



Evaluation and suitability of groundwater for irrigation purposes in Basra city -Iraq

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Abstract

This study was carried out with the aim of evaluating the quality of water for irrigation purposes in a number of wells in the Um Qasr, Safwan, and Al-Zubair areas in the city of Basra, Iraq. Groundwater samples from 9 wells have been compiled during the period July, 2024–April, 2025. The necessary laboratory analyzes were conducted on the samples to determine their physicochemical properties, comparing the results with the approved specifications for irrigation water according to the US Salinity Laboratory (USSL) and Food and Agriculture Organization classification. The results according to the USSL evaluation showed that all samples were greater than the limits specified in the classification, such as the electrical conductivity (EC) values (9077-23079 $\mu\text{s}/\text{cm}$) and SAR values (23.296-42.39). Whereas according to the FAO classification, the values of total dissolved solids (TDS) (5131-17173 mg/L), Cl^- (1458-6694 mg/L), NO_3^- (137.59-318.31 mg/L), EC (9.077-23.079 ds/m), and pH values (7.08-8.26). Therefore, all parameters exceeded the optimal limits of the FAO classification, except for the pH, which was at natural limits. This study concluded that most of the wells studied are not suitable for irrigation under normal conditions and should be following specific methods and techniques to exploit it, the most important of which is adding appropriate allocations for salt washing and following the rotational irrigation method with fresh water whenever possible; choosing crops that are tolerant to salt and sodium; and avoiding using them on heavy, poor soil exchange.

Keywords: Irrigation water, FAO, USSL classification, Groundwater Quality.

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1. Introduction

Groundwater quality assessment for irrigation and drinking water has become an indispensable and important task for economic and social development and integral management. Quality assessment as a necessary task stem from the growing trend of deteriorating groundwater and surface water quality in the study area. Therefore, for this purpose, this research was undertaken with the main focus of analyzing the physico-chemical properties of water and calculating the indices to see that this water meets the conditions to be used for irrigation.

Groundwater is one of the most valuable natural resources, supporting socio-economic development, human health, and the functioning of ecosystems. Besides, it forms one of the primary resources for development activities (Ali and Ali, 2018). Groundwater is an important source for human life and represents an important source in arid and semi-arid areas. Increasing population, municipal, industrial, and agricultural activities, as well as the natural climate changes resulting from the phenomenon of global warming, have led to major changes in water resources (surface and groundwater);

therefore, these factors have seriously increased demand for water around the world (Al-Asadi *et al.*, 2020). The water quality may yield information about the environments through which the water has circulated. Accordingly, groundwater quality is a function of its chemical and physical properties, which in turn are highly influenced by anthropogenic activities, climatic conditions, and geological formations in any area (Ramkumar *et al.*, 2013). In addition, the use of fertilizers and pesticides enhances agriculture production, but they result in an indirect and negative impact on water quality. Groundwater has received great attention since water of high quality is required for irrigation and domestic needs. The groundwater resources are not only the most important resources for drinking purposes but also exclusively for domestic, agricultural, and industrial water demands (Sen Gupta *et al.*, 2022). Groundwater pumping has allowed for significant social development, which is essential for eradicating poverty and promoting economic progress. It has also improved food security and reduced drought risk in many agricultural areas and is essential for a variety of habitats that depend on groundwater. The availability, quantity, and quality of freshwater flows, along with their levels, are critical to the sustainability of aquatic ecosystems that promote human cultures, economies, sustainable livelihoods, and public well-being (Velis *et al.*, 2017).

The main objective of this study was to assess the quality and suitability of

groundwater from some wells in the Um Qasr, Safwan and Al-Zubair area in Basra city for irrigation purposes

Materials and Methods

a. Study areas

The study was carried out on wells geographically located in the southwestern part of Basra Governorate, with an average area of 2874.2 km² between two latitudes, 30°0'-30°27' North, and longitudes 47°30'-47°55' East (Abdulameer and Al-mallah, 2018).

From a hydrological standpoint, the study area is mainly located in the Dabdaba Formation (Upper Miocene-Pliocene Dibdibah Formation), which consists primarily of gravelly-sandy soils. This formation tends to be light towards the northeast, forming the flat Dibdibah Plain.

