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Evaluation of Groundwater Quality in East of ThiQar Governorate (South Iraq)

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Abstract

Fifty groundwater samples were collected from east of Thi Qar governorate in south of Iraq. Studied area belongs to Mesopotamia plain which is considered as a part of stable shelf of Arabian plate . Quaternary sediments are covered this area by clay, silt and sand beds. The aim of this study is evaluating of hydrochemical facies and suitability of groundwater for different purposes. The groundwater samples were analyzed for physico-chemical characteristics (pH, TDS, EC, TH) besides of major cations & anions. The results indicated that groundwater samples are between neutral and light alkaline, slightly-brackish, excessively mineralized and hard to very hard water. Two hydrochemical facies were identified, they are " earth alkaline water with increased portions of alkalis with prevailing sulfate and chloride" and " Alkaline water with prevailing sulfate and chloride" belong to (Ca^{2+} - Mg^{2+} - Cl^{-} - $SO4^{2-}$) and (Na^{+}- K^{+} - Cl^{-} - $SO4^{2-}$). The evaluation of groundwater suitability for different purposes, It turned out that this groundwater is unsuitable for human drinking and industrial purposes, satisfactory for livestock. Concerning to suitability for irrigation purposes, It is ranged between unsuitable to doubtful according to (Na%) and RSC , but it is still excellent to good limits according to SAR.

Keywords: groundwater, hydrochemistry, water quality, Thi Qar

تقييم نوعية المياه الجوفية في شرق محافظة ذي قار (جنوب العراق)

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الخلاصة

تم في هذا البحث جمع خمسين عينة من المياه الجوفية من شرق محافظة ذي قار في جنوب العراق. تنتمي منطقة الدراسة الى سهل وادي الرافدين الواقع في الرصيف المستقر من الصفيحة العربية. حيث تغطي ترسبات العصر الرباعي هذه المنطقة بطبقات طينية وغرينية ورملية. ان هدف هذه الدراسة هو تقييم السحنات الهيدروكيميائية ومدى صلاحية هذه المياه الجوفية للأستخدامات المختلفة.

اجريت التحليلات لنماذج المياه الجوفية المدروسة للحصول على الخواص الفيزيوكيميائية من اس هيدروجيني والمواد الصلبة الذائبة الكلية والتوصيلية الكهربائية وعسرة المياه واضافة الى تحليل العناصر الرئيسية الموجبة

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والسالبة. حيث اظهرت النتائج ان المياه الجوفية في المنطقة هي متعادلة الى قليلة القلوية، مالحة خفيفة، شديدة المعدنية، ذات عسرة قوية الى قوية جداً. بعد ذلك تم تحديد سحنتين هيدروكيمائية هما ، الاولى هي سحنة المياه القلوية الأرضية مع زيادة في القلويات مع الكبريتات السائدة والكلورايد ($Ca^{2+} - Mg^{2+} - Cl^{-} - SO4^{2-}$) والثانية هي سحنة المياه القلوية مع الكبريتات السائدة والكلورايد ($Na^{+} - K^{+} - Cl^{-} - SO4^{2-}$) . ان تقييم مدى صلاحية هذه المياه للاستخدامات المختلفة بين انها غير صالحة لشرب الانسان ولكنها مقبولة لشرب المواشي، وغير صالحة للاستخدامات الصناعية. اما فيما يخص مدى صلاحيتها لأغراض ري المزروعات فقد تم الاعتماد على عدة معايير ، فطبقاً الى معياري نسبة الصوديوم المئوية وكربونات الصوديوم المتخلفة تراوحت هذه المياه من غير صالحة للسقي الى مشكوك بها، واعتماداً على نسبة امتزاز الصوديوم ، كانت جيدة الى ممتازة لسقي المزروعات.

