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Evaluating the Suitability of Groundwater for Irrigation uses at Al-Salhubia Area, Al-Muthana Governorate, Southern Iraq

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Abstract

Al-Salhubia, area is located within the arid region in southern Iraq. Although no surface water is available in this area, the groundwater is considered the basis in the area, it is available in both good quality and quantity. For that reason, it is of prime importance to examine water type in the unconfined aquifer to determine suitability of groundwater for irrigation purposes. The groundwater type in the studied area is Ca-Mg dominant SO_4 facies according to Piper and Stiff diagrams. Based on SAR, Na%, RSC, EC, and PI, the groundwater quality in the study area is suitable for irrigation in general.

Keywords: groundwater suitability, irrigation, groundwater type, Al-Salhubia

تقييم مدى ملائمة المياه الجوفية لأستخدامات الري في منطقة آلسلحوبية محافظة المثنى جنوب العراق

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الخلاصة

تقع منطقة السلحوبية ضمن المنطقة القاحلة في جنوب العراق. ولعدم توفر المياه السطحية، تعتبرالمياه الجوفية الأساس في المنطقة وهي متوفرة بصورة جيدة نوعا وكما. لهذا السبب فان من المهم دراسة نوعية المياه في الخزان غير المحصور لتحديد ملائمة المياه الجوفية لأغراض الري. تتميز المياه الجوفية في منطقة الدراسة بسيادة سحنة كبريتات الكالسيوم والمغنيسيوم وفقا لمخططات Piper وStiff . استنادا الى EC, RSC, Na%, SAR و PI تبين أن نوعية المياه الجوفية في منطقة الدراسة هي مناسبة للري بشكل عام.

Background

In southern Iraq, semiarid and arid regions with low precipitation and high potential of evapotranspiration are abundant. Rapid investment growth through last years, increased irrigation, and industrial development during the past decades have caused an increasing demand on water resources in semiarid and arid regions [1].

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The increased knowledge of geochemical processes that control groundwater chemical composition could lead to improve the understanding of hydrochemical systems in such areas. Such understandings like rock-water interactions, aquifer lithology, and dissolution and residence time of groundwater may be helpful to improve the groundwater quality. The hydrochemical of groundwater is an important factor in determining its use for different patterns such as agriculture, industry, livestock ranches and household activities. Water quality has an individual pattern of physical and chemical characteristics, which are determined largely by the climatic, geomorphological and geochemical conditions prevailing in the drainage basin and the underlying aquifer [2].

Al-Salhubia area is considered one of the good areas in Al-Samawa Governorate, where it depend on groundwater in possessing different economic activities such as agriculture, industry, and livestock breeding for pastoral purposes. Groundwater is regarded as the only essential source for water in the area and is available in both good quality and quantity. Water users in that region have been dependent on groundwater quality and use to meet their needs for water-related irrigation [3].

Some previous investigations were conducted in this region. The authors, Parsons Company (1957) [4] and GEOSURV (1983) [5] carried out some of the hydrogeological and hydrochemical studies for southern desert, which include the Salman basin. These studies covered the evaluation of some hydrochemical properties of the water springs, the discharge measurement and suitability of available water in the area**,** and the reasons for the presence of springs along the western edge of the Euphrates river. They reported that the reason for this amount of water was due to the presence of faults in Al-Furat fault zone, which is of great importance. These authors were not able to break out historical groundwater use patterns across the various uses such as agriculture, industry, livestock ranching, and domestic uses. This important gap motivates the current investigation.

AL-Shamma`a (2000) [6] focused on investigating the origin of the spring water in south of Euphrates river. She studied the water chemistry for some wells and springs in an approach to find the relationship between the compositional structure of the basin and spring water.

A comprehensive study of Al-Rehab area located southwest of Samawa city was carried by Al-Shamari (2006) [7]. He found that the groundwater use patterns have exceeded the amount of groundwater recharge at the basin.

Despite these achievements described above, important gaps remain in the search for suitability of groundwater in different uses including agriculture. Therefore, the present study aims to evaluate the suitability of groundwater in Al Salhubia for agricultural activities.

Study Area

The study area is located in the stable zone of Iraq southwest Al-Samawa city in a distance of about 70 km. It occupies an area over 3,000 km^2 (80km in length and 37.5km in width). The surface of the study area is nearly flat and generally slopes in a southwest where the elevation reaches 200 m above sea level while towards the northeast; the elevation is less than 110m with low degrees of slope as seen from the main direction towards the Euphrates river Figure-1.