The Dibdibah Formation consists mainly of gravel and sand with clay and silt, particularly in the western part of the Zubair area (Albadran, 2021).

The Dibdibah deposits also contain some minerals such as feldspar (NaAlSi₃O₈), quartz (SiO₂), calcite (CaCO₃), and gypsum (CaSO₄·2H₂O), while the clay minerals consist of alkalinite (K,H₃O)Al₂(Si₃Al)O₁₀(OH)₂ and polycrystalline slate (Mg,Al)Si₄O₁₀(OH)₂·4H₂O, chlorite, kaolinite Al₂Si₂O₅(OH)₄, in addition to montmorillonite (Al-Dabbas *et al.*, 1989).

Groundwater samples were collected at equally distributed locations to cover the entire study area in Um Qasr, Safwan, and Al-Zubair regions; the coordinates of wells were shown in table 1.

Table (1) Coordinates of wells in the study area.

Stations	Wells No.	Latitude	Longitude
Um Qasr	1	N 30°11'22.73"	E 47 ° 48'46.94"
	2	30°10'31.48"	47 ° 47'13.87"
	3	30°10'36.96"	47 ° 47'4.84"
Safwan	4	30°12'59.82"	47 ° 39'42.37"
	5	30°13'11.31"	47 ° 39'40.13"
	6	30°13'11.31"	47 ° 39'40.13"

Al-Zubair	7	30°22'4.21"	47 ° 33'43.49"
	8	30°22'4.31"	47 ° 33'43.53"
	9	30°22'4.31"	47 ° 33'43.53"

The hydrochemical investigation that took place involved the collection and analysis of seventy-two groundwater samples. These water samples' collection was done utilizing five-liter containers and transported from the location of sampling to the laboratory under optimal conditions for preserving their chemical integrity. Some of the parameters of groundwater, such as temperature, pH, and electrical conductivity (EC), were measured directly in the field. In the laboratory, the analyzed water parameters included major cations and anions. The chemical assays for

these major ions in natural waters were conducted as follows. Total dissolved solids (TDS) were estimated by the weighting method. Magnesium (Mg^{2+}) and Calcium (Ca^{2+}) were measured by titration (via the EDTA complex); Sodium (Na^+) was measured by flame photometry. The sodium adsorption ratio (SAR) was also calculated for the water samples according to equation ...1 as describe in Al-Hejuje (2014).

$$SAR = Na / \sqrt{[(Ca + Mg)/2]} \dots\dots\dots (1)$$

where:

SAR = sodium adsorption ratio.

Na^{+1} , Ca^{+2} , Mg^{+2} = Estimated dissolved cations in water samples (meq/L).

2. Classification of irrigation water

1- According to the USSL

The groundwater was classified according to the US Salinity Laboratory (USSL) classification of the US Department of

Agriculture (Richards, 1954). The classification was based on two basic indicators to evaluate the quality of irrigation water: The total concentration of salts expressed in electrical conductivity (EC) and sodium absorption ratio (SAR) includes 16 different categories of irrigation water, as shown in Table (2) and Figure (1).

Table (2) Limits of SAR and EC values according to the system (Richards, 1954).

Quality	SAR	Symbol
Low sodium water	0-10	S1
Medium sodium water	10-18	S2
High sodium water	18-26	S3
Water is very high in sodium	26 <	S4
Quality	EC ($\mu g/cm$)	Symbol
Low salinity water	100-250	C1
Medium salinity water	250-750	C2
Water with high salinity	750-2250	C3
Water with very high salinity	2250-5000	C4