Introduction

Water resources have been a paramount importance in human life over all civilizations. With the development of the 21st century, the need has increased to seek additional resources to provide water from other sources besides rivers and rain falls. Groundwater has been an important source of water in many regions of the world, So it is the focus of attention for many researchers to study in terms of quantity and quality. The studied area is located in Thi Qar governorate in Iraq, between latitudes (31°01′30″ - 31°38′24″N) and longitudes (46°21′18″ - 46°44′42″E)with an approximate area of (3486km^2) Figure-1.In general the climate in this area is semi arid with maximum temperature up to +53C° in July and August and minimum temperature of -7C° in January. Average of rain precipitation is almost 150 ml/year (from November to March) [1]. This area lies in Euphrates sub zone of Mesopotamian zone from stable shelf of Arabian plate, in this location exist Mesopotamian flood plain deposits ,where alluvial fans (Pleistocene age) consist of quartz sands with heavy metals assemblage of mostly rutile and zircon. These deposits are covered by Holocene sediments which comprise fluvial and lacustrine deposits in addition to gypcrete on the surface of some fans [2]. The research in hand deals with the qualitative aspects of groundwater by studying hydrochemical facies and suitability for different purposes in Thi Qar governorate in Iraq. Groundwater was studied in this area due to water scarcity, especially in the eastern and north-eastern parts of the governorate, while most of the marshes are far away in the southern parts.

The accuracy (A) of the results of the water samples are estimated from the results of reaction error test (U), When ($U \leq 5\%$)(certain) the results could be accepted for interpretation, but if ($5\% \leq U \leq 10\%$) (probable certain) the results are acceptable with risk , but if the value ($U > 10\%$) (uncertain) can not depended on the results in hydrochemical interpretation [3]. U values are ranged between (0.009 – 9.711) for studied samples, Therefore the results of the analysis could be depended for hydrochemical interpretation.

Sampling and Analysis Methods:

The groundwater samples were collected from (50) wells, each well stands for one sample. The type of wells are non-artesian rotary drilled wells, the average of wells depths was (13.8m) , which are drilled in 2011 by the State of the Ground Water Drilling Wells. The water samples put on plastic bottles of one liter size after washing for twice by samples water in order to avoid the contamination, and determine the locations (Longitude, Latitude and height) for each well. Each sample was measured directly in the field, Acidity (pH), Electrical Conductivity (EC) and Total Dissolved Salt (TDS) by using device HANA (HI9811-5). Major and minor elements were analyzed at the chemical laboratory of General Commission for Groundwater.

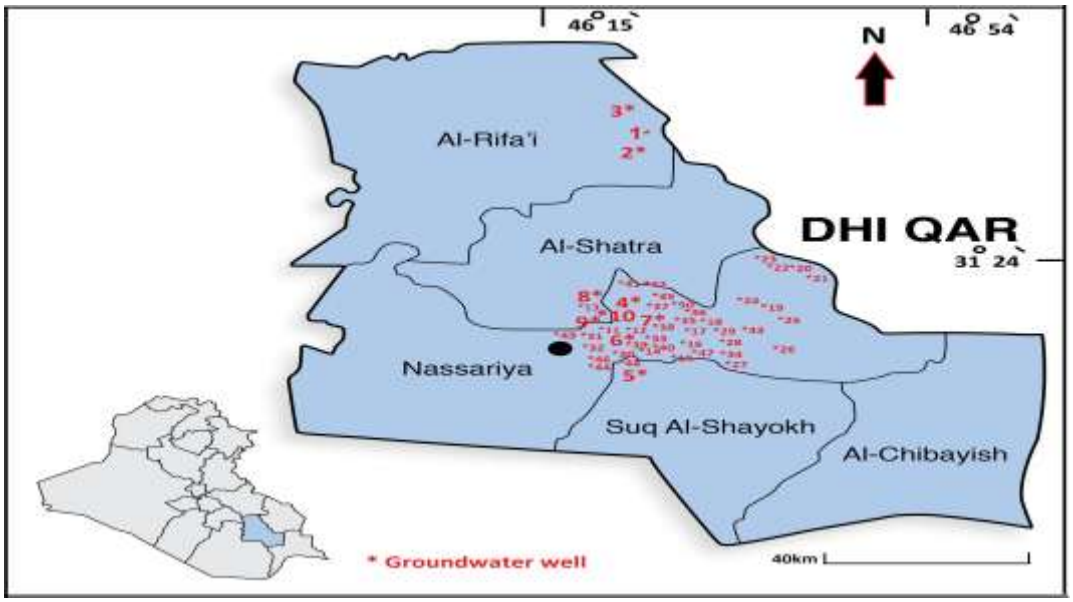

Figure 1- Map of studied area

Results and Discussion

The measurement of pH is an indicator of the acidity or alkalinity of water is expressed by pH = -log (+H). The acidic function of groundwater in Thi Qar is ranged between (7.09-7.71) and by average (7.31) therefore it is between neutral and light alkaline. The calcareous rocks present in the region affect the pH water and was the reason behind high-bicarbonate in groundwater [4].

