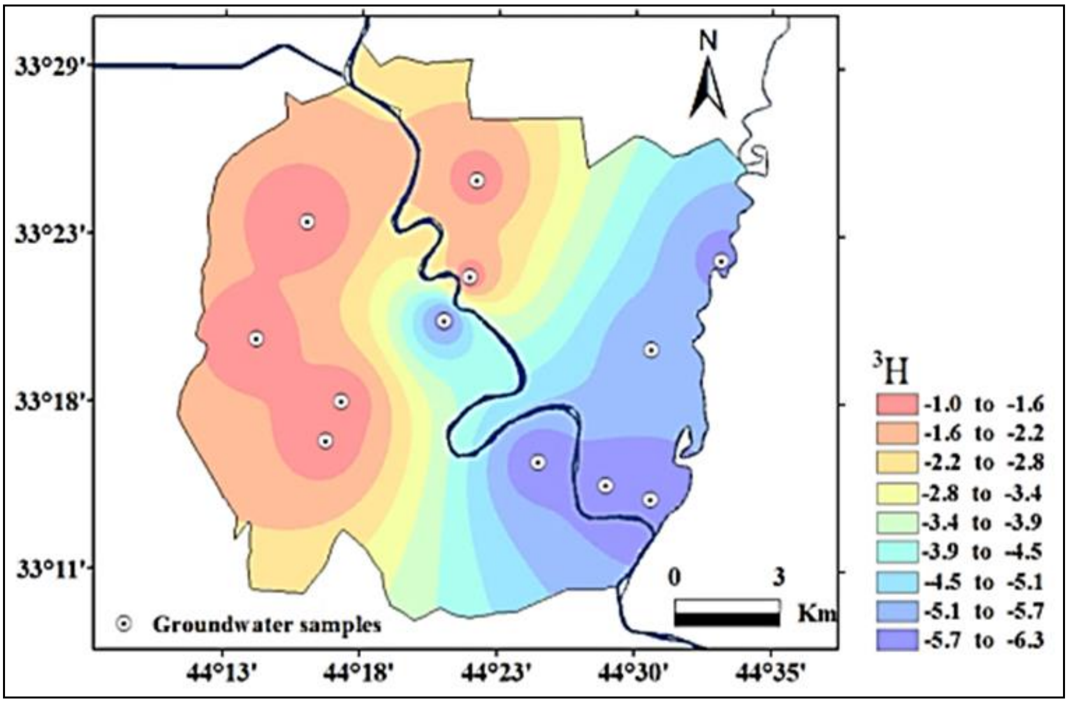

Fig.9: Spatial distribution of tritium (^{3}H) in groundwater samples

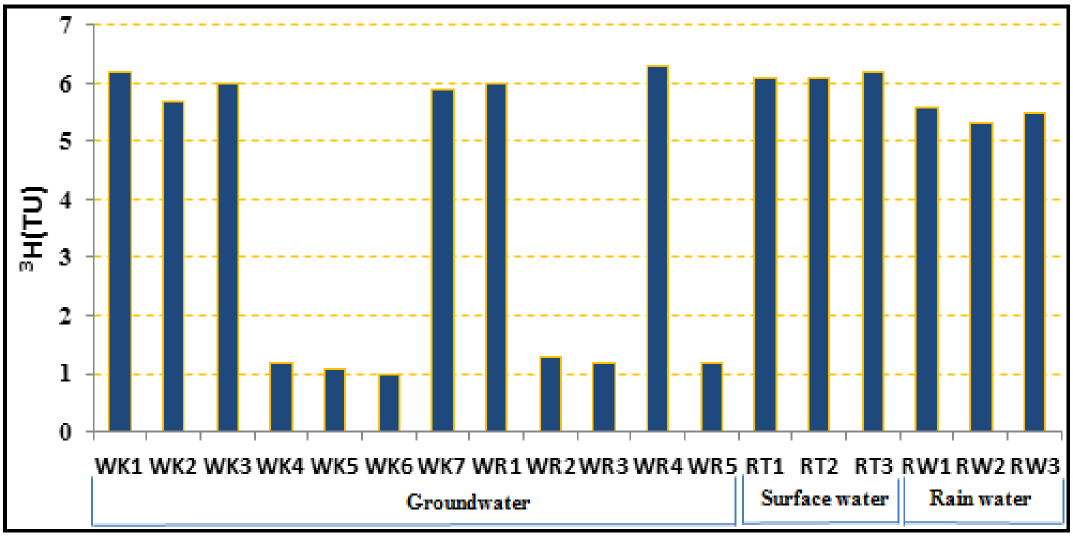

Fig.10: Tritium values in groundwater, Tigris river and rain water

Similarly, when comparing tritium values in river water and groundwater, it can be clearly observed that the values are very close at the same locations. This supports the suggestion that there is interaction between surface and groundwater in these areas and indicates that the surface water and some groundwater are interconnected by direct leakage throw permeability beds. In the rainwater samples, the δD values ranged between -7.8‰ and -6.0‰, the δ^{18}O ranged between -43.3‰ and -41.8‰. Rainfall and temperature cause adverse effects on isotope fractionation where hydrogen and oxygen isotopes are significantly depleted in precipitation (Al-Paruany, 2013). Two meteoric water lines were plotted in order to describe the isotopic data for different sources of water in the study area as shown in Fig.11.

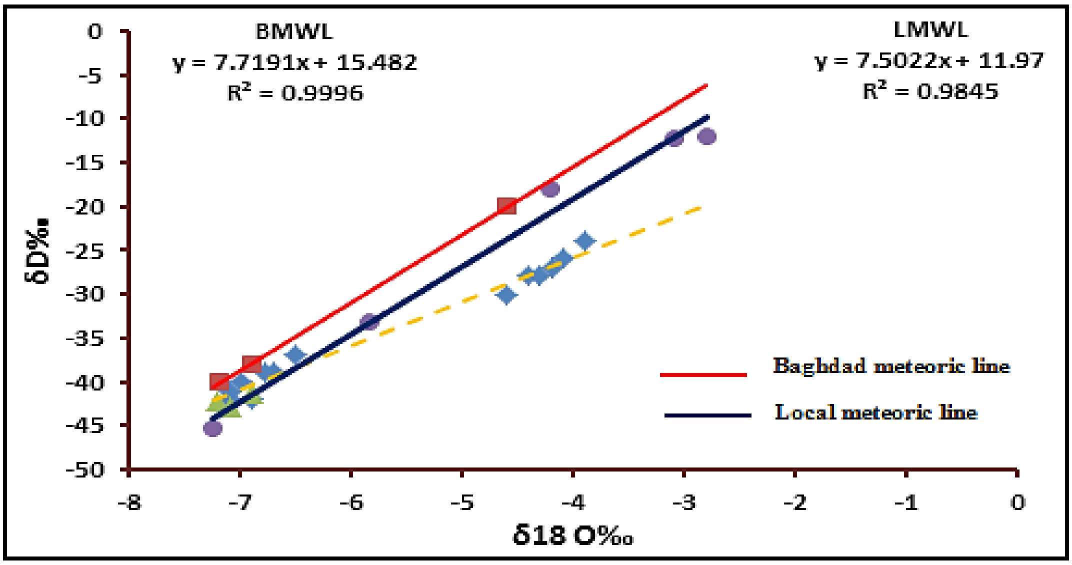

Fig.11: Relation between the δ^{18}O and δ^{2}H for groundwater (blue squares), surface water (green triangles) and rainfall (red squares). BMWL = Baghdad Meteoric Water Line and LMWL = Local Meteoric Water Line

Baghdad Meteoric Water Line (BMWL) δD = 7.719δ18O + 15.48 and Local Meteoric Water Line (LMWL) δD = 7.5022δ18O + 11.97 (Al-Paruany, 2013). The comparison of hydrogen and oxygen isotope compositions between rainwater and river water shows that the composition of the hydrogen and oxygen isotopes from river water matched with the local meteoric water in the Tigris river basin. This indicates that rainfall contributes, as a source, to the river water. The low slope of groundwater regression line belongs to the evaporation effect on the residual infiltrated water.

CONCLUSIONS

Isotopic compositions supported by hydrochemistry study were used in the current study to identify the interaction between groundwater and the Tigris River in Baghdad City. Water chemistry of surface water samples show significant spatial variation; the hydrochemical parameters gradually increase from north to south, following the direction of the river flow. It shows that there is a rational similarity between surface and groundwater in the wells located in the area of Al-Mansour (WK4), Shulah (WK6), Adamia (WR3), Zafrania (WR1) and Diala (WR4), indicating an interaction between surface and groundwater in these areas. Based on isotopes composition of groundwater and surface water, it was found that some groundwater samples are plotted on the Tigris river regression line. This can be considered as additional evidence supporting an interaction between surface water and groundwater in these sites. The comparison of isotope compositions between rainwater and river water indicates that the composition of the ^{2}H, ^{18}O stable isotopes from river water matched that of the local meteoric water in the Tigris river basin. This suggests that rainfall has significant contribution to the river water. The low slope of the stable isotope regression line of groundwater is an indicator of the evaporation under the arid condition and low infiltration capacity (low recharge rate) of the alluvial sediments. The high value of tritium in some groundwater samples also refers to river and groundwater interaction.

