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Hydrochemical Classification of Groundwater in Bahr Al-Najaf, Western Desert, Iraq

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Abstract

The chemical composition of groundwater varies by many complex factors that change with depths and over geographic distances. Groundwater quality may be affected by geological formations, in addition to different hydrological conditions and human activities. Eight groundwater samples taken from eight wells are employed to evaluate their hydrochemical properties. TDS values of analyzed samples are ranged between 3080 to 2450 ppm, while their EC values lie between 4.20 to 3.308 mmhos/cm. There is a direct relationship between TDS and EC, square coefficient of correlation is (0.8499). Three methods are used to classify the groundwater samples; Sulin, Scholler and Scholler-Sulin Sulin's graph is indicates that the water source is of marine origin. Scholler-Sulin's method was used to classify groundwater in the studied area. Sulfate ions are the dominant anions. Two major families in the group of sulfate are sulfate sodium and sulfate calcium. The factors (rNa/rCl), (r(Na-Cl)/rSO_4) and (rSO_4/rCl) are used to determinate the origin of this groundwater. After comparing the values of these factors obtained in the studied area with those known standard values, it appears that the origin of groundwater from type of marine origin.

Key words: Hydrochemical, Classification, Groundwater, Bahr Al-Najaf

Introduction

Groundwater quality data give an important clue to the lithological and mineralogical composition and some indications about the groundwater recharge, movement and storage. Much of the chemical behavior of groundwater is established within the soil and the unsaturated zone. This is a zone where there are rapid changes in water chemistry. Geochemical inputs which coming from the atmosphere, soil, and bedrock give rise to varying concentrations of different chemical elements and biological species [1].The study area is located at about 30 km of south west of Najaf city. The considered area is about 209.25 km^2 and it is a part of a topographic depression "Bahr Al-Najaf". It lies between longitudinal line 44^o $20^{'}$ $40^{"}$ – 44^o $10^{'}$ $40^{"}$ and latitude line 31^o $49^{'}$ $20^{"}$-31^o $40^{'}$ $05^{"}$ (figure .1). The climate here is of a desert type. The maximum value of rain may be attended during February, the maximum and minimum of monthly rainfall rate of the surrounding station is 19.71mm and 0.47mm respectively. The maximum and minimum value of evaporation rate is 589.71mm and 84 mm respectively, while the maximum and minimum average of monthly relative humidity is 69.9 % and 22.96 % respectively. The wind's speed measured in the metrological station of Al-Najaf and Al-Nakhib is ranged between 2.18 m/sec during November and 4.26 m/sec during July. It is worth to be mentioned that the data employed in this research abstracted from (Al-Suhail, 1996) [2].The aim of the present work is to classify the groundwater samples by using three methods such as Sulin, Scholler and Scholler-Sulin. Determining factors of groundwater origin such as (rNa/rCl), (r(Na-Cl)/rSO_4) and (rSO_4/rCl) are used to determine the groundwater origin in Bahr Al Najaf area.