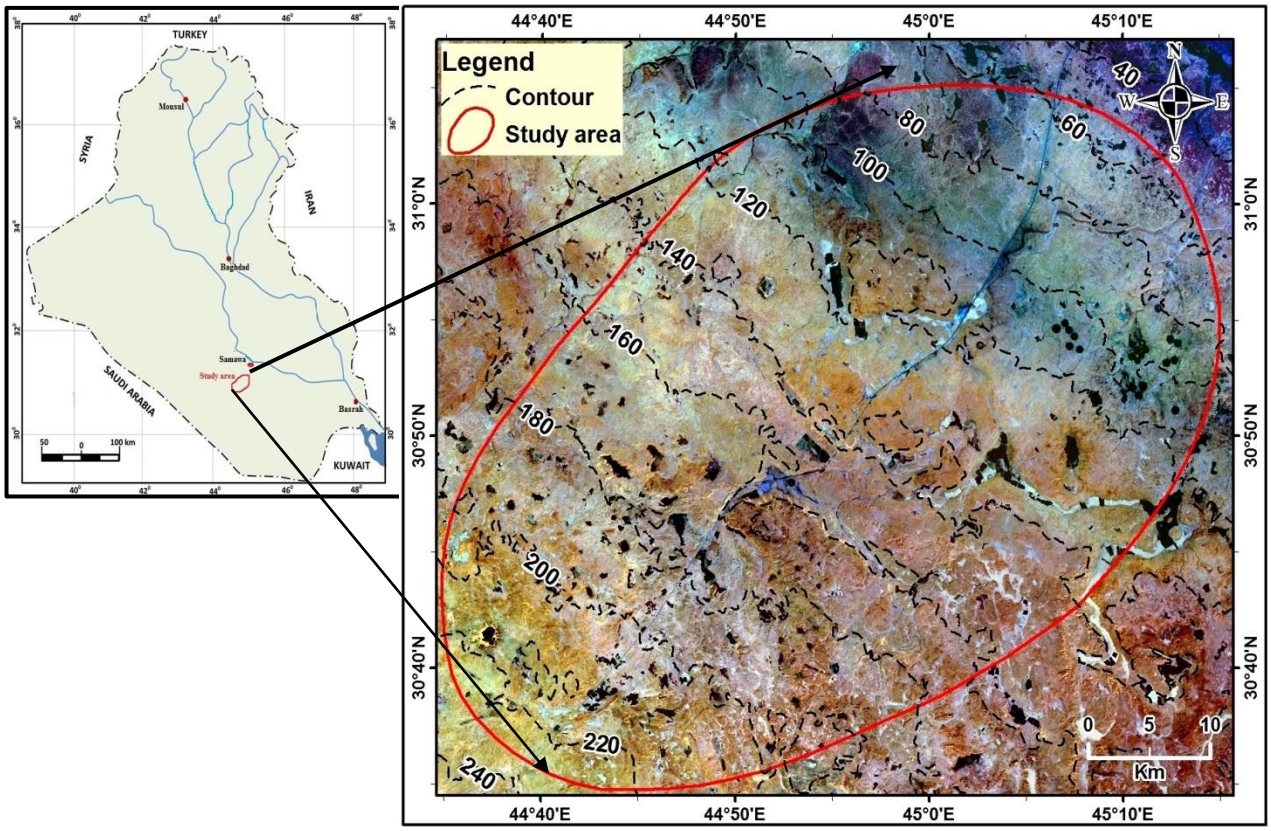

Figure 1-Location map of Al-Salhubia area, Iraq.

The main aquifer in Al-Salhubia area is located within Al- Dammam Formation that exposed in most of the study area and it is one of the most important aquifers in southwestern Iraq. It is composed of variable carbonate rocks mainly limestone, dolomitic limestone and dolomite, with marl and evaporates Figure- 2. It is characterized by the presence of cavities and karstified canals in addition to fractures, fissures and joints that caused the formation to have high transmissivity and permeability in most areas [8]. Such conditions disturb the flow regime of groundwater and open up places where groundwater appears as springs.

