Hydrochemical Assessment of Groundwater in Rawah District Wells and Its Relation to Irrigation Suitability, Soil Salinization, and Desertification

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Abstract

This study aimed to evaluate the groundwater quality in the district by selecting seven wells randomly distributed within the agricultural lands parallel to the Euphrates River. Samples were collected during November and December 2024, physical chemical tests were conducted on the water samples, including: temperature, total hardness (T.H), total dissolved solids (TDS), hydrogen ion function (pH), electrical conductivity (EC), turbidity, in addition to estimating the concentrations of some positive and negative ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}), with the sodium adsorption ratio (SAR) calculated to determine the suitability of the water for irrigation. The results indicated an obvious spatial distribution of water quality, the temperature varied from 23.4 to 24.6 °C, turbidity ranged from 0.9 to 1.4 NTU and electric conductivity varied between 5200 to10500 (µs cm^{-1}) dS m^{-1}. The pH ranged from 6.9 to 7.8, TDS from 6.9 to 13 g l^{-1} and the total hardness varied between 90–140 mg l^{-1}. Cation and anion concentrations ranged from 564 to 7560 mg l^{-1} Ca, 38.1-59.22 Mg, with Na of between 175 -1564 mg l^{-1}), K (6.5-132.5 mg l^{-1}), Cl (336.3-1309.8) and SO_4 (66.3 -102.5). SAR was in the range of 10.5–37.3 mg l^{-1}. These signs are indicative of moderate to high salinity with moderate or low sodicity hazard in some areas, which restricts the direct use for irrigation without correction behind drainage or for adopting suitable crops that tolerate salt and also by employing methods of salinity problems in soil by the induced method.

Keywords: Water quality, Rawah District, well water.

التقييم الهيدروكيميائي للمياه الجوفية في آبار قضاء راوه وعلاقته بصلاحيتها للري وتملح التربة والتصحر

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المستخلص

هدفت هذه الدراسة إلى تقييم نوعية المياه الجوفية في القضاء عبر اختيار سبعة آبار موزعة عشوائياً ضمن الأراضي الزراعية الموازية لنهر الفرات. جُمعت العينات خلال شهري تشرين الثاني وكانون الأول عام 2024، وأُجريت عليها فحوصات فيزيائية وكيميائية شملت: درجة الحرارة، العسرة الكلية(T.H) ، المواد الصلبة الذائبة الكلية(TDS) ، الدالة الحامضية(pH) ، التوصيل الكهربائي(EC) ، العكورة، إضافة إلى تقدير تراكيز بعض الأيونات الموجبة والسالبة (Ca^{+2}، Mg^{+2}، Na^{+}، K^{+})، (Cl^{-}، SO_4^{-2}) مع احتساب نسبة امتزاز الصوديوم (SAR) لتحديد صلاحية المياه للري. أظهرت النتائج تغايراً مكانياً واضحاً في نوعية المياه؛ إذ تراوحت درجات الحرارة بين 23.4–24.6 م°، والعكورة بين 0.9–1.4NTU ، والتوصيل الكهربائي بين 5200–10500 (مايكرو موز $سم^{-1}$) ديسي سيمنز $م^{-1}$. كما تراوح pH بين 6.9–7.8، و TDSبين 2.6–5.2 غم $لتر^{-1}$، والعسرة الكلية بين 90–140 ملغرام/لتر. وسُجلت تراكيز للأيونات ضمن المديات الآتية: Ca 564–7560، Mg 38.1–59.22، Na 175–1564، K 6.5–132.5، Cl 336.3–1309.8، SO4 66.3–102.5 ملغم $لتر^{-1}$. وبلغت SAR بين 10.5–37.3 ملي مكافئ $لتر^{-1}$. تشير هذه المؤشرات إلى ملوحة متوسطة إلى عالية مع خطورة صوديومية متوسطة إلى مرتفعة في بعض المواقع، ما يحد من الاستخدام المباشر للري دون إدارة ملائمة مثل تحسين الصرف، اختيار محاصيل متحملة للملوحة، واعتماد طرائق ري تقلل تراكم الأملاح في التربة.