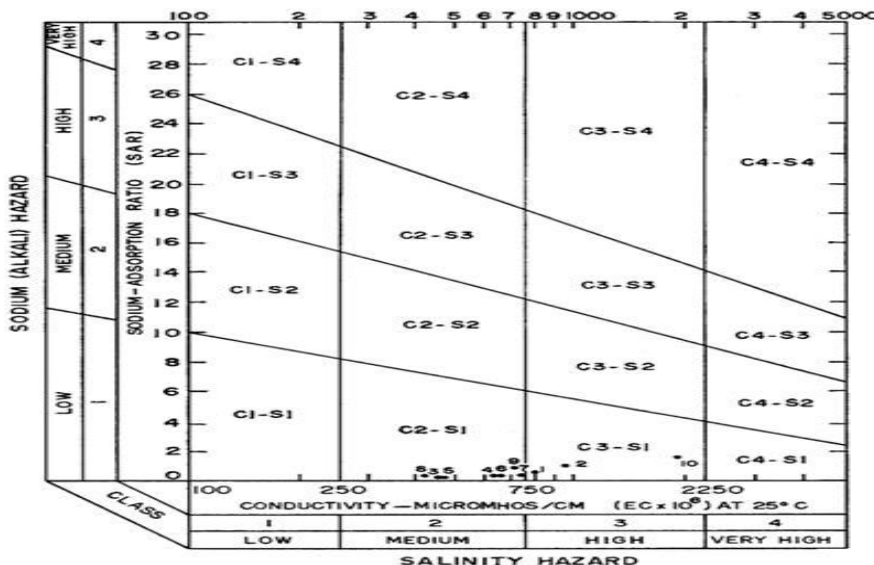


Figure (1): Schematic of the American salinity laboratory for evaluating irrigation water (Richards, 1954).

2- According to FAO Classification of Water Salinity classification, while table 4 showed the guide for evaluating irrigation water.

Table 3 showed the Description of irrigation water according to FAO

Table (3): Description of irrigation water according to Food and Agriculture Organization (FAO) classification.

Class	Electrical Conductivity (EC)	Description
Freshwater	EC < 0.75 dS/m (or < 750 μS/cm)	Suitable for most crops without restrictions.
Slightly Saline	EC 0.75 - 3 dS/m (or 750 - 3000 μS/cm)	Can be used for salt-sensitive crops with some management
Moderately Saline	EC 3 - 6 dS/m (or 3000 - 6000 μS/cm)	Limited use; salt-tolerant crops recommended
Strongly Saline	EC 6 - 12 dS/m (or 6000 - 12000 μS/cm)	Not suitable for most crops; only very salt-tolerant species can survive.
Very Strongly Saline	EC > 12 dS/m (or > 12000 μS/cm)	Generally unsuitable for agricultural use.

Table (4): Food and Agriculture Organization guide for evaluating irrigation water (Ayers and Westcot,1985)

nature of the problem	Limit value of use			
	Units	Nothing	Little - moderate	Severe
Salinity				
EC	ds/m	<0.7	0.7-3.0	>3.0
TDS	mg/l	<450	450-2000	>2000
Infiltration				
SAR=0-3 and EC _w		> 0.7	0.2-0.7	< 0.2
3-6		> 1.2	1.2-0.3	< 0.3

6-12		>1.9	1.9-0.5	< 0.5
12-20		> 2.9	2.9-1.3	< 1.3
20-40		> 5.0	5.0-2.9	< 2.9
Toxicity				
Sodium (Na)				
Surface irrigation	SAR	< 3	3-9	> 9
Sprinkler irrigation		< 3	< 3	—
Chlorine Cl				
Surface irrigation	Meq.L	< 4	4-10	>10
Sprinkler irrigation		< 3	> 3	
Boron (B)	mg / l	< 0.7	0.7 - 3	> 3
Incidental effects				
Nitrates (NO₃)	mg / l	< 5.0	5-30	> 30
Bicarbonate (HCO₃) sprinkler irrigation	Meq.L	< 1.52	1.5-8.5	> 8.5
The degree of reaction (pH) the normal limits			6.5-8.4	

3. Results and discussion

Laboratory analyses were conducted on well water samples in the study area to estimate both electrical conductivity (EC) and major dissolved cations (Ca⁺², Mg⁺², Na⁺¹) Table (5) showed the descriptive statistics of the physical and chemical properties of well water in the study area.

1- Evaluation the groundwater according to the USSL:

The results obtained were shown by plotting the EC and SAR values of the well water subject of the study on a classification chart. Irrigation water according to the American Salinity Laboratory system figure (1) for the four studied seasons: Summer (July and August), Autumn (October and November), Winter (January and February), and Spring (March and April).