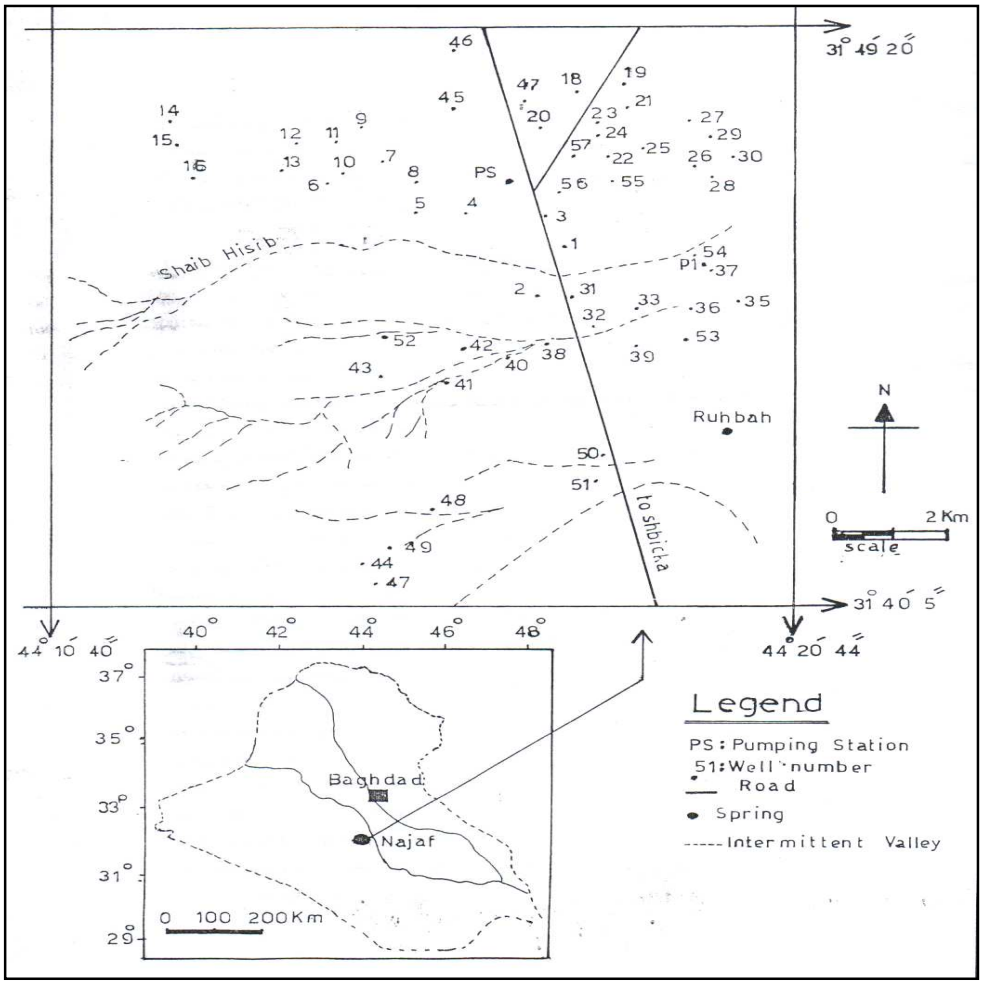


Fig. 1 Study area and locations of the wells [2].

Geological Features of the Study Area

Results of drilled wells revealed there are two main aquifers, knows Dammam and Euphrates Formations. The first aquifer (late lower- upper Eocene) circulation, which is spared from the one proceeding it, including regression, uplift and erosion took place during the Eocene age, then it was followed by marine advancement. This separation is almost evident at stable shelf. This aquifer is considered as the most important one; it is of confined type with high productivity due to its high permeability developed as a result of fracturing and jointing. This aquifer consists of dolomite which has color between white and gray. Sometimes these rocks seem to be of chalky type [3]. This formation is considered to be generally homogeneous according to rock facies. Thickness of this formation reaches to 250 m at the type section in Iraq. The second aquifer represents an unconfined aquifer having small areal extent and productivity. This formation (late early Miocene-early Midmiocene) which is characterized by having a marine advancement at its base as a starting point, where as it ends with salty sedimentation. The ideal section of this formation is situated in the valley of Fihaihi , where this formation consists of well bedded limestone with shells remains [4]. The average thickness of this formation is (60-70) m. This formation is clearly outcrop in the studied area especially in the eastern parts and disappears at some wells, where the Dammam formation appears directly after the quaternally sediments as shown in figure (2).