Total dissolved solids (TDS) is the total amount of solids remaining when a water sample evaporates to dryness. Dissolved solids include both organic and inorganic materials dissolved in a sample of water and are commonly used as a general indicator of water salinity or quality [5]. Concentration of dissolved ions within natural water depends on the type of rock and soil that are in contact with them and on the length of time that the contact process has taken. TDS is measured by the (ppm) or (mg/l) units. The TDS in studied wells is ranged between (1130-40400 ppm) and by average (4926.6ppm). The highest values were in wells number (4 and 45, 48) because of the impact of local salt lakes . And by comparing total dissolved solids (TDS) of studied wells with the classifications [6 – 8], It turned out that water type is (Slightly-brackish) as shown in Table-1.

Table1- Classifications of water salinity according to (TDS) in ppm.[6-8]

Water Class	Altoviski, 1962	Drever(1997)	Todd(2007)
Fresh Water	0 - 1000	<1000	10 - 1000
Slightly Water	1000 – 3000	1000 - 2000	-----
Slightly-brackish Water	3000 - 10000	2000- 20000	1000 – 10000
Brackish Water	10000 - 100000	-----	10000 - 100000
Saline Water	-----	35000	-----
Brine Water	> 100000	> 35000	> 100000

Electrical Conductivity (EC) is the ability of (1cm³) of water to conduct electrical current, at temperature of 25C°, measured by micro Siemens per centimeter (µS/cm).It depends on the concentration of soluble salts and the temperature of the water [9].The values of electrical conductivity of studied samples ranged between (1370-58500 µs/cm) and their average was (6691.8 µs/cm). When comparing EC values with suggested Table- 2 by [10], which show the relationship between electrical

conductivity and water mineralization, it can be concluded that the type of groundwater in the studied area is as excessively mineralized water due to the salinity.

Table 2 - Relationship between electrical conductivity and water mineralization [10].

EC µS/cm	Mineralization
<100	Very Weakly Mineralized water
100-200	Weakly Mineralized water
200-400	Slightly Mineralized water
400-600	Moderately Mineralized water
600-1000	Highly Mineralized water
>1000	Excessively Mineralized water

Hardness is a measure of the effect of water on the ability of soap to form suds, this results from the presence of dissolved calcium and magnesium salts usually carbonates , it can cause scaling problems in pipework and heating systems due to the nature of the dissolved salts. TH values of this study are compared with classifications of water hardness [6,8,9], and as a result the groundwater in the studied area is classified as hard to very hard water, and Table-3 shows the maximum, minimum and average values of pH, TDS, EC, TH, cations and anions of studied wells in ppm units.

Table 3-the maximum, minimum and average values of pH, TDS, EC, TH, cations and anions in ppm, in comparison with [13,14].

Parameters	Range	Average	Iraqi Standard 2009	WHO Standard 2007	Exceeding limits
pH	7.09-7.71	7.31	6.5 - 8.5	6.5 - 8.5	Not exceed
TDS	1130 - 40400	4926.9	1000	1000	Exceed
EC	1370 - 58500	6691.8	1500	1530	Exceed
TH	174.6 -12457.5	1592.93	500	500	Exceed
Ca^{2+}	37 - 3006	353.76	150	75	Exceed
Mg^{2+}	20 - 1213	172.44	100	125	Exceed
Na^{+}	80 - 5539	621.44	200	200	Exceed
K^{+}	1 - 897	57.802	12	12	Exceed
Cl^{-}	154 - 7384	851.5	350	250	Exceed
$SO4^{2-}$	309 - 10176	1305	400	250	Exceed
HCO_3^{-}	47 - 6100	563.04	200	200	Exceed
$NO3^{-}$	1.1 - 24	4.9	50	50	Not exceed

Piper [11] trilinear diagram is hydrochemical classification to determine the quality and the important properties of groundwater, this classification depends on the main cations and anions concentrations by equivalent weight unit of ion (epm). GW MODFLOW version.4 software was used for drawing this diagram to display the relative concentrations of the different ions in water samples of studied area Figure-2. It shows that there are two hydrochemical facies for all groundwater samples ;they are "

earth alkaline water with increased portions of alkalis with prevailing sulfate and chloride" and " Alkaline water with prevailing sulfate and chloride" respectively. The major hydrochemical facies being (Ca^{2+} - Mg^{2+} - Cl^- - $SO4^{2-}$) and (Na^+- K^+ - Cl^- - $SO4^{2-}$).