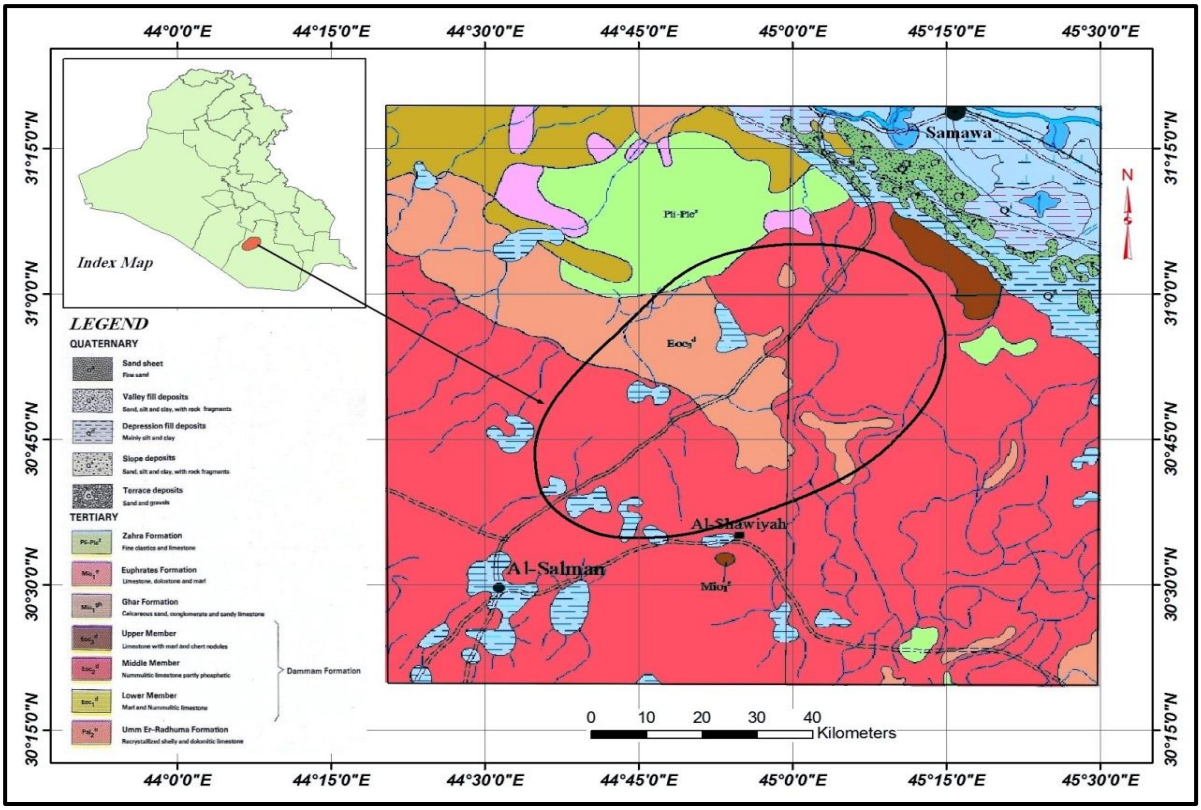

Figure 2-Geological map of Al- Salhubia area (Modified from GEOSURV, 1996) [9].

Dammam Formation is considered the main invested reservoir in the area through existing wells. This aquifer is unconfined and inhomogeneous. The thickness of the aquifer increasing from southwest to northeast direction and the aquifer is gently dipping in the same direction, the movement of groundwater from the west and southwest towards the east and northeast Figure-3.