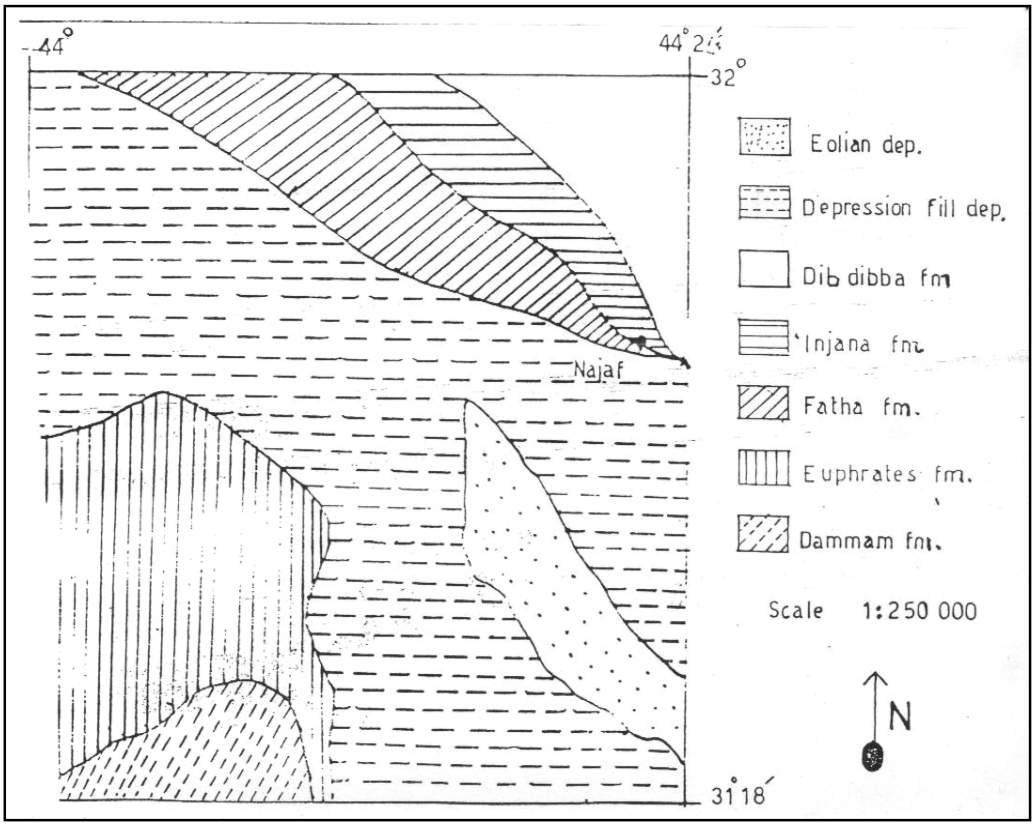


Fig. (2) Geological map of study area. [2]

Chemical Analyses of the Groundwater of the Studied Area

The chemical analyses of eight groundwater samples represents eight wells were employed for evaluation the hydrochemical properties. Chemical analyses were conducted in the laboratories of wells digging company. Results of their chemical analyses, electrical conductivity, and total dissolved solids of these groundwater samples are shown in table (1). The correctness of groundwater analyses can be achieved by carrying out a cation-anion balance, the criterion for acceptance is that

$$\frac{\sum cations - \sum anions}{\sum cations + \sum anions} \times 100\% \quad \text{Is within} \quad \pm 5\% \text{ [5]}$$

The results of percentage errors are shown in table (2). Total dissolved solids (TDS) are considered a general index for the amount of salt and the quality of water. The maximum value of TDS is (3080) ppm in well (22) and the minimum value is (2450) ppm in well (23), this variation could be attributed to the variation in lithological or mineralogical contents of the aquifer. Electrical conductivity (EC) can be defined as the water ability of conducting the electrical current. The EC of a water sample provide a rapid estimation of its total mineralization and reliable way is readily available. The maximum value of EC is (4.2) mmhos/cm in well (22) and the minimum value is (3.308) mmhos/cm in well (23). There is a direct relationship between the values of TDS and EC in the studied area, square coefficient of correlation is (0.8499) as shown in figure (3). By this relationship the value of TDS can be calculated through knowing the value of EC via following equation.

$$TDS = \frac{EC + 0.0117}{0.0014}$$

$$R^2 = 0.8499$$

Table (1), Results of the percentage ratios of the ions concentration, TDS and EC for groundwater in the study area at year (1993) [2].

Well No.	Date	EC (mmhos/cm)	TDS (ppm)	Ca meq%	Mg meq%	Na meq%	K meq%	SO_4 meq%	HCO_3 meq%	Cl meq%
14	24/7	3.80	2880	41.77	30.73	26.56	0.92	65.50	2.77	31.72
19	31/8	4.10	2940	35.40	29.18	34.41	0.87	50.19	5.59	44.20
20	22/8	4.15	2941	35.80	26.86	36.86	0.96	47.39	6.16	46.44
22	1/9	4.20	3080	37.35	28.83	32.37	1.0	48.22	7.33	44.43
23	2/9	3.308	2450	45.74	29.32	24.92	-	56.75	7.38	35.86
30	12/9	4.05	2914	35.52	29.28	35.19	-	52.81	5.49	41.68
31	16/10	4.10	2874	32.73	28.72	37.18	1.35	45.92	6.38	47.68
32	12/10	3.86	2680	33.0	28.51	37.20	1.28	48.86	4.42	46.70

Table (2), Percentage error of chemical analyses for groundwater in the study area.

Well No.	∑cations	∑anions	Error %
14	44.195	47.295	-3.388
19	46.507	49.769	-3.388
20	47.433	48.508	-1.120
22	48.092	51.801	-3.712
23	39.267	40.510	-1.558
30	46.352	49.193	-2.973
31	47.254	48.736	-1.543
32	43.849	44.997	-1.292