الكلمات المفتاحية: مدينة راوه، مياه الآبار، نوعية المياه.

Introduction

As competition for fresh water intensifies, the utilization of groundwater pumping in irrigated agriculture is expanding. Unorganized and uncontrolled exploitation of the groundwater resource has become a serious impediment to agricultural development on more than 111 million hectares of irrigated areas; hence demand for proactive, integrated governance, management and protection of the subsurface water resources is vital reflecting sound technical, institutional, legal, social economic and environmental approaches (Madramootoo 2012).

Water quality does not pertain only to its availability, but also depends on whether it is suitable for different uses such as drinking, agriculture, etc (Hamid 2023). Water is one of the survival resources required to be available in order to extend life on planet Earth. This flexible component comes under basic sources to fulfill human needs and agricultural requirements (Al-Hadithy, and Al-Mallah, 2023). The water quality index for irrigation is employed as an

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overall assessment tool for groundwater quality used in agricultural irrigations, and this plays an important role in its suitability to sustain the health of soil and crop (Al-Aizari *et al.,* 2024).

Groundwater renewis a sequence of processes by which water infiltrates through the soil in order to reach groundwater. Groundwater recharge is likewise the procedure of water infiltrating into the soil until it saturates, ascending again to become ground level and meeting earth's groundwater levels, whether that-like process happens in natural or through human intervention. This process is affected by various factors such as rainfall intensity and frequency, soil moisture condition, depth of the groundwater and soil properties related to water permeability. A need to accurately understand and address these factors is essential to enabling the renewal of groundwater stock, as well as ensuring water resources sustainability (Al-Zubaidi, 2021).

The qualitative nature of substances dissolved in water is one of the most fundamental factors that affect its versatility to be used in numerous fields, and groundwater consists of a range of dissolved mineral compounds in different proportions due to natural processes inside and outside the Earth's crust (Khalaf Allah, 2022).

The Iraqi environment has witnessed a substantial degradation over the last two decades starting from air to soil and water pollution. There is also a degraded environmental situation within Iraq leading to quantitatively and qualitatively deterioration in water quality because of the diversity of pollution sources relative to the lack of sound plans that adopt scientific and developing bases for healthy and secure environment because it begins from clean drinking water. Iraq's water sources are contaminated by various types of pollution anthropogenic and natural resources (Al-Dulaimi 2024). "Despite studies in Iraq/Anbar, there is limited recent, site-specific well-water characterization for Rawah agricultural lands; therefore, farmers lack evidence-based guidance on irrigation suitability and management (leaching, drainage, blending, gypsum).

Although several studies have investigated groundwater quality in Iraq and the Anbar region, there remains a noticeable shortage of recent, site-specific assessments focused on the irrigation wells serving agricultural lands in Rawah. Consequently, farmers and water managers lack critical, evidence-based information necessary to guide effective irrigation practices—such as soil leaching, drainage optimization, water blending, and the use of amendments like gypsum—limiting their ability to sustainably manage water resources in this area. (FAO, 2015; Madramootoo, 2012; Al-Hadithi et al., 2019).

This study aimed to evaluate groundwater quality in Rawah District and assess the suitability of well water for irrigation in arid and desertification-prone regions. Several physicochemical parameters were analyzed, including electrical conductivity (EC), total dissolved solids (TDS), pH, hardness, turbidity, calcium, magnesium, sulfate, chloride, potassium, and sodium. The Sodium Adsorption Ratio (SAR) was also calculated to assess salinity and sodicity risks and determine the suitability of groundwater for sustainable agricultural use.

Materials and Methods

The study was conducted on a group of groundwater wells distributed in Rawah District, within the administrative boundaries of Al-Anbar Governorate. Water samples were collected from seven (7) wells randomly distributed across the study area during the period between November and December 2024. Their locations were determined using the Global Positioning System (GPS). Water samples were taken after operating the water pump for several minutes. The water samples were preserved in clean plastic containers, which were washed several times with the sample water before being filled with the well water. Chemical and physical tests were carried out in the laboratories of the College of Agriculture/ University of Anbar in 2024–2025 to study groundwater quality and the extent of its suitability for agricultural. Excel was used to calculate the analyzed results for the selected samples. Neither SPSS nor any other analytical software was used because the study did not rely on replicates. The study was descriptive in nature, focusing on the groundwater wells in the area to determine whether any problems existed that could cause damage to the crops irrigated with the water from those wells.