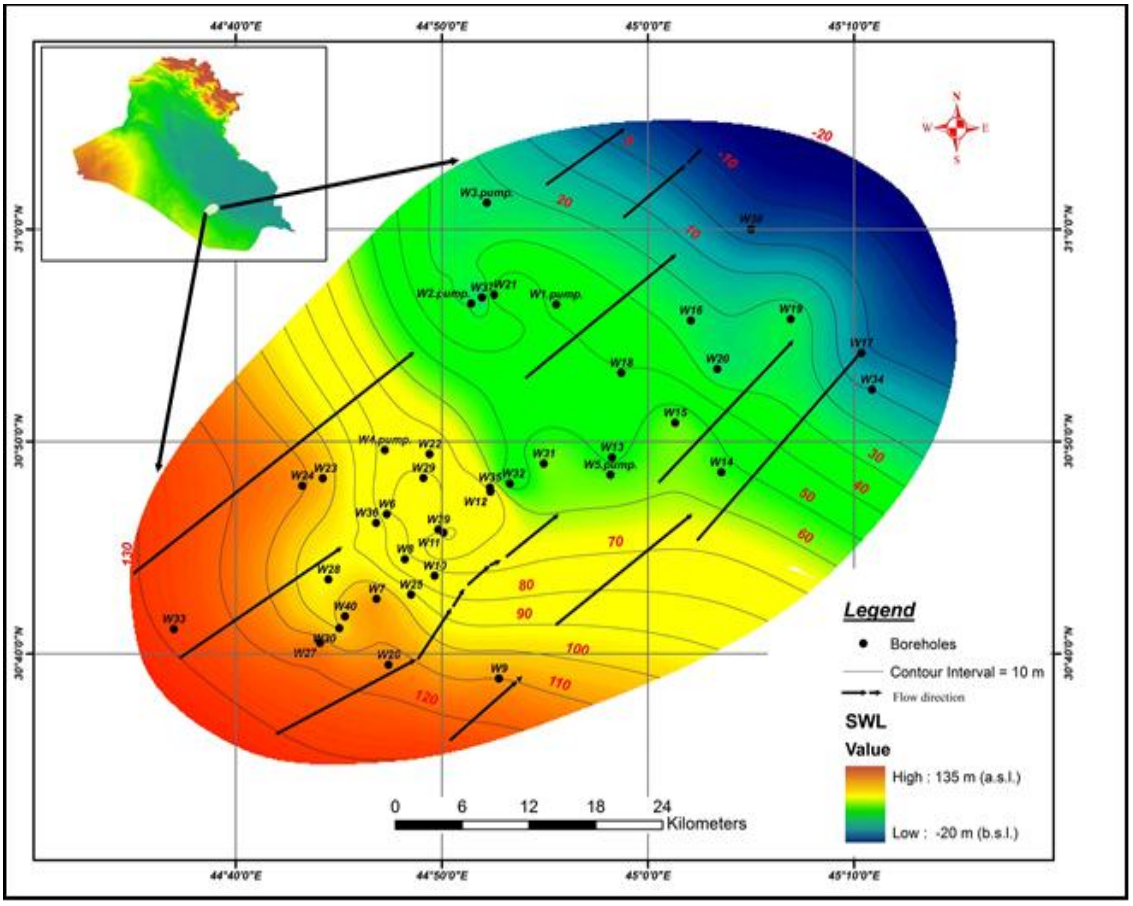

Figure 3- Flow net map of Dammam aquifer in Al- Salhubia area.

1. Methodology

2.1.Field Work

Twenty groundwater samples in the study area were collected from production wells and pumping wells Figure -4. It is clear that measuring the chemical composition of a water sample collected in the field is just the first step in determining water quality. The sample analysis in the laboratory is the second step to determine the following physicochemical properties: Electrical Conductivity (EC), Total Dissolved Solid (TDS), pH, cations which are Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^{+}) and Potassium (K^{+}), and the anions which are Chloride(Cl^{-}), Sulfate (SO_4^{2-}), Total Alkalinity (HCO_3^{-} and $CO_3^{=}$). The concentrations in ppm (mg/l) for cations and anions were converted to equivalent per million (epm).

The physicochemical analysis of water samples were carried out in accordance to standard analytical methods [10]. These analyses were performed at the Hall Environmental Analysis Laboratory, Albuquerque, New Mexico State, USA, in March 2015.

The fieldwork was carried out with support from the General Commission for Groundwater and Ministry of Water Resources in Iraq.

The survey included questionnaire farmers to determine the type of cultivated crops, their cultivated season and the water quantity needed for irrigation [3].