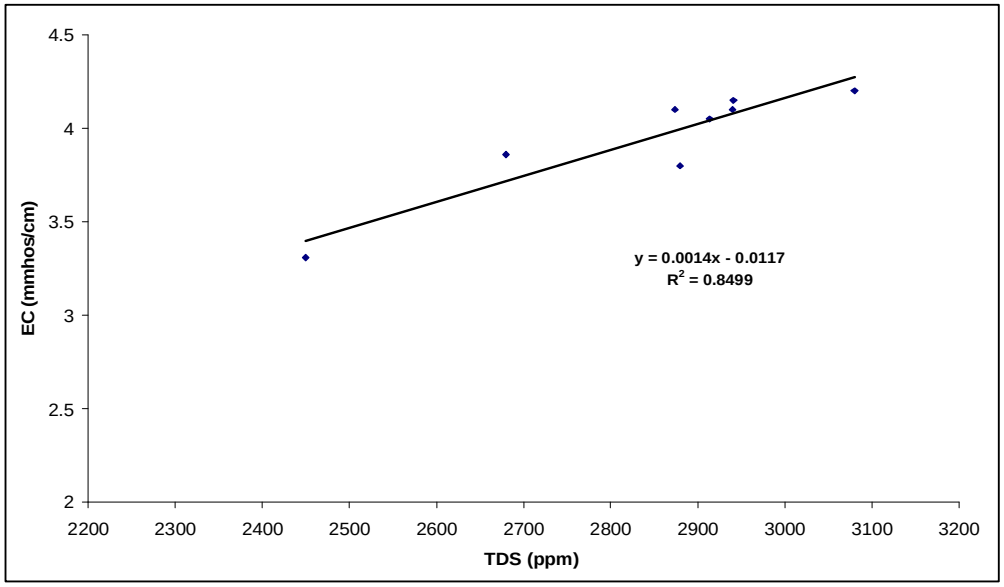


Fig.(3). Relationship between TDS (ppm) and EC (mmhos/cm) in the study area.

Groundwater Classification Methods

There are many methods of hydrochemical groundwater classifications, such as (Plamer, 1911), (Rogers, 1917), (Hill, 1940), and (Lnagelier and Cudwing, 1942), but the well known methods are (Sulin, 1946), (Schoeller, 1962) and (Schoeller-Sulin, 1981).

1- Sulin's Method

The percentage of the concentration (meq %) is used in this method instead of the value of concentration itself, as well as, the condition of

terminating the concentration of each ion participated in the classification in ratio 15 %. Sulin could terminate 15 x 15 type of water, (table 3). Sulin graph is divided into two squares depending upon the concentration ratio of both sodium and potassium in meq% to the concentration of chloride (meq %) [6]. The upper square represents marine water. According to the ratio,

$$A = \frac{rCl^{-} - r\left(Na^{+} + K^{+}\right)}{rMg^{++}}$$

This square is divided into two triangles, the first when A>1 which represents water from marine origin in confined basin and from the family (Ca- chloride). The second triangle when A<1 which represents water from marine origin in semi-confined basin. The lower square represents meteoric water. According to the ratio,

$$B = \frac{r\left(Na^{+} + K^{+}\right) - rCl^{-}}{rSO_4^{=}}$$

This square is divided into two triangles, the first one when B>1 which represents meteoric origin (continental) and its type from the family of Na+K- bicarbonate. The second triangle when B<1 which represents a meteoric origin and its type from the family of Na+K- sulphate.When using the values of the ionic concentration upon Sulin' graph as shown in figure (4), it reveal that the water samples in the studied area from marine origin in semi-confined basin.

2- Schoeller's Method

Schoeller used the deductive arrangement of the concentration of cations and anions to classify the water, and by this arrangement, he arrived at 36 types of water (table. 4). Water samples can be recognized in two numbers, the first is on the left which represents the deductive arrangement of cations concentration, and the second number is on the right which represents the deductive arrangement of anions concentration [7]. Results of the analyzed groundwater samples by using this method are listed in table (5). The variation of groundwater type is attributing to spatial variation in controlling factors that responsible for sedimentation and dissolution of different minerals.

3- Schoeller-Sulin Method

This method comprise Schoeller's graph in addition to line 15% which is taken by Sulin in his classification, where cations and anions participate in this classification if there concentration rate is more than 15%. Schoeller –Sulin used two numbers to indicate the concentration of cations and anions. The first number represents Schoeller's number, (table 4), the second number on the right depends on Sulin's classification, where number (1) means to eliminate the last two concentration of cation and anion (both concentration less than 15%), whereas number (2) means to eliminate the last concentration of cation and anion, number (3) means that there is no elimination in the concentration of the ions. This method was applied to classify groundwater in Bahr Al-Najif region to identifying the water type and its quality in this area. The results are shown in figure (5) and table (6). It clearly appears that sulphate is the dominant anion in the study area. The group of sulphate in study area contains two major families, which are, Sulphate-sodium and Sulphate - calcium

Table (3), (15x15) water type (Sulin's method, 1946)