Laboratory Work

The water samples were stored in plastic containers in a refrigerator at 4°C in the central laboratory of the College of Agriculture / University of Anbar. Laboratory analyses of the water samples were conducted as follows:

Physical Tests

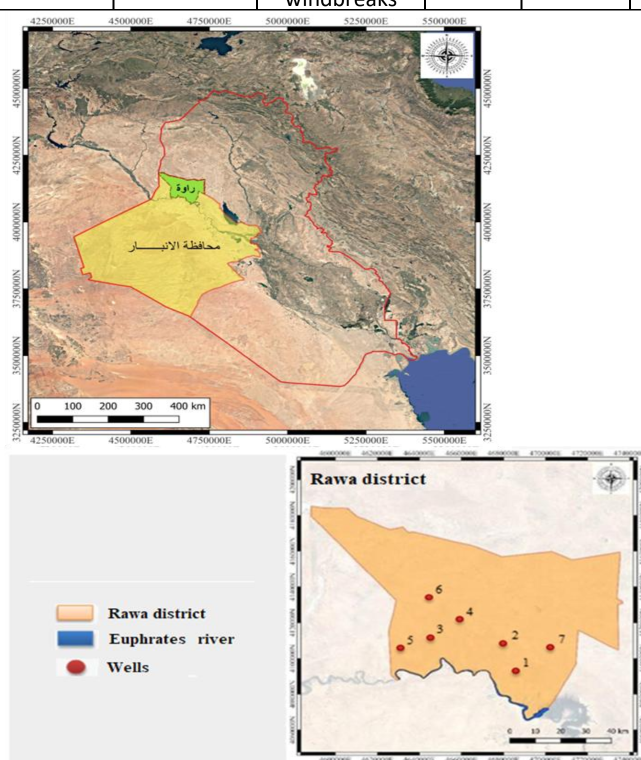
1. **Temperature:** The water temperature was measured directly at the site, where the thermometer in the water for a few minutes, and the reading was accurately documented. After that, this reading was classified according to the standards of the World Health Organization.
2. **Turbidity:** Turbidity was measured using a Turbidity meter, model (Micro 950) manufactured in Singapore. Two readings were taken for each sample after calibrating the device with standard solutions. The results were

expressed in (Nephelometric Turbidity Unit, NTU) according to what was stated in the reference (APHA, 1985). Before measurement, the sample was shaken well to ensure homogeneity of its contents. These values were also classified according to the standards of the World Health Organization calibration.

3. **Electrical conductivity:** Electrical conductivity was measured in the different groundwater samples using a conductivity meter, according to what was reported in Page's study (1982).

Table 1. Locations of wells within the study a rea, Rawah District

The geological nature of the area	Date of sample collection	Coordinates		Nature of use	Date of well drilling	Well depth	Area name	Site code
		E	N					
Desert / Near the river	1/11/2024 5	42.077829°	34.450955°	Olive, date palm, pomegranate,	2010	60-65	Al-Zaytoun District / Abu Kowa	L1
Desert / Near the river	1/11/2024 5	42.033593° "	34.579180°	Wheat, onion, alfalfa	2022	62.5	Al-Zaytoun District	L2
Agricultural area	1/11/2024 5	41.740353°	34.598320°	Date palm	2021	60	Al-Zaytoun District / Abu Kowa	L3
Rugged	1/11/2024 5	41.822555°	34.677541°	New / Agricultural	2024	71	Al-Zaytoun District / Abu Kowa	L4
Agricultural	1/11/2024 5	41.606914°	34.560523°	Onion, leafy crops	2022	55-60	Al-Zaytoun District / Abu Kowa	L5
Rugged	1/11/2024 5	41.729700°	34.731582°	Wheat, alfalfa, barley	2012	55	Rashid District	L6
Rugged	2/12/2024 1	42.235627°	34.546603°	Eucalyptus, windbreaks	2007	75	Abu Kowa	L7



Map 1. Location of the study area in Iraq

Chemical Analyses: These include the following:

1. **(pH):** Measurement was performed using a pH-meter, based on the method described by Richards in 1954.