Table (5): Some of the physical and chemical properties of groundwater in the study areas.

Stations	Seasons	Water Tem.	pH	EC (dS/m)	Na ⁺ (mg/l)	Ca ⁺² (mg/l)	Mg ⁺²	Cl ⁻	SAR	NO ₃ ⁻ (mg/l)	TDS
Um Qasr	Summer	31.42	7.26	9.382	3441.1	418.2	364.34	1820	42.39	159.05	5131
Safwan		31.48	7.19	23.079	4439.2	793.9	639.96	4499	39.81	306.13	9465
Al-Zubair		30.63	7.08	14.586	3963.9	731.8	546.92	3820	38.14	318.31	7581
Um Qasr	Autumn	26.44	8.07	9.077	2731.9	360.1	278.42	1458	37.27	155.28	7061
Safwan		29.78	7.79	17.586	3896.9	588.2	441.69	5069	41.50	288.27	13407
Al-Zubair		31.61	7.96	13.634	3397.6	575.1	442.63	3732	36.50	293.65	10554
Um Qasr	Winter	25.50	8.10	9.514	2304.1	473.9	303.22	1545	29.07	137.59	7220
Safwan		26.83	7.86	18.444	3144.6	715.1	623.27	6694	29.08	286.55	15091
Al-Zubair		26.83	7.81	15.924	2823.2	613.9	495.34	4045	29.07	281.39	12329

Um Qasr	Spring	25.83	8.26	9.805	2071.7	527.1	406.93	2195	23.30	178.72	9476
Safwan		26.75	8.26	16.616	3006.2	798.9	695.24	5523	26.28	314.70	17173
Al-Zubair		26.92	7.94	13.350	2551.3	545.8	655.11	4390	24.54	297.80	13948
MIX		31.61	8.26	23.079	4439.2	798.9	695.24	6694	42.39	318.31	17173
MIN		25.50	7.08	9.077	2071	360.1	278.42	1458	23.30	137.59	5131

Results showed that all stations were outside the classification and could not be used in irrigation due to the high values of the two standards adopted in this classification, which are electrical conductivity (EC) and sodium adsorption ratio (SAR); that is, they are not suitable for irrigation. In all cases, the

values of TDS, EC, and SAR were more than the permissible limits for irrigation, according to this classification. This means that this water should not be used as irrigation water during all seasons, as shown in Table 6.

Table (6): Classification of well water according to the American Salinity Laboratory system (Richards, 1954).

Stations	Seasons	TDS	EC ($\mu\text{s}/\text{cm}$)	SAR	Water Class
Um Qasr	Summer	5131	9382	41.983	> C4 S4
Safwan		9465	23079	40.205	> C4 S4
Al-Zubair		7581	14586	38.195	> C4 S4
Um Qasr	Autumn	7061	9077	37.173	> C4 S4
Safwan		13407	17586	41.828	> C4 S4
Al-Zubair		10554	13634	36.629	> C4 S4
Um Qasr	Winter	7220	9514	28.754	> C4 S4
Safwan		15091	18444	29.336	> C4 S4
Al-Zubair		12329	15924	29.069	> C4 S4
Um Qasr	Spring	9476	9805	23.310	> C4 S3
Safwan		17173	16616	26.545	> C4 S4
Al-Zubair		13948	13350	24.641	> C4 S3

> means greater than the limits set in the classification.

Through the classification of the American Salinity Laboratory, it is clear that the well water of the study area is not suitable for irrigation under the circumstances. Ordinary needs to follow special methods and techniques, such as alternating irrigation with fresh water whenever possible and adding an appropriate washing factor with the selection

of salt-tolerant crops, provided that the soil is light in texture and well-drained, free of hard layers, and that salt-tolerant crops are used.

2. Evaluation the groundwater according to the FAO:

The evaluation of irrigation water quality is based on the Food and Agriculture Organization's guide to evaluating water (Ayers and Westcot, 1992). The irrigation shown in Table 4 is based on four indicators:

Salinity, rate of infiltration into the soil, effect on sensitive crops, and other problems or incidental effects.

Total dissolved solids (TDS)

According to the results shown in Table (5), the highest value of total dissolved solids was recorded in station 2 (Safwan) in Spring (17173mg/l), and the lowest value was in station 1(Um Qasr) in the summer(5131mg/l).