Cations	Anions
Ca-Mg-Sodium	HCO_3-SO_4-Chloride
Mg-Sodium	SO_4-Chloride
Mg-Ca-Sodium	SO_4- HCO_3
Ca-Sodium	HCO_3-Chloride
Sodium-	-Chloride
Ca-Na-Magneisum	HCO_3-Cl-Sulphate
Na-Magnisum	Cl-Sulphate
Na-Ca-Magneisum	Cl-HCO_3-Sulphate
Ca-Magneisum	HCO_3-Sulphate
Magneisum	-Sulphate
Mg-Na-Calcium	SO_4-Cl-Bicarbonate
Na-Calcium	Cl-Bicarbonate
Na-Mg-Calcium	Cl-SO_4-Bicarbonate
Mg-Calcium	SO_4 -Bicarbonate
-Calcium	- Bicarbonate

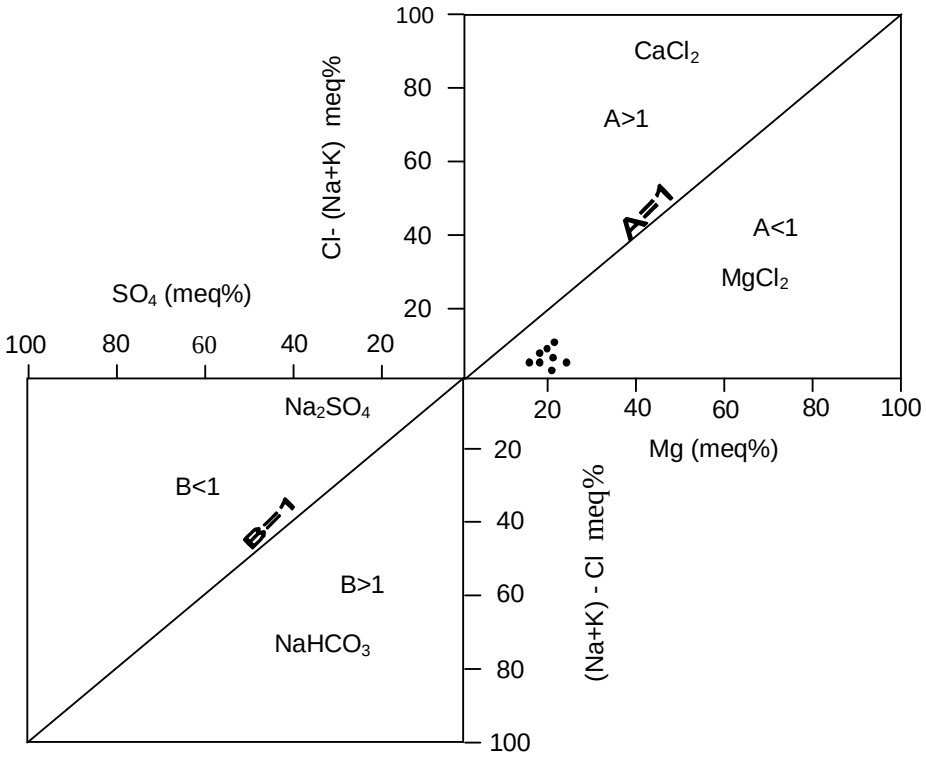


Fig. (4) Groundwater type on Sulin's graph of the study area.

Table (4), Coding number of Schoeller's method with 36 water type, r = meq%

Code index	Anions	Code Index	Cations
1	$rCl>rSO_4>rHCO_3$	1	r (Na+K)>r Mg>rCa
2	$rCl>rHCO_3>rSO_4$	2	r(Na+K)>rCa>r Mg
3	$rSO_4>rCl>rHCO_3$	3	rMg>r(Na+K)> rCa
4	$r\ HCO_3>rCl>rSO_4$	4	r(Ca>r(Na+K)>r Mg
5	$rSO_4>r\ HCO_3>r$ Cl	5	rMg>rCa>r(Na+K)
6	$rHCO_3>r\ SO_4>$ rCl	6	rCa>r Mg> r(Na+K)

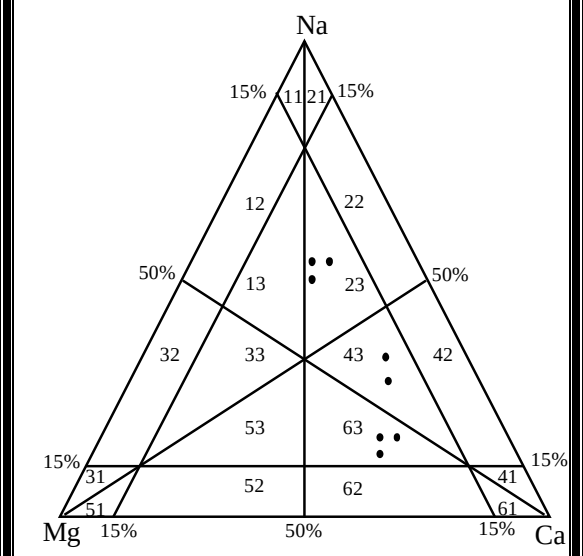
Table (5), coding index of groundwater samples in the study area according to Schoeller's method.