In this study, is used Chadha [12] classification to get to the general properties of water for more accurate details that are not available in Piper classification. It is constructed by deciding the difference between alkaline earth and alkali metals and the difference between weak acidic anions and strong acidic anions by milliequivalent percentage (epm%) on the X &Y axises. X- axis represents the difference between Alkaline earth and Alkaline metallic [(Ca^{+2} +Mg^{+2}) - (Na^+ + K^+)](epm %), while Y-axis represents the difference between weak and strong acids [(HCO_3^- + CO_3^{-2}) – (Cl^- + $SO4^{-2}$)] (epm %) [12] Figure-3. It is clear from Chadha plot of the analyzed samples, that water types are located within (part 4), (part 6) and (part 7), which means type of groundwater samples. (part 4) is strong acids anions exceed weak acids anions. While the samples that belong to (part 6) are (Alkaline earths exceed alkali metals and strong acids anions exceed weak acids anions). This type has permanent hardness and not residual sodium carbonate Na_2CO_3 in irrigation use; represented by Ca^{2+}-Mg^{2+}-Cl^- water type, and Ca^{2+}- Mg^{2+} dominant - Cl^- type, or Cl^--dominant Ca^{2+}-Mg^{2+} type water. And the last type (part 7) is (Alkali metals exceed alkaline earths and strong acids anions exceed weak acids anions). This type generally creates salinity problems both in irrigation and drinking uses; represented by Na^+-Cl^--type, Na_2SO_4-type, Na^+ dominant Cl^--type, or Cl^--dominant Na^+-type water.