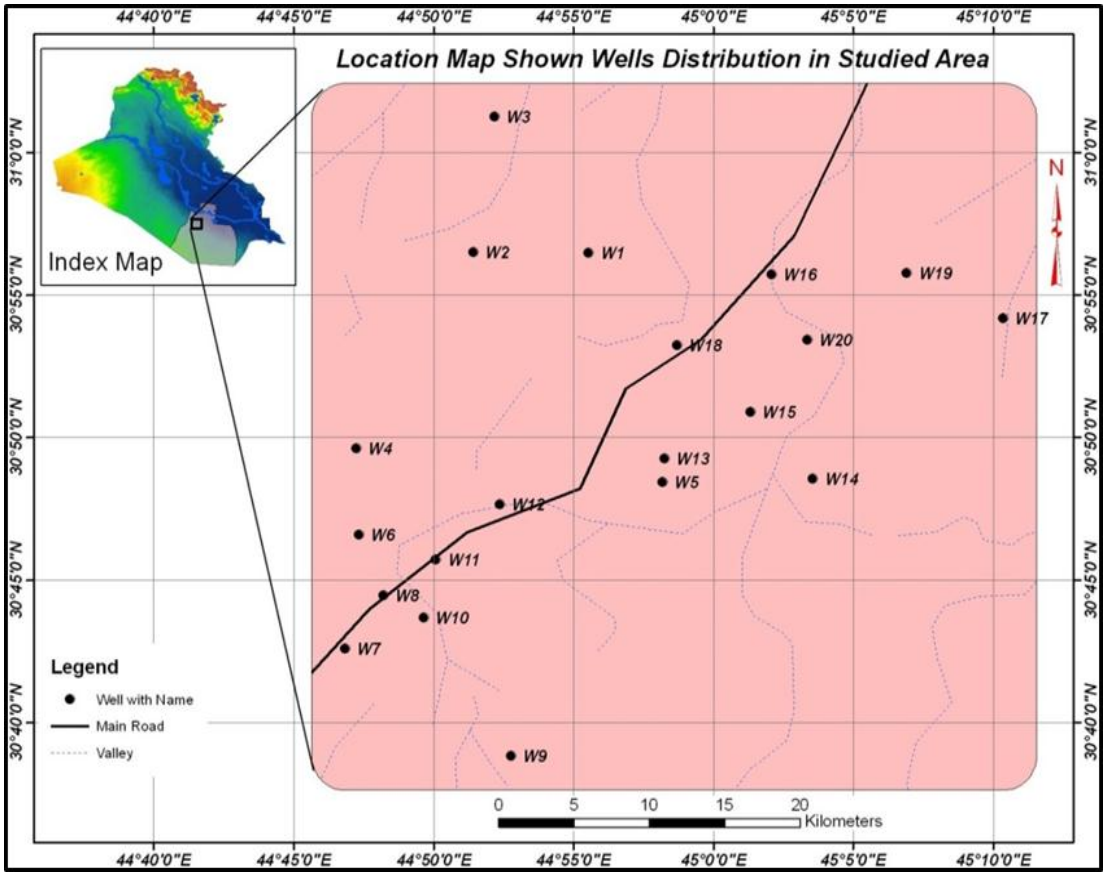

Figure 4 - Location map of groundwater samples, Al-Salhubia area

2.2 Groundwater Used in Irrigation

Water quality analysis is one of the most important aspects in groundwater studies. Hence, the hydrochemistry of groundwater is an important factor in determining its use for different aspects such as agriculture, industry, livestock ranches and household activities. The suitability of groundwater for irrigation depends on the plant's ability to withstand the groundwater salinity. Therefore, the water quality plays a significant role in agriculture.

There are many problems, which may originate during the use of water for irrigation, such as salinity, infiltration and permeability due to other factors effect on sensitive crops, so, the groundwater that contain high ratio of salt will effects on crop growth. As well as, the pH, Sodium, and trace elements also effect the suitability of water for irrigation [11]

2.3 Results and discussion

Classification of Groundwater in the study area

The classification of the groundwater depends on Piper (1944)[12]and Stiff (1951)[13] diagrams. It shows that the groundwater has a secondary salinity due to Piper classification (Figure-5), while according to stiff diagram; the groundwater in the study area is of a single source and not from different sources Figure-6. Depending on the above classifications, the hydrochemical facies are Ca–Mg dominant SO_4facies with a same source.

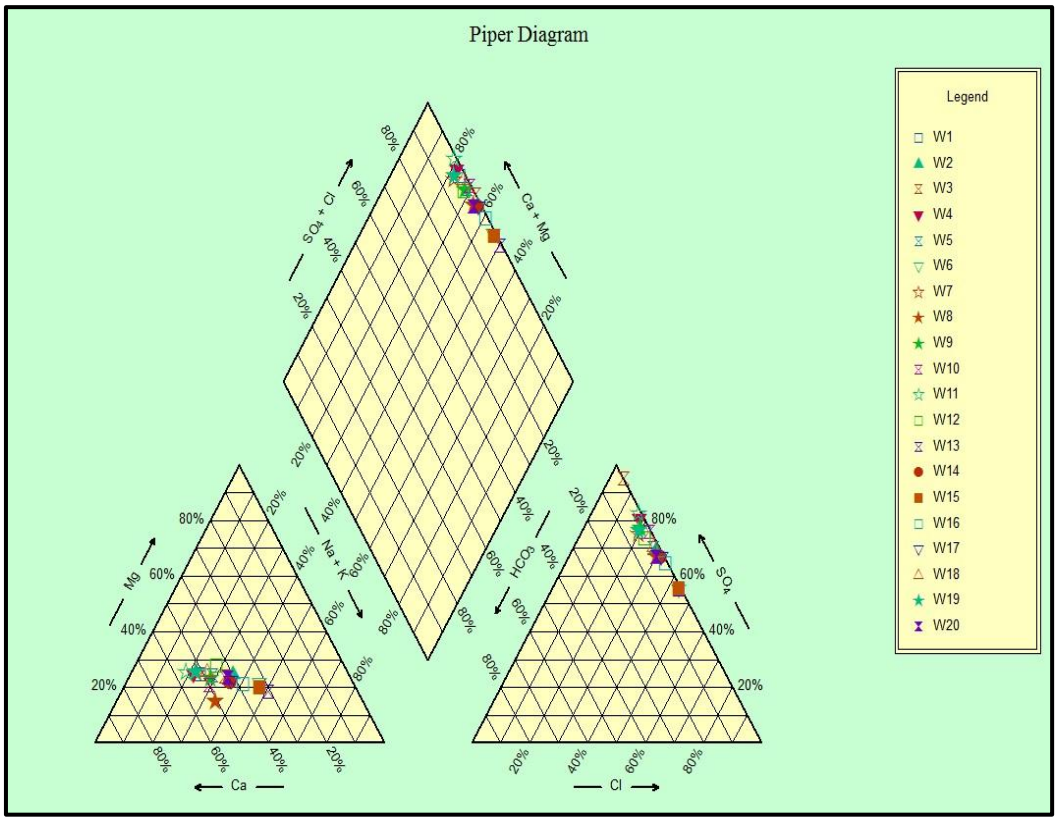

Figure 5- Piper diagram for groundwater samples that showing hydrochemical facies, Al-Salhubia area.