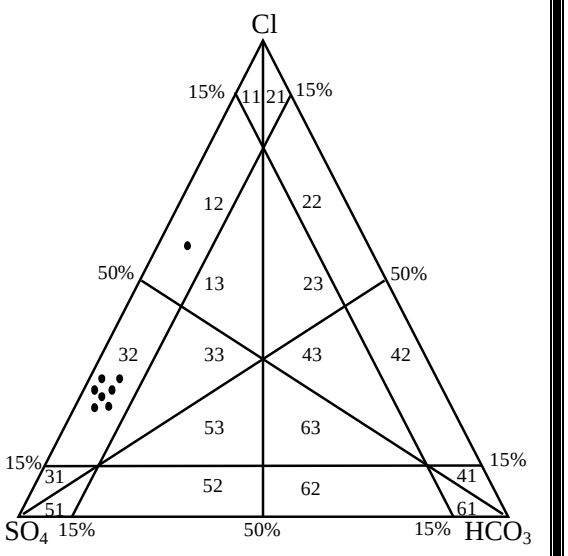
Well No.	14	19	20	22	23	30	31	32
Code index	63	63	23	43	63	43	21	23

Table (6), Quality and family of groundwater in the study area.

Family	Group	Well No.	Water type	Index
Sulphate- Sodium	Sulphate	20,32	$rNa>rCa>rMg; rSO_4>rCl$	23; 32
Sulphate-Calcium		14,19,23	$rCa>rMg>rNa; rSo_4>Cl$	63; 32
Sulphate-Calcium		22,30	$rCa>rNa>rMg; rSo_4>Cl$	43; 32
Chloride-Sodium	Chloride	31	$rNa>rCa>rMg; rCl>SO_4$	23; 12

SS-GRAPH





11 12 13	rNa rNa > rMg rNa > rMg > rCa	11 12 13	rCl rCl > rSO_4 rCl > rSO_4 > $rHCO_3$
21 22 23	rNa rNa > rCa rNa > rCa > rMg	21 22 23	rCl rCl > $rHCO_3$ rCl > $rHCO_3$ > rSO_4
31 32 33	rMg rMg > rNa rMg > rNa > rCa	31 32 33	rSO_4 rSO_4 > rCl rSO_4 > rCl > $rHCO_3$
41 42 43	rCa rCa > rNa rCa > rNa > rMg	41 42 43	$rHCO_3$ $rHCO_3$> rCl $rHCO_3$> rCl > rSO_4
51 52 53	rMg rMg > rCa rMg > rCa > rNa	51 52 53	rSO_4 rSO_4 > $rHCO_3$ rSO_4 > $rHCO_3$ > rCl
61 62 63	rCa rCa > rMg rCa > rMg > rNa	61 62 63	$rHCO_3$ $rHCO_3$> rSO_4 $rHCO_3$> rSO_4 > rCl

Fig. 5 Groundwater type of study area on SS-Graph.

Determining Factors of Groundwater Origin

The factors (rNa/rCl), ($r(Na-Cl)/rSO_4$) and (rSO_4/rCl), are used to determinate the origin of groundwater in the study area. Where

r = meq%

1. rNa/rCl

The rNa/rCl ratio is considered one of the most important guides in determining the origin of groundwater. Chloride is used in calculating the hydrochemical ratio, because this ion is considered to be the least effected by physical and chemical changes.

The value of this factor becomes less than (1) in marine water and more than (1) in meteoric water [8] figure. (6), is indicated the groundwater in this study area from marine origin.

2. $r(Na - Cl)/rSO_4$

The value of this ratio becomes more than (0) and less than (1) in case the water from meteoric origin while in ordinary seawater the value is (-1.33).
After comparison the values of this ratio obtained in the studied area as shown in figure (7) with those reference values, it appears that the origin of groundwater is type of marine origin.

3. rSO_4/rCl

The important of the ratio (rSO_4/rCl) comes from the identification of the sulphate and chloride ions contained in the groundwater of the study area. The values of this ratio ranged between (0.963087, 2.064943) as shown in figure (8). The value of this factor becomes more than (2.75) in meteoric water [8]. After comparison the obtained values with those values of the ratio for water of meteoric and marine origin, it clarifies the groundwater of the study area is of marine origin.