2. **Total dissolved solids (TDS)**: Total dissolved solids were measured for the different groundwater samples using a TDS meter, according to what was reported in Page's study (1982).
3. **Total hardness**: Water hardness was determined by titrating 10 mL of the sample with Na_2 EDTA solution at a concentration of 0.02 N, after adjusting the pH to 10 using an ammonia buffer solution. Eriochrome Black-T indicator was added, which caused the color of the solution to change from purple to bluish-green, based on the protocol stated in APHA (2012).
4. **Calcium ions (Ca^{2+}):** Dissolved calcium was determined by titration using (Na_2 EDTA) solution, with the aid of Ammonium purprate reagent, as mentioned by Page et al. (1982).
5. **Magnesium ions (Mg^{2+})**: Dissolved magnesium was determined through titration using (Na EDTA) solution, relying on Eriochrome Black-T reagent, as reported in the study by Page et al. (1982).
6. **Sodium and potassium ions (Na^+, K^+)**: Sodium and potassium concentrations were determined using a flame photometer (Flame-Photometer) according to the method described by Richards (1954).
7. **Chloride ion (Cl^-)**: Chloride ions were determined by titration with silver nitrate solution ($AgNO_3$ 0.05 N) in the presence of potassium chromate indicator (5%), as mentioned in Page et al. (1982).
8. **Sulfate ion (SO_4^{2-})**: Sulfate content was determined according to the Fersin method as reported in the study conducted by Black et al. (1965).
9. **Sodium adsorption ratio (SAR)**: The (SAR) ratio was calculated as in the following equation:

$$SAR = \frac{[Na^+]}{\frac{\sqrt{[Ca^{++}] + [Mg^{++}]}}{2}}$$

The estimated ions in the equation were calculated in units of milliequivalents per liter (meq/L).

Results and Discussion

Physical Tests

1. Temperature (T)

Table 2 present the value of temperature of well water in the study area, ranging from 23.4–24.9 °C. These results are considered within the standards set by the World Health Organization (WHO, 2003, 2006). Most likely, the well water is not affected by climatic temperatures and different factors because the wells are far from direct exposure to them. This agrees with what was confirmed by Imneisi and Albadri (2022).

2. Turbidity

The turbidity values of the well water in the study area ranged between 0.9–1.4 nephelometer, and they are within the permissible limits of the World Health Organization standards (WHO, 2003, 2006). The reason for the low turbidity percentages in the wells of the study area is explained by the nature of the area and the geology of the soil layers, as they act as filters for polluted materials and turbidity-causing agents such as organic materials or microorganisms present with the water, which work to increase turbidity levels; this is what Al-Zubaidi confirmed in her study (2023).

Table 2. Physical Characteristics of Well Water in the Study Area

Examination	Site						
	L1	L2	L3	L4	L5	L6	L7
Temperature °C	23.4	24.5	23.6	23.7	24.6	24.9	24.8
Turbidity NTU	1.4	0.9	1.4	1.2	1.1	0.9	1.1

Chemical Analyses

1. Hydrogen ion function (pH)

The pH of the well water in the study area were from 6.9 to 7.8 (Table 3). This is a qualitative factor that significantly affects the alkalinity and acidity property of water and its application level (Sarala & Ravi, 2012). These limits were also well within the values of FAO (1985) 6-8.4 and WHO (2003, 2006) standards (6.5–9.5). These wells water is of neutral to slightly alkaline in nature, a fact which agreed with that found by Ismail and El-Rawy (2018).