High values of dissolved salts are linked to several factors, including natural chemical processes such as corrosion of rocks and

minerals and high concentration of mineral salts. The interaction of water with rocks and the discharge of domestic wastewater into underground reservoirs also affects the concentration of dissolved salts. In addition to water pollution with chemical fertilizers used for agriculture, it affected the number of salts dissolved in the water (Dore *et al.*, 2021).

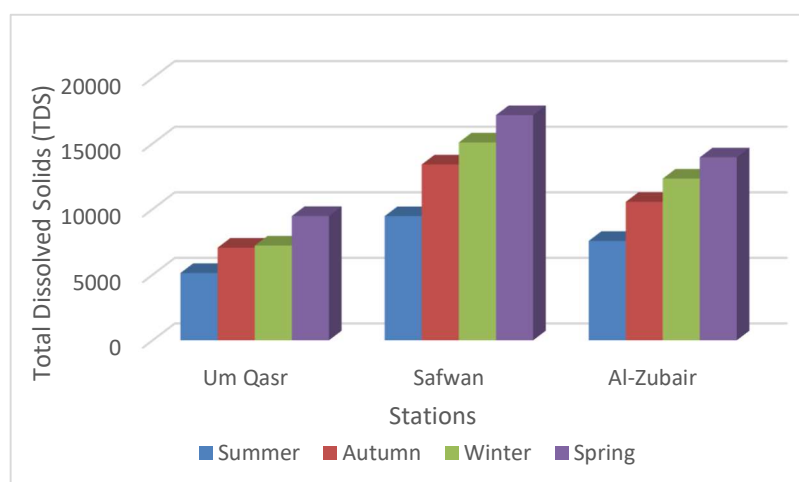


Figure (2): Values of total dissolved solids (mg/l) in well water in the study area

1. Chloride (Cl)

The chloride concentration in well water was evaluated according to the FAO guide, and according to the results shown in Table

5, it is clear that the chloride concentrations in water samples ranged from 1458 to 6694 mg/L, and therefore the chloride ion affects plants irrigated with this water.

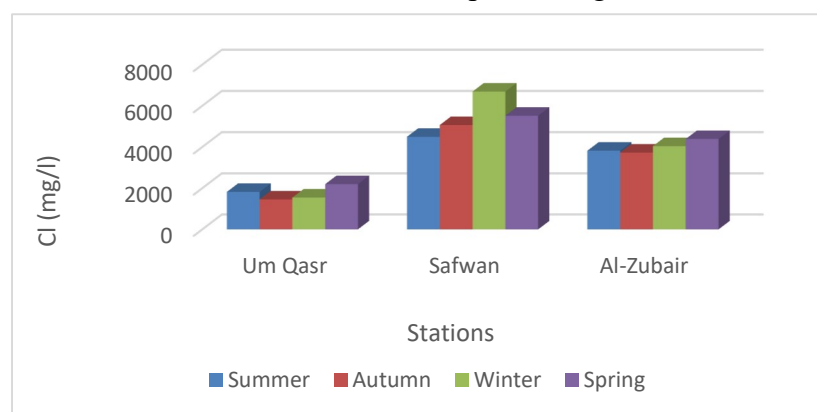


Figure (3): Values of Chloride (mg/l) in well water in the study area.

The main reason for the increase in the chloride ion in the studied wells is that the geological formations in the region contain this ion in their rocks, such as the mineral halite (NaCl), which dissolves in water when it passes over it, and thus the concentrations of chlorides in it increase, in addition to evaporite rocks and igneous rocks (Amteghy

2. Soil seepage rate

The measure of the effect of the infiltration rate or permeability of the soil depends on two standards, SAR and EC (dS/m), for irrigation water. From Table 5, the values of sodium adsorption ratio (SAR) ranged between (23.30 – 42.39), whereas values of electrical conductivity (EC) ranged between (9.077-23.079 ds/m). Figure 4 shows the variation in values of SAR and EC.