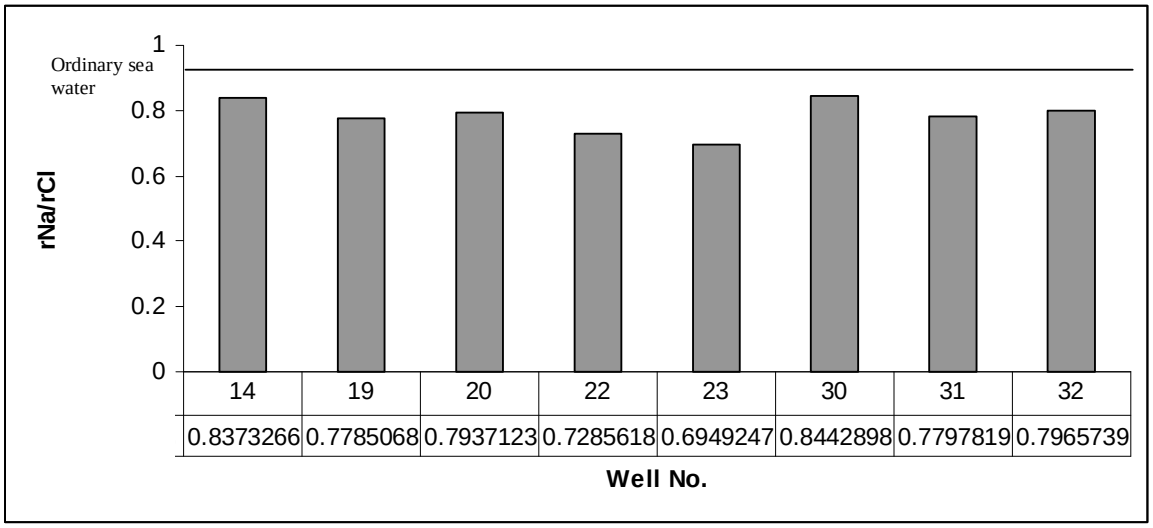


Fig. 6 rNa/rCl histogram of groundwater in the study area.

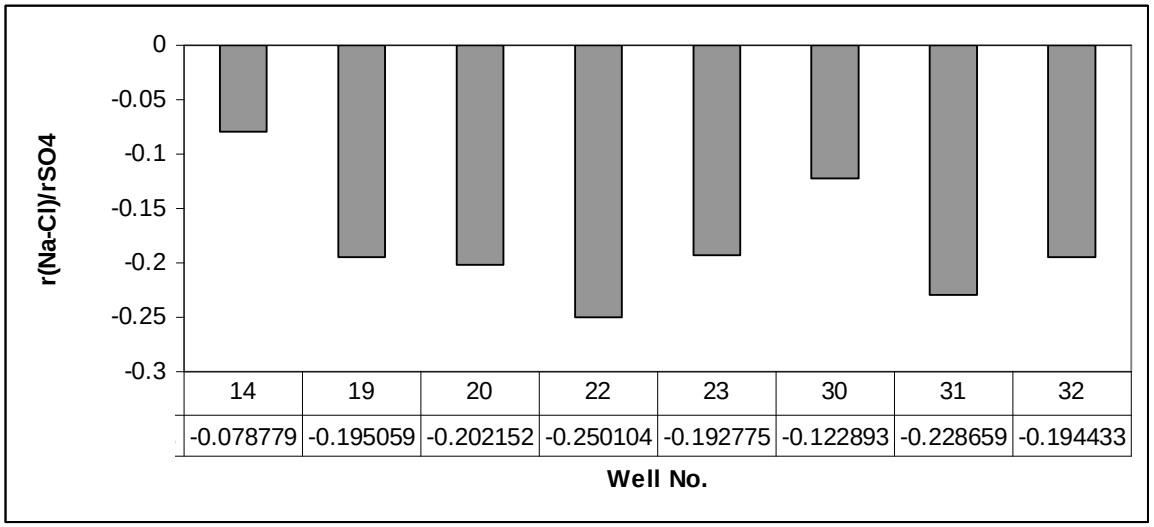


Fig. (7). $r(Na-Cl)/rSO_4$ histogram of groundwater in the study area.