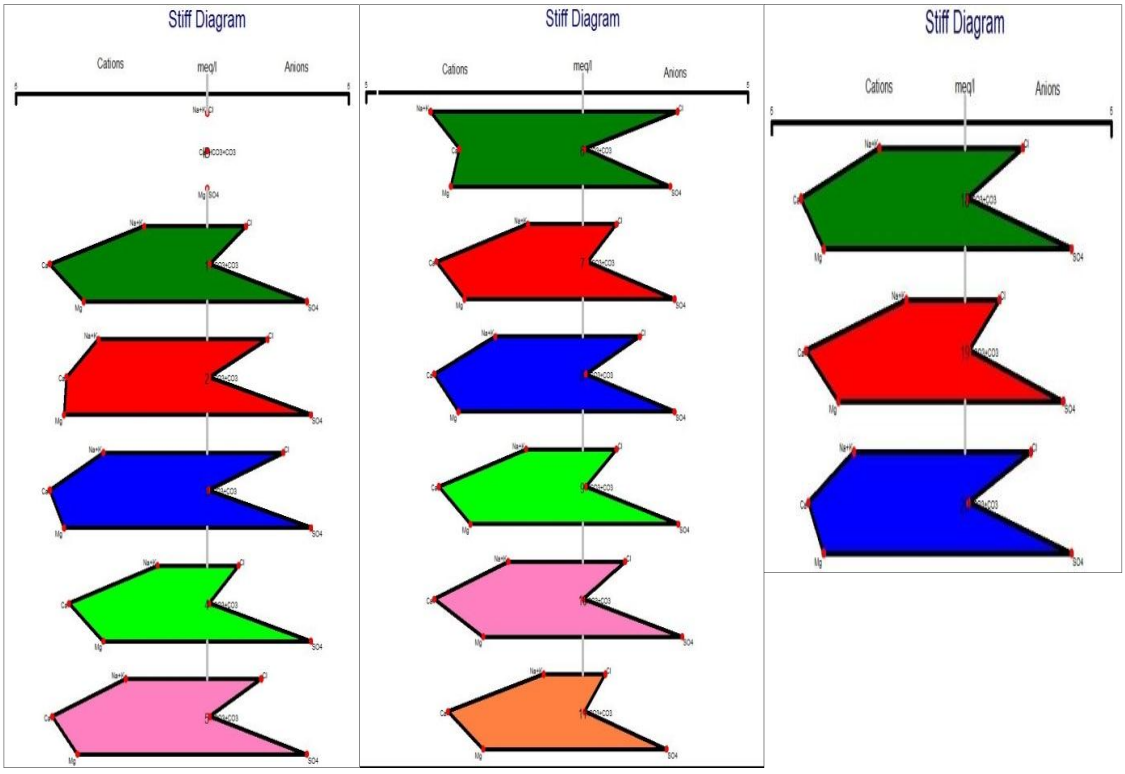

Figure 6- Stiff diagram for the ionic concentrations in groundwater samples Al-Salhubia area.

The main results of groundwater chemical analysis in the study area are given in Table -1. The interpretation of the groundwater quality data for irrigation has been carried out through measuring Sodium Adsorption Ratio (SAR), Sodium percentage(%), Residual Sodium Carbonate (RSC), Electrical conductivity (EC) and Permeability Index (PI).The following explain and describe the classifications in details:

1-Sodium Adsorption Ratio (SAR)

SAR is an important parameter for the determination of soil alkalinity or alkali hazard in the use of groundwater for irrigation purposes. Calculation of SAR value for a given groundwater provides a useful index of the sodium hazard in water for soils and crops. The value of SAR can be calculated using the following equation [14]:

$$SAR = \frac{Na}{\sqrt{\frac{Ca+Na}{2}}} \text{ -----} \qquad \text{----- (1)}$$

The value of SAR in the groundwater samples of the study area ranged from 2.2 to 8.2 epm with an average 4.4 epm (Table 1), which represent low alkali hazard and is suitable for any type of crops to be cultivated. Don (1995) [15] has classified water for irrigation purposes depending on the values of pH, EC, TDS, SAR, and Na% Table- 2. Accordingly, all groundwater samples fall under the classification of good.

Table 1- Concentration of ions and important irrigation water classifications, Al-Salhubia area.

