Kirkuk University Journal for Agricultural Sciences
ISSN:2958-6585
https://kujas.uokirkuk.edu.iq
RESEARCH ARTICLE
https://doi.org. 10.58928/ku25.16417

A hydrological study to evaluate Groundwater quality and its suitability for irrigation purpose in Kharayeb Al-Sheikh area using geographic information systems within Western desert, Iraq

AbdulKarem A. M. Alalwany [1] **Fadhil Hussein Mukhlif[2]**
Mohammed H. M. Abdulrazzaq[3] ***Basim A. Zaidan*** **[4]** **Mayada Safaa