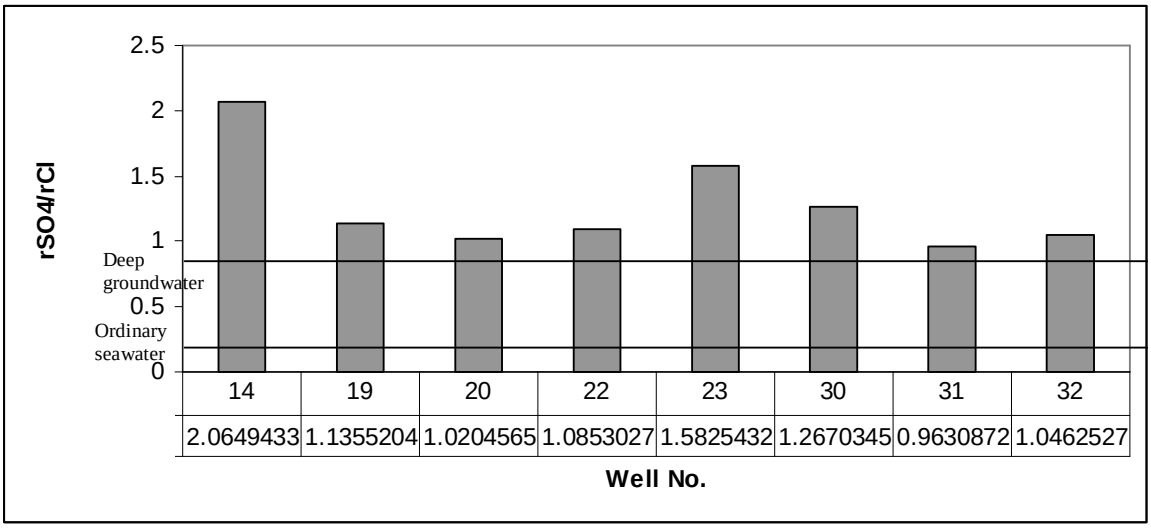


Fig. 8 rSO_4/rCl histogram of groundwater in study area.

Results and Discussion

The groundwater of Bahr Al-Najaf has wide variation in values of total dissolved solids (TDS) and electric conductivity (EC). The difference in results of chemical analyses over this area caused by the variation in lithological or mineralogical contents of the aquifer, and the spatial variation in controlling factors that responsible for sedimentation and dissolution of different minerals. Sulin's Graph appeared, the groundwater in the study area is of marine origin. According to Schoeller-Sulin method, sulfate ion is the dominant anions. Two majors families in the group of sulfate, which are sulfate sodium and sulfate calcium, this is indicate, that Dammam water is supersaturated with calcite and dolomite.

Conclusions

The groundwater of Bahr Al Najaf characterized by their wide variation in total dissolved solid contents (TDS). This variation could be attributed to the variation in lithological or mineralogical contents of the aquifer. Direct relationship between the value of TDS and electrical conductivity (EC), this relationship may be used to calculate the amount of TDS through knowing the value of EC. Moreover, the water type of the Bahr Al-Najaf area is of marine origin preserved in semi-confined basin.

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التصنيف الهايدروكيميائي للمياه الجوفية في منطقة بحر النجف – الصحراء الغربية, العراق

علي حسن العبودي

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الخلاصة

يَتفاوتُ التركيبُ الكيميائيُ للمياه الجوفيّةِ نتيجة عدد مِنْ العواملِ المعقّدةِ التي تَتغيّر تبعا للأعماق وعلى المسافاتِ الجغرافيةِ. نوعية المياه الجوفيّةِ قَدْ يؤثّرُ عليها التركيب الجيولوجي، بالإضافة إلى الظروف الهيدرولوجية المختلفة والنشاطات البشرية.نتائج تحاليل ثمانية عينات من المياه الجوفيّةِ تمثل ثمانية أبار موزعة على مساحة منطقة بحر النجف استخدمت لتَقييم الخصائص الهايدروكيميائية لتلك المياه . بينت نتائج الفحوصات الكيميائية أن قيمة الأملاح الذائبة الكلية تتراوح بين (2450-3080) جزء بالمليون بينما تراوحت قيم الايصالية الكهربائية بين(3.308-4.20) مليموز /سم . هناك علاقة مباشرة بين الأملاح الذائبة الكلية والايصالية الكهربائية، حيث بلغ مربع معامل ألارتباط (0.8499). ثلاثة طرائق استعملت لتَصنيف المياه الجوفيّةَ؛ بعد تمثيل نتائج الفحوصات الكيميائية على مخطط سولن تبين إن أصل هذه المياه يعود للأصل البحري في حين أظهرت طريقة شولير– سولن إن ايون الكبريتات هو الايون المهيمن في منطقة الدراسة وان هناك عائلتان لمجموعة الكبريتات هما عائلة كبريتات الصوديوم وكبريتات الكالسيوم. استخدمت الدوال((rNa/rCl) , r(Na-Cl)/rSO_4 , (rSO_4/rCl)) لتحديد أصل المياه الجوفية في منطقة الدراسة وبعد مقارنة قيم هذه الدوال المحسوبة من المياه الجوفية في المنطقة المدروسة مع القيم المرجعية لتلك الدوال اتضح أن المياه ذات أصل بحري.