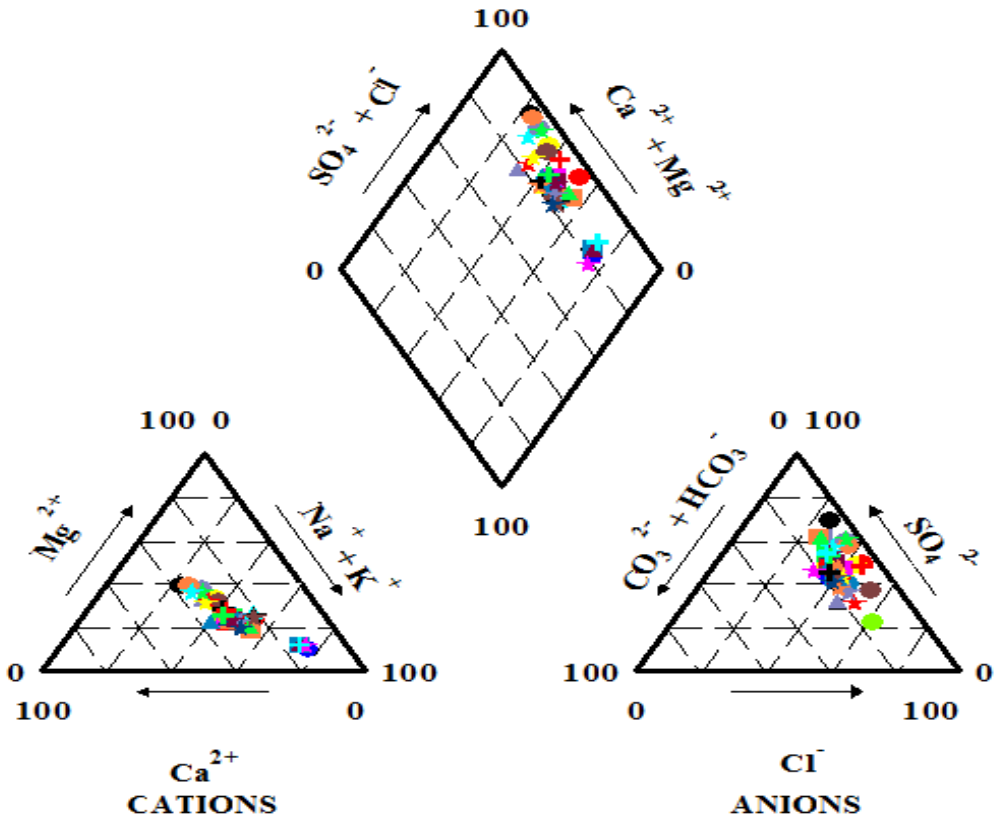

Figure 2- Piper [11] Trilinear diagram of studied samples

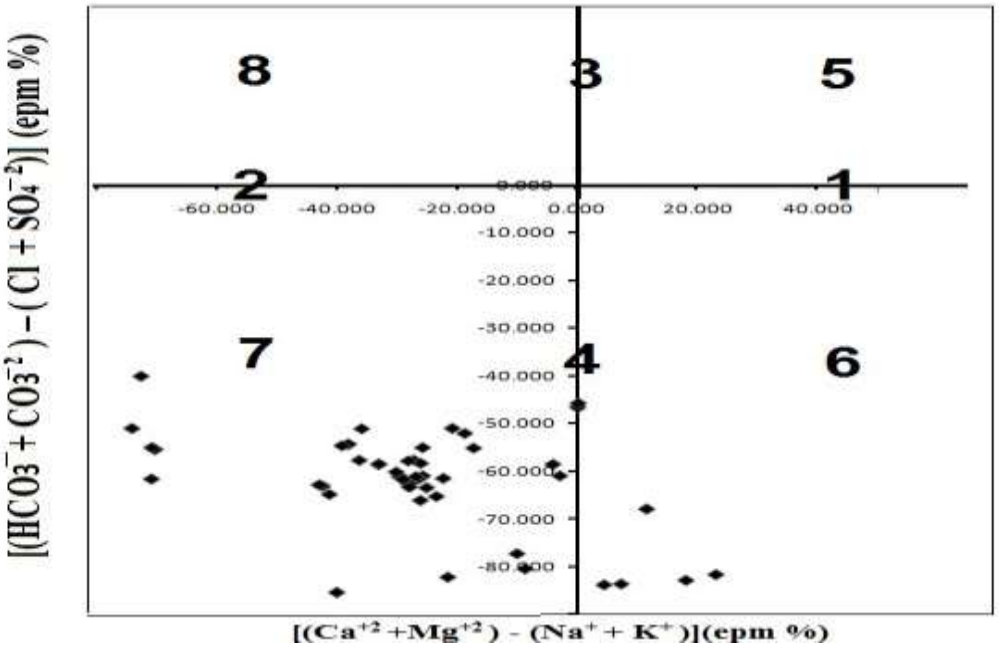

Figure 3- Chadha [12] classification for water samples of studied area.

The evaluation of Groundwater suitability for human drinking purposes is carried out by comparing its hydrochemical parameters with some standard limits. In this study they are Iraqi standard [13] and World Health Organization standard [14]. The average of analyzed water samples in (ppm) unit are compared with these standards as shown in Table-3. As a result the groundwater, in study area, is unsuitable for human drinking purposes.

Concerning suitability for livestock purposes, they are evaluated by using classification of [15] Which shows that all water samples in the study area are satisfactory for livestock. After that , evaluation for industrial purposes have been done according to [16], It is clear that all water samples are not suitable for industrial purposes. And for conducting Suitability for building purposes is carried out by [6] standard, which emphasized all water samples are suitable for building purposes, except (HCO_3^-) concentration is unsuitable.

As for the subject of groundwater suitability for irrigation purposes. Salts are present in variable concentrations in all water and the salt concentrations influence osmotic pressure of the soil solution. Plants can absorb water readily when osmotic pressure is low, but absorption becomes more difficult as the pressure increases [17], therefore this evaluation depends on three classifications, as follows :Soluble Sodium Percentage (Na%), Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonate (RSC).

Soluble Sodium Percentage (Na%) in irrigation water will affect in porosity and permeability of soil, When it increases it leads to a decrease in porosity and permeability , thus it will affect the plant growth. It can be determined using the following formula [8]:

% Na = $(Na^{+1} + K^{+1}) / (Ca^{2+} + Mg^{2+} + Na^{+1} + K^{+1})$ X 100

Where: Concentration of ions by (epm) units.

It is clear from Figure-4, that almost analyzed samples lie within the permissible to doubtful limits except wells No. (10, 16, 33, 41, 50) were within unsuitable limit as shown in Figure-4.