The dominance of the concentrations of divalent positive ions (Mg^{+2} , Ca^{+2}) over the concentrations of monovalent positive ions (Na^{+}) caused a difference in the rate of sodium adsorption in the water of the studied wells, which ultimately led to a decrease in SAR, whereas if there is intense adsorption of sodium by the exchange complex and its displacement of magnesium and calcium, as

et al., 2018). Chloride concentrations in groundwater can also be affected by soil leaching processes using rainwater or irrigation, as the studied areas are mostly agricultural areas treated with fertilizers and pesticides that contain chloride compounds of different types (Mohanavelu *et al.*, 2021).

a result, precipitation of carbonate and bicarbonate ions will occur in the form of magnesium and calcium carbonate. In addition, gypsum also begins to accumulate in the form of a small precipitate. In most cases, this is consistent with Amteghy *et al.* (2018).

The high value of EC may be due to the continuous and intensive use of water from these wells to withdraw groundwater to operate desalination plants. This led to a significant decrease in the level of groundwater, which led to water being withdrawn from the lower, highly salinity layers and mixing with the upper layers, which led to a clear increase in the number of salts and thus an increase in conductivity values, this finding was in agreement with Abdulameer and Al-mallah (2018).

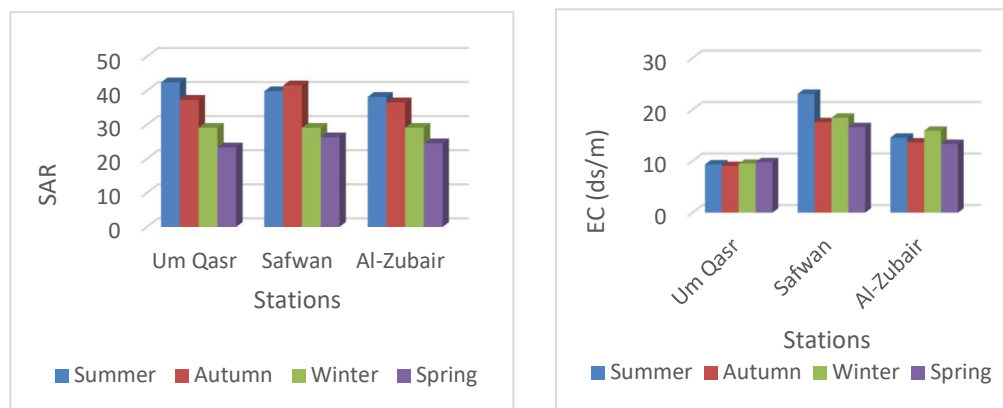


Figure (4): Values of SAR and EC (ds/m) in well water in the study area.

3.pH

Referring to the values shown in Figure (5), the pH values for all samples and in all

seasons ranged between 7.08 to 8.26. Using the FAO guide, these values is within the normal range for irrigation water.

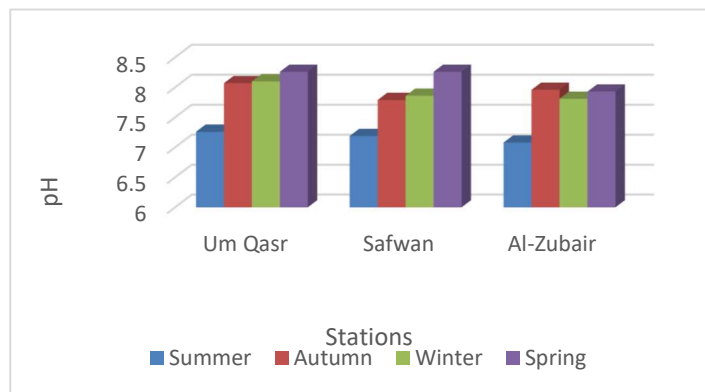


Figure (5): Values of pH in well water in the study area

4. Nitrates (NO_3^-)

The highest values of nitrate (318.31 mg/L) were recorded in summer at station 3 (Al-Zubair), and the lowest value (137.59 mg/L) was recorded in winter at station 1 (Um Qasr).

The high concentrations of nitrates are due to the oxidation and reduction action of nitrogen present in the soil, in addition to the

leakage of sanitary waste water and its leakage into groundwater. It is also due to the presence of areas used for raising livestock and sheep, which contribute to the transfer of nitrogenous compounds to the soil and thus to groundwater, in addition to the presence of nitrates among the soil compounds (Khalaf *et al.*, 2023).