REFERENCES

Al-Paruany, K.B.N., 2013. Hydrochemical and Isotopic study of water resources between Haditha dam and site of Al-Baghdadi dam, Science College, University of Baghdad, Unpublished. Ph.D. thesis.

Back, W. and Hanshaw, B., 1965. Chemical Geohydrology Advances in Hydro science. Academic Press, New York, p. 49 – 109.

Clark, I. and Fritz, P., 1997. Environmental Isotopes in Hydrologeology, Lewis, Boca Raton, FL. 328pp.

Coplen, T.B., Herczeg, H.L. and Barnes, C., 1999. Isotope engineering-using stable isotopes of the water molecule to solve practical problems, In: Cook, P., Herczeg, A. (eds.), Environmental Tracers in Subsurface Hydrology. Kluwer, Boston, p. 79 – 110.

Gat, J.R., 1996. Oxygen and hydrogen isotopes in the hydrologic cycle: Annual Review of Earth and Planetary Sciences, Vol.24, p. 225 – 262.

Hunt, R.J., Bullen, T.D., Krabbenhoft, D.P. and Kendall, C., 1998. Using stable isotopes of water and strontium to investigate the hydrology of a natural and a constructed wetland, Ground Water, Vol.36, No.3, p. 434 – 443.

Hunt R.J., Steuer, J.J., Mansor, M.T.C. and Bullen, T.D., 2001. Delineating a recharge area for a spring using numerical modeling, Monte Carlo techniques, and geochemical investigation, Ground Water, Vol.39, No.5, p. 702 – 712.

Hsin, F.Y., Hung, I.L., Cheng, H.L. and Kuo, C.H., 2014. Identifying Seasonal Groundwater Recharge Using Environmental Stable Isotopes. Water 2014, Vol.6, p. 2849 – 2861; Doi: 10.3390/w6102849.

International Atomic Energy Agency (IAEA), 1983. Guidebook on Nuclear Techniques in Hydrology; IAEA Technical Reports Series No.91; IAEA: Vienna, Austria, 4pp.

Jassim, S.Z. and Goff, J.C., 2006. Geology of Iraq, Dolin Prague and Moravian Museum, Brno, 341pp.

Jan, H.F., Sttefan, H. and David, H., 2010. Groundwater-surface water interactions: new methods and models to improve understanding of processes and dynamics, Advances in Water Resources, Vol.33, No.11, p. 1291 – 1295.

Maloszewski, P., Moser, H., Stichler, W., Bertleff, B. and Hedin, K., 1990. Modeling of groundwater pollution by river bank infiltration using oxygen-18 data, In Groundwater Monitoring and Management, Proceedings of the Dresden Symposium, March 1987. IAHS Publication No.173, p. 153 – 161.

Meybeck, M. and Helmer, R., 1989. The quality of rivers: from pristine stage to global pollution, Palaeogeogr. Palaeocl, Vol.75, p. 283 – 309.

Naiman, R.M., Magnuson, J.M. and McKnight, D.M., 1995. The Freshwater Imperative: A research Agenda, Island Press, Washington, D.C.

Piper, A.M., 1944. A graphic procedure in the geochemical interpretation of water analyses. Trans. Amer. Geophys. Union, Vol.25, p. 914 – 923.

Shoeller, M., 1972. Edute Geochimique De La Nappe Des sables in fericurs Du Basin D aquitainse Journal of hydrology Vol.15, No.4, p. 317 – 328, (in French).

Sulin, V.A., 1946. Oil water in the system of natural ground waters Gostopichezdat Moscow, USSR, (in Russian), 215pp.

Singh, M., Kumar, S., Kumar, B., Singh, S. and Singh, I.B., 2013. Investigation on the hydrodynamics of Ganga Alluvial Plain using environmental isotopes: A case study of the Gomati River Basin, northern India. Hydrogeology Journal, Vol.21, p. 687 – 700.

Thomas, C., Winter, W., Harvey O., Lehn, F., and William M., 1998. Ground Water and Surface Water .A Single Resource. U.S. Geological Survey Circular, 1139.

Vandenschrick, G., van Wesemael, B., Frot, E., Pulido-Bosch, A.,Molina, L., Stiévenard, M. and Souchez, R., 2002. Using stable isotope analysis (δD and δ18O) to characterise the regional hydrology of the Sierra de Gador, south east Spain. Journal of Hydrology, Vol.265, No.1, p. 43 – 55.

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