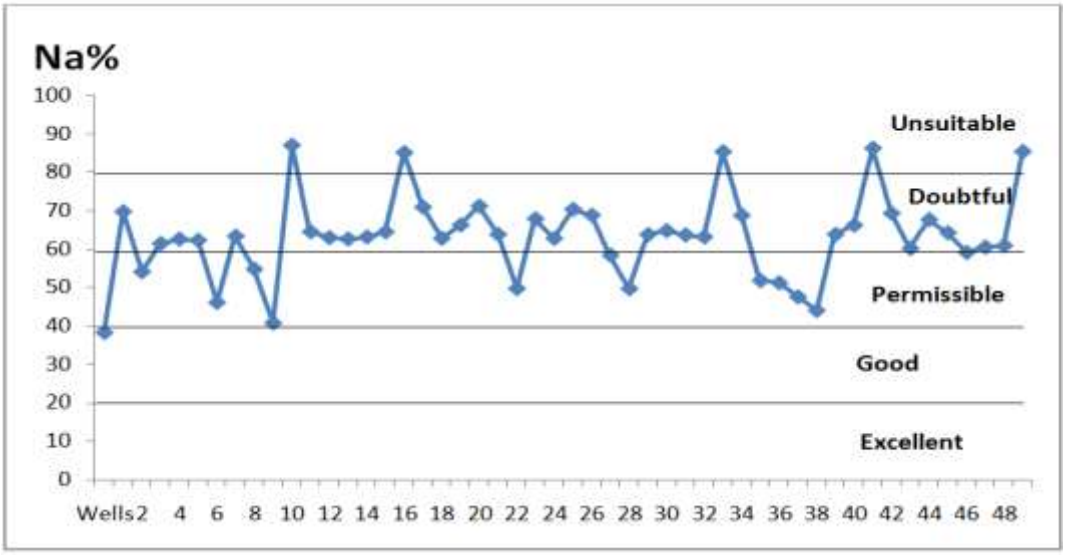

Figure 4- Na% limits for irrigation purposes of studied wells.

The sodium adsorption ratio (SAR) values are used for estimation of infiltration problems for soil. As a result of sodium increase with relative to the sum of calcium and magnesium in a ratio of (1:3) (SAR) can be calculated by the following equation:

$$SAR = \frac{Na^{+}}{\left\{\frac{Ca^{2-} + Mg^{2+}}{2}\right\}^{1/2}}$$

Where: Concentration of ions by (epm) units.

The result of (SAR) plot according to The US Salinity Laboratory of the Department of Agriculture [18] in Figure-5, indicated that all groundwater samples are located within the excellent and good limits except well number (45) which was in doubtful zone.