2. Electrical conductivity and total dissolved solids (EC, TDS)

Table 3 shows the results of electrical conductivity, which ranged between 5200–10500 µs cm^{-1}. Well (L2) recorded the lowest value, whereas the highest value was at well (L3). These values correspond to the specified values of the total dissolved salts quantity, as the values of total dissolved solids ranged between 2.6–5.2 g l^{-1}, with the lowest value in well (L2) and the highest value in well (L3). This increase in total dissolved solids values is mainly associated with the increase in electrical conductivity at the locations of these wells. When comparing the results with the standards of the World Health Organization (WHO, 2003, 2006, 2011, 2017) (400–1500) µS cm^{-1} and the Food and Agriculture Organization (FAO, 2015) 3 µS cm^{-1}, the values were much higher than the global limits; therefore, they are not suitable for human, agricultural, and animal use. However, they may be suitable for agricultural use for some crops that tolerate moderate to high salinity levels. These results were mostly consistent with what was found by Al-Hayani (2010).

3. Total hardness (T.H)

The results for the well water in the study area indicated that total hardness values ranged between 90–140 mg l^{-1}. The lowest total hardness value was in well (L6), reaching 90 mg l^{-1}, while the highest value was repeated in well (L3), reaching 140 mg l^{-1}. This is one of the basic indicators that expresses the extent of water suitability for daily domestic use (Nsabimana, 2022). These results did not exceed the permissible limits of the standards set by the World Health Organization (WHO, 2003, 2006, 2011, 2017) 500 mg l^{-1}, and they were also lower than the results reached by Al-Dulaimi (2024). These results determine the extent of limited dissolution of some soil components in groundwater, or as a result of the reactions of limestone with carbon dioxide gas for the process of forming bicarbonate in these waters (Al-Hayani, 2009).

Table 3. Chemical Characteristics of Well Water in the Study Area

Examination	Site						
	L1	L2	L3	L4	L5	L6	L7
Ph	7.5	7.5	6.9	7.4	7.3	7.8	7.6
EC (µs Cm^{-1}) dS m^{-1}	5500	5200	10500	6700	6500	8800	7100
TDS mg l^{-1}	2.8	2.6	5.2	3.4	3.2	4.4	3.5
T.H mg l^{-1}	120	120	140	110	110	90	120

4. Concentration of Calcium, Magnesium, Sodium, and Potassium Ions (Ca^{+2}, Mg^{+2}, Na^{+1}, K^{+1})

Calcium is considered one of the essential vital elements for the functions of living organisms (Al-Dulaimi, 2024). Dolomite rock is the primary source of dissolved magnesium ions in natural water (Al-Dulaimi, 2011). The study results presented in Table 4 show that the concentrations of calcium ions in well water ranged between (564-7560 mg l^{-1}), with the lowest value in well No. (L6) at (564 mg l^{-1}) and the highest value in well No. (L4) at (7560 mg/L). The results also showed that magnesium concentrations ranged from a low of 38.1 mg l^{-1} in well L6 to a high of 59.22 mg l^{-1} in well L3.

Calcium ion concentrations exceeded the permissible limits according to the standards of the World Health Organization (WHO, 2003, 2006, 2011, 2017) 200 mg l^{-1}) and the Food and Agriculture Organization (FAO, 2015) 400 mg l^{-1}, and they were also higher than the results reached by (Al-Obaidy and Hameed, 2014). As for magnesium ion, the results were within the standards specified by the World Health Organization and the Food and Agriculture Organization; therefore, they were suitable for human and agricultural use, and these results were lower than what was reached by Al-Obaidi and Salman (2011) in their study.

As for sodium, it is considered one of the most widespread alkaline elements, which makes it rank sixth among the most abundant elements in nature (Khafaji et al., 2021). Sodium is also considered one of the essential nutrients, and it plays a pivotal role in plant metabolic processes (Al-Khafaji et al., 2021). The results shown in Table (4) indicated that the concentration of sodium ions in the well water of the study area ranged between (175–1564 mg l^{-1}). Results also revealed that the potassium ion concentrations in well water of the study area varied between (6.5–132.5 mg l^{-1}). From the table, it is observed that concentration of sodium and potassium ions exceeded their maximum allowable limits. This indicate that the water could not be fit for agriculture irrigation and drinking as per international requirements.