Parameters, Ions and classifications	Units	Minimum	Maximum	Average
pH	-----	7.5	7.9	7.7
TDS	ppm	3760	6460	4834
Ca^{+2}	epm	26.5	33.5	30.5
Mg^{+2}		13.2	18.2	16.0
Na^{+}		9.6	52.2	22.8
K^{+}		0.4	1.1	0.7
Cl^{-}		8.7	50.7	22.2
$SO_4^{=}$		43.8	56.3	50.1
HCO_3^{-}		0.4	3.0	1.5
SAR		2.2	8.2	4.4
Na%		19.0	53.0	32.0
RSC		-50.0	-37.5	-45.0
EC	µs\cm	4000	7800	5635
PI	epm	20.8	51.9	34.7

2- Sodium percentage (Na %)

The sodium concentration is very important in assessing groundwater with respect to suitability as irrigation water [16]. The high content of sodium ion in irrigation water will be dangerous on soil since it leads to decrease its porosity as a result of ionic exchange of calcium and magnesium in the soil with sodium. Ordinarily, either type of sodium-saturated soil will support little or no plant growth. Na% value can be calculated by the following equation [14]:

$$\text{Na\%} = \frac{\text{Na+K}}{\text{Ca+Mg+Na+K}} \times 100 \text{ ----------} \qquad \text{------- (2)}$$

Table -1 shows that Na % lies within the permissible limits and do not exceeds 60% according to Don classification (1995) Table- 2 .

3-Residual Sodium Carbonate (RSC)

Eaton (1950) [17] has suggested a formula to the residual sodium carbonate (RSC). Where the concentration of bicarbonate and carbonate used in assessing groundwater quality also influences the suitability of water for irrigation purpose. RSC can be calculated using the following equation:

$RSC = [(CO_3^{2-} + HCO_3^-) – (Ca^{2+} + Mg^2)]$ --- ---------- (3)

Richard (1954) [18] classified the water on the basis of RSC Table- 3. Based on this classification, results indicate that the groundwater in the study area is good for irrigation.

Table 2- Classification of Don (1995) for irrigation water.

EC µs\cm	TDS Ppm	SAR	Na%	pH	Water Quality
250	175	3	20	6.5	Excellent
251−750	175-525	3-5	20-40	6.5-6.8	Good
751−2000	525-1400	5-10	40-60	6.8-7.0	Permissible
2001−3000	1400-2100	10-15	60-80	7-8	Doubtful
>3000	>2100	>15	>80	>8	Unsuitable

Table 3-Richard classification (RSC) for irrigation water (1954).

Range	Water quality
< 1.25	Good
1.25-2.5	Medium
>2.5	Bad

4- Electrical conductivity (EC)

Electrical conductivity (EC) is important in assessing groundwater quality that affecting on crop productivity. Don, (1995) [15] classified water for irrigation purposes, which depends on EC values Table- 1. Based on this classification, results indicate that the groundwater in the study area is unsuitable for irrigation, because the water of the Dammam unconfined aquifer is excessively mineralized water. Todd classification (2007) [14], which depends on electrical conductivity for the plants tolerance difference show that the groundwater of the study area is suitable for all kinds of crops Table- 4.

Table 4-Todd classification for tolerance crops by relative salt concentrations for agriculture (2007).

Crops Division	Low salt tolerance crops Ec (µs /cm)	Medium salt tolerance crops Ec (µs /cm)	High salt tolerance crops Ec (µs /cm)
Fruit Crops	0 ─ 3000 Limon, Apricot, Pear, Orange, Apple, Peach	3000 ─ 4000 Olive, Figs, Cantaloupe, Pomegranate	4000 ─ 10000 Date palm
Vegetable Crops	3000 ─ 4000 Green beans, Celery, Radish	4000 ─ 10000 Cucumber, Onion, Carrot, potatoes, Lettuce, Tomato, Cauliflower	10000─12000 Spinach, beets
Field Crops	4000 ─ 6000 Fields beans	6000 ─ 10000 Sunflower, Flax, Corn, Rice	10000─ 16000 Cotton, Sugar beet, Barley (grains)

5- Permeability Index (PI)

The soil permeability is influenced by long-term use of irrigation water and sodium, calcium, magnesium, bicarbonate content of the soil [19]. Doneen (1964) [20] has evolved a formula for permeability index (PI) to measure the soil permeability for assessing suitability of groundwater for irrigation purpose. This index is depended on Ca, Na, Mg, and HCO_3 ions, which can be calculated by the following equation:

$$PI = \frac{Na + \sqrt{HCO3}}{Ca+Mg+Na} \times 100 \text{----------} \quad \text{---------- (4)}$$

Doneen (1964) [20] has divided this classification, the Permeability Index (PI) values less than 25% falls into Class-I and Class-II includes PI values that range between 25% and 75% are classified as good for irrigation, as for Class-III includes PI values greater than 75% is unsuitable for irrigation [21]Table- 5. Based on this classification, results indicate that the groundwater in the study area is under class-II, and class-I, which represents 5% and 75% respectively, which considered as good for irrigation.