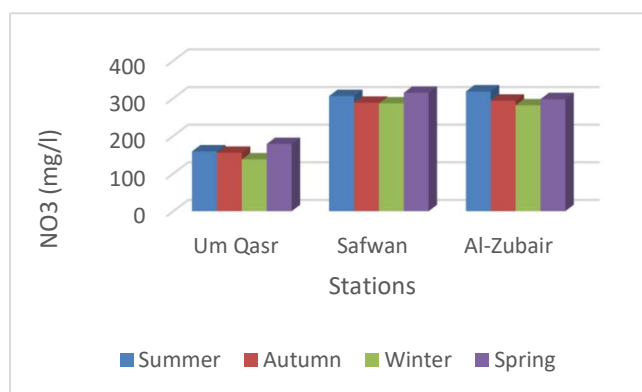


Figure (5): Values of NO_3^- in well water in the study area

Conclusion

Through physical and chemical analyzes conducted on well water samples of the study area for the purpose of evaluating their suitability for irrigation, the classification of this water in the four seasons according to the American Salinity Laboratory classification was greater than the limits set in the classification. This type of water cannot be used to irrigate sensitive crops for salinity; its use is limited only to rough, well-drained lands that allow for high-

efficiency salt washing operations. Temperature measurements of well water in the study area were within the normal range (25.5-31.6°C), and pH values were also within the normal values (6.5-8.5). The evaluation according to the FAO and Ayers and Westcot system (1985) showed that total dissolved solids (TDS), Cl^- , SAR, EC, and NO_3^- values were high in all stations during the study period and thus were within the level (severe problem).

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تقييم مدى ملائمة المياه الجوفية لأغراض الري في مدينة البصرة – العراق

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الملخص:

أجريت هذه الدراسة بهدف تقييم جودة المياه لأغراض الري في عدد من آبار مناطق أم قصر وسفوان والزابير في مدينة البصرة- العراق. جمعت عينات المياه الجوفية من 9 آبار للفترة الممتدة من تموز 2024 – نيسان 2025. وتم إجراء التحاليل المختبرية اللازمة على العينات لتحديد خواصها الفيزيائية والكيميائية ومقارنة النتائج مع المواصفات المعتمدة لمياه الري حسب تصنيف مختبر الملوحة الأمريكي (USSL) ومنظمة الأغذية والزراعة (FAO). وأظهرت النتائج حسب تقييم USSL أن جميع العينات كانت أكبر من الحدود المحددة في التصنيف، إذ تراوحت قيم التوصيل الكهربائي (EC) بين (9077-23079) ميكروسيمنز/سم. وتراوحت قيم SAR بين 23.310-42.39 وحسب تصنيف منظمة الأغذية والزراعة تراوحت قيم المواد الصلبة الذائبة الكلية (TDS) بين 5131-17173 ملغم/لتر، وتركيز الكلورايد (Cl⁻) (1458-6694) ملغم/لتر والنترات (NO₃⁻) (137.59 - 318.31) ملغم/لتر، و EC (9.077 - 23.079) دسم / متر وقيم الاس الهيدروجيني (7.08-8.26). وبذلك تجاوزت جميع المتغيرات الحدود المثلى لتصنيف منظمة الأغذية والزراعة (FAO)، باستثناء الاس الهيدروجيني pH الذي كان عند الحدود الطبيعية. وخلصت هذه الدراسة إلى أن معظم الآبار التي تمت دراستها غير صالحة للري في الظروف العادية ويجب اتباع أساليب وتقنيات محددة لاستغلالها، أهمها إضافة المواد المناسبة لغسل الأملاح واتباع طريقة الري التناوبي بالمياه العذبة كلما أمكن ذلك، واختيار المحاصيل التي تتحمل الملوحة والصوديوم، وتجنب استخدامها في التربة الثقيلة والفقيرة التبادل.

الكلمات المفتاحية: مياه الري، منظمة الاغذية والزراعة، تصنيف USSL، جودة المياه الجوفية.