5. Chloride ion concentration (Cl^-)

These concentrations are used as an indicator to understand the extent of toxicity of the ion in water. Although chloride plays an important role in some regional water-classification systems, many modern classifications do not rely heavily on it because it does not noticeably affect the physical properties of soil (Al-Hadithi et al., 2019). According to the adopted international specifications. Two categories were identified among the groundwater wells in the area under investigation fell within the permissible limits for irrigation and drinking water and included wells

Table 4. Concentrations of Dissolved Cations in Well Water of the Study Area.

Examination	Site						
	L1	L2	L3	L4	L5	L6	L7
Ca mg/l	912	672	1024	7560	716	564	952
Mg mg/l	50.76	50.76	59.22	46.53	46.53	38.1	50.76
Na mg/l	515	459	1564	804	752	1112	175
K mg/l	6.5	13	102	132.5	112	84	38.5

(1, 2, 5, and 7) (Table 5). However, the second group—wells (L3, L4, and L6)—exceeded the permissible limits according to the international specifications (WHO, 2003, 2006, 2011, 2017), 45–600 mg l^{-1}. Nevertheless, all wells were within the Food and Agriculture Organization standards except well (L3), which exceeded the permissible limit under those standards (FAO, 2015), 1100 mg l^{-1}.

6. Sulfate ion concentration (SO_4^{2-})

Sulfate is considered one of the essential components that dissolve in rainwater, which plays an important role in shaping its chemical composition. Based on World Health Organization recommendations related to drinking-water quality, the maximum permissible limit for sulfate concentration has been set at 400 mg l^{-1} to establish global health standards (Ismael, 2019). When the results were compared with the standards adopted in (WHO, 2003, 2006, 2011, 2017) 400 mg l^{-1} and (FAO, 2015) 1000 mg l^{-1}, they were found not to exceed the relevant international standards; therefore, the water is considered suitable for human and agricultural use.

Table 5. Concentrations of dsolved anions in Well Water of the Study Area

Examination	Site						
	L1	L2	L3	L4	L5	L6	L7
Cl mg l^{-1}	336.3	354	1309.8	637.2	389.4	831.9	531
SO_4 mg l^{-1}	102.5	91.1	86.8	73.3	84.1	88.8	66.3

Sodium adsorption ratio (SAR)

It is one of the significant criteria used to assess irrigation water quality (Al-Hayani, 2009). The physio-chemical characteristics of the study area groundwater indicated its partial suitability for irrigation as well as agricultural and livestock purposes. Thus, waters in the wells were categorized in three groups with regard to their suitability for drinking, agriculture and animal use. Group one includes wells (L1, L2, L5 and L7) which had an optimum-sodium-range (OSR) but from each of these a risk may have been occurred for crops grown in fine-textured soils. Conversely, group two includes wells (L4 and L6) presented a problematic sodium range that could potentially cause sodium hazards, and as such would need to be well managed. For the significance of sodium their group three which include well (L3) was classified as a `very high' sodium level (hazard), and is generally considered to be unsuitable for use in irrigation.

According to the accepted standards, the ground waters of the studied area appear to be generally irrigable but with a significant need for caution in their usage in these wells, employing irrigation methods that would minimize salt accumulation and choosing crops resistant to sodicity and salinity so that an upturn in agricultural productivity will not be sustainable when applied on soils irrigated with such waters.

Table 6. Results of Sodium Adsorption Ratio (SAR) Values

Examination Site	SAR	range	Its specifications
L1	10.5	18-10	It is likely to cause a sodium hazard in soft soils where there are few leaching conditions and can be used in coarse-textured soils with high permeability.
L2	10.9	18-10	It is likely to cause a sodium hazard in soft soils where there are few leaching conditions and can be used in coarse-textured soils with high permeability.
L3	37.8	> 26	It is usually unsuitable for irrigation purposes.
L4	18.7	26-18	It may result in sodium hazards and requires special soil management (good drainage, washing, and the use of chemical amendments such as agricultural gypsum).