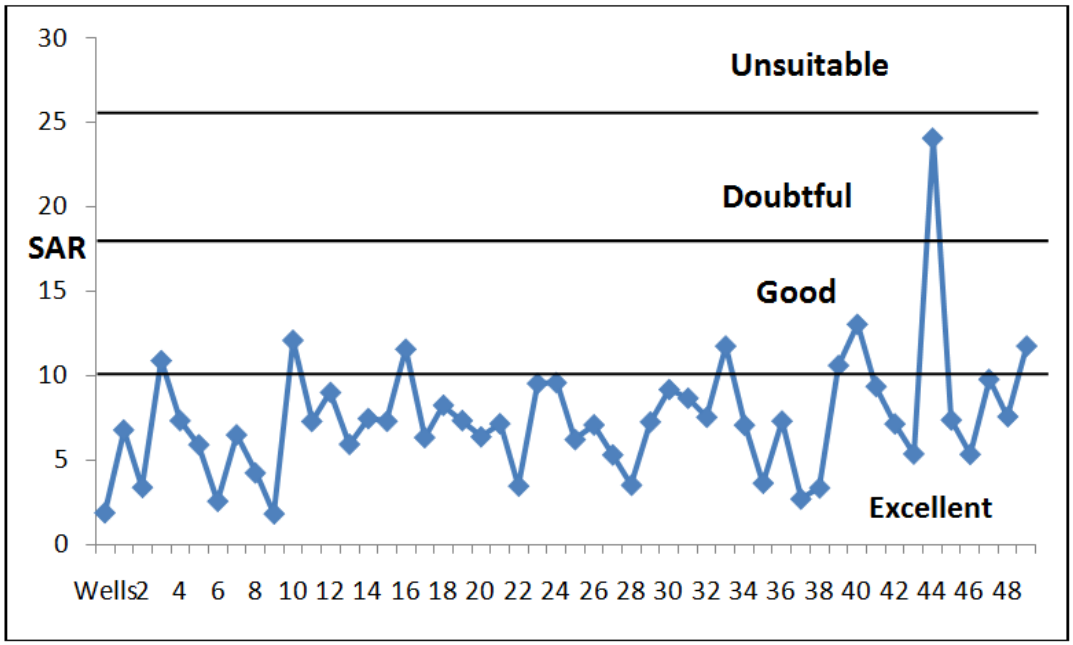

Figure 5- SAR limits for irrigation purposes of studied wells.

The last classification of irrigation water in this study is residual sodium carbonate (RSC). Increasing of concentration of bicarbonate leads to precipitation of calcium and magnesium in the soil, thus the sodium concentration will increase [19]. RSC is calculated using the following equation:

$RSC = (CO3^{2-} + HCO3^{-}) - (Ca^{2+} + Mg^{2+})$ (epm)

It is noted from plotted (RSC) values in Figure-6, that most values are ranged from doubtful to unsuitable for irrigation purposes, except wells No. (10, 16, 33, 41, 50), they proved good quality for irrigation purposes.

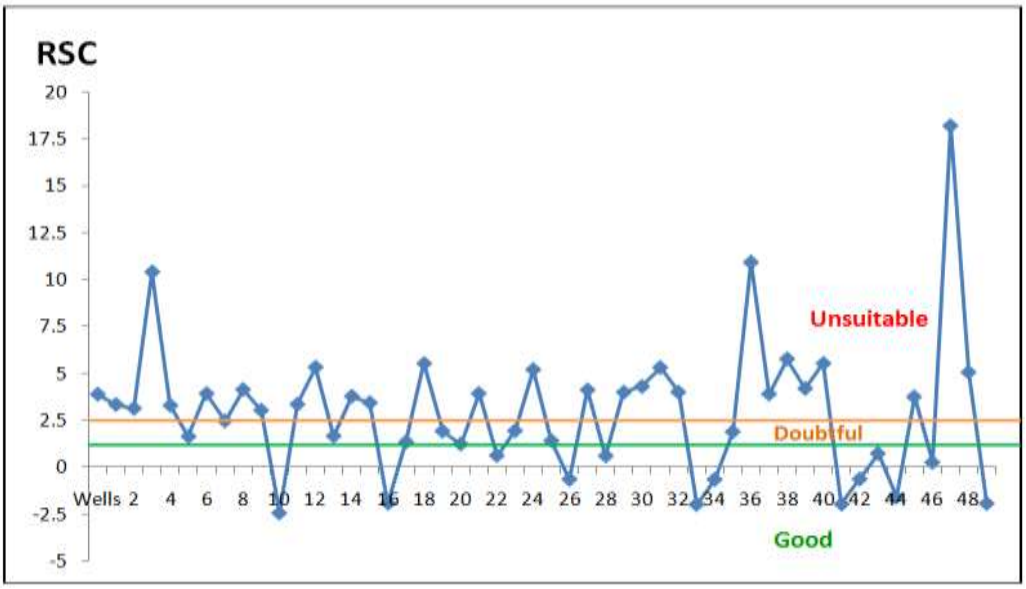

Figure 6- RSC limits for irrigation purposes of studied wells.

Conclusion

1- The pH of groundwater in the studied area indicate that there are two kinds ; neutral and light alkaline water . TDS values of groundwater are classified as slightly-brackish water.
2- According to EC values, the type of this groundwater is excessively mineralized water due to the salinity, and TH values indicate hard to very hard water.
3- There are two hydrochemical facies for all groundwater samples , " earth alkaline water with increased portions of alkalis with prevailing sulfate and chloride" and " Alkaline water with prevailing sulfate and chloride" belong to (Ca^{2+} - Mg^{2+} - Cl^{-} - $SO4^{2-}$) and (Na^{+}- K^{+} - Cl^{-} - $SO4^{2-}$).
4- The groundwater in study area is unsuitable for human drinking purposes, satisfactory for livestock, and unsuitable for industrial purposes.
5- The suitability for irrigation purposes for studied wells ranged between unsuitable to doubtful according to (Na%) and RSC , but it was excellent to good limits according to SAR.

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