Table 5-Doneen classification for Permeability Index(PI) for irrigation water(1964), Al-Salhubia area.

PI class	**Range**	**Sample no.**	**Total no.**	**Percentage (%)**
Class-I	< 25	3,6,10,18,22	5	25
Class-II	25-75	1,2,4,5,7,8,9,11,12, 13,14,15,16,17,19,20	15	75
Class-III	>75	----------	----------	----------

2.5 Conclusions

The Dammam unconfined aquifer is considered the most important regional aquifer in the studied area. According to the type of groundwater, the water type shows that the hydrochemical facies are Ca–Mg dominant SO_4 facies of the same source.

The suitability of groundwater for irrigation has been assessed based on SAR, Na%, RSC, EC, and PI. According to these classifications, the groundwater quality in the study area is suitable for irrigation in general. During the fieldwork, flood irrigation methods are the only irrigation method used in the area, which may lead to increase in levels of water use as well as increased soil salinity. Therefore, it may be more suitable to irrigate by modern irrigation methods such as drip irrigation or sprinkler systems, especially in conditions where these methods will save water and protect soils.

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References

1. Elaine, D., Kristina, D., Roland, M., Geoffroy, P., and Tetsuya, U. **2008**. Sustainable Water Strategies for Jordan, International Economic Development Program Gerald R. Ford School of Public Policy, University of Michigan.

2. Sen, A. Z. **2015**. *Practical and Applied Hydrogeology*, Elsevier, Inc. First edition, 407p.

3. Directorate of Al-Samawa Agriculture, **2015.** Data of Agricultural production in Al-Salhubia,Iraq.

4. Parsons, R. M., Eng. Co. **1957**. Groundwater Resources of Iraq-Ministry of development, Government of Iraq. Unpublished report- Engineering co.

5. GEOSURV.**1983.** Final report on key well No.5 Al-Salhubia Hydrogeological and Hydro-technical exploration in block1,2,3,Vol. (8-5).

6. Al-Shamma′a, A. M. **2000.** The Source of Water Springs along the faulted zone of Southern Euphrates River. *Iraqi Geological Journal*, vol. 33, pp:129-145.

7. Al-Shamari, A. N. **2006.** Hydrogeology and Hydrochemistry of Rehab area/South and South-West of Samawa city. M.Sc. Thesis, University of Baghdad, College of Science (un published). 110p. (In Arabic).

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

9. GEOSURV, **1996**. Geological map of Iraq, scale1:1,000,000 Baghdad, Iraq.

10. USEPA (United State Environmental Protection Agency),2012: 2012 Edition of the Drinking Water Standards and Health Advisories, Report EPA 820-R-11-002, Office of Water U.S. Environmental Protection Agency Washington, DC.
11. Todd, D.K. **2005.** *Groundwater Hydrology*, 3rd ed., Wiley and Sons Inc., New York, U.S.
12. Piper, A. M. **1944.** A graphic procedures in geochemical interpretation of water analysis. *Trans. Am. Geophys. Union* 25, pp: 914 – 923.
13. Stiff, H. A. **1951** :The interpretation of chemical water analyses by means of Patterns', *Jour. Petroleum Technology*, 3(10), Section1, 15-17; Section 2,3.
14. Todd, D. K. **2007**. *Groundwater hydrology*, second edition, John Wiley and Sous, Third Reprint. Inc. India. 535p.
15. Don, C.M. **1995**. A grows guide to water quality. University college station, Texas.
16. Khodapanah, L., Sulaiman, W.N.A., and khodapanah, N. **2009**. Groundwater quality assessment for different purposes in Eshtehard District, Tehran, Iran. *European Journal of Scientific Research*, 36(4), pp:543-553.
17. Eaton, E.M. **1950.** Significance of carbonate in irrigation water. *Soil. Sci*., 69, pp: 123-133.
18. Richards, L.A**. 1954.** *Diagnosis and Improvement of Saline and Alkali Soils*. USDA and IBH Pub, Coy Ltd., New Delhi, India. Agric. Handbook 60, pp: 98-99.
19. Raju N. Janardhana., **2007**. Hydrogeochemical parameters for assessment of ground water quality in the upper Gunjanaeru River basin, Cuddapah District, Andhra Predesh, South India, *Environmental Geology*, 52, pp: 1067-1074.
20. Doneen L. D. **1964**. Water Quality in Agriculture, Water Science and Engineering Paper 4001, California, Department of Water Science and Engineering, University of California.
21. Nagaraju, A., Suresh, S.,Killhan, K.,and Hudson-Edwards,K. **2006.** Hydrogeochemistry of waters of management barite mining area, Cuddapah Basin, Andhra Pradesh, India. *Turkish Journal of Engineering Sciences*, 30, pp: 203-219.