Table 6. Contained

Examination Site	SAR	range	Its specifications
L5	11.8	18-10	It is likely to cause a sodium hazard in soft soils where there are few leaching conditions and can be used in coarse-textured soils with high permeability.
L6	24.4	26-18	It may result in sodium hazards and requires special soil management (good drainage, washing, and the use of chemical amendments such as agricultural gypsum).
L7	15.6	18-10	It is likely to cause a sodium hazard in soft soils where there are few leaching conditions and can be used in coarse-textured soils with high permeability.

Table 7. Classification of Global and Iraqi Water Standards

Numbering	Physical and chemical properties	Unity	WHO (2003,2006)	FAO (2015)	WHO (2011,2017)
1	Temp	C°	15-35	-	-
2	pH	-	6.5-9.5	6.5-8.5	8.5
3	EC	dS m^{-1}	400	3	1500
4	TDS	ppm	-	2000	1000
5	T.H	mg l^{-1}	500	-	500
6	Turb	NTU	5	-	-
7	Ca^{+2}	mg l^{-1}	75	400	200
8	Mg^{+2}	mg l^{-1}	100	60	150
9	Na^{+}	mg l^{-1}	200-250	900	400
10	K^{+}	mg l^{-1}	10-12	2	12
11	Cl^{-}	mg l^{-1}	45-250	1100	600
12	SO_4^{-2}	mg l^{-1}	400	1000	400

Table 8. Global Classification of Irrigation Water (Moghimi, 2016; Das & Nag, 2014)

Category	range	Standard	Numbering
excellent S_1	10-0	SAR (Richards, 1954)	1
Good S_2	18-10		
Doubtful S_3	26-18		
unsuitable S_4	26 <		

Table 9. Classification of Groundwater for Irrigation Based on SAR Values

Numbering	Water classification	SAR	The symbol	Specifications
1	Low sodium	0<SAR<10	S1	It can be used for irrigation on most soils, although low levels of harmful sodium may be observed.
2	medium sodium	10<SAR<18	S2	It may pose a sodium hazard in soft soils where leaching is minimal, but it can be used in coarse-textured, highly permeable soils.
3	high sodium	18<SAR<26	S3	It may produce a sodium hazard and requires special soil management (good drainage, leaching, and the use of chemical amendments such as agricultural gypsum).
4	Very high sodium	26<SAR	S4	It is generally unsuitable for irrigation purposes.

Conclusion

The results indicated that well waters of this area are generally in the moderate to very high saline water and SAR values of well water samples revealed sodicity hazard. It is thus necessary to install certain agricultural practices, proper soil management (adequate leaching, effective drainage system) and the use of agronomical gypsum or applied on coarse pored soils with high infiltration rates. In addition, some wells produce water that is completely unsuitable for irrigation or human uses. As a result, it is recommended that Mix freshwater with salty well water when using it for irrigation. Apply leaching and a subsurface drainage in agricultural areas to avoid accumulation of salts into the soil. Utilize salt-resistant crop varieties. The results indicated an obvious spatial distribution of water quality, the temperature varied from 23.4 to 24.6 °C, turbidity ranged from 0.9 to 1.4 NTU and electric conductivity varied between 5200 to10500 ds m^{-1}. The pH ranged from 6.9 to 7.8, TDS from 6.9 to 13 g l^{-1} and the total hardness varied between 90–140 mg l^{-1}.

Sustainability Statement

This study contributes to sustainable groundwater and soil resource management by evaluating the hydrochemical characteristics of groundwater and its suitability for irrigation in the Rawah District. Assessing irrigation water quality and its relationship with soil salinization and desertification provides essential information for protecting agricultural lands, optimizing water resource utilization, minimizing land degradation, and supporting sustainable agricultural development in arid and semi-arid environments.

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Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions (CRediT)

First author: Conceptualization, Investigation, Data curation, Formal analysis, Visualization, Writing – original draft. Second author: Methodology, Validation, Supervision, Writing – review & editing. Third author: Resources, Laboratory analyses, Project administration, Supervision, Validation, Writing – review & editing. All authors have read and agreed to the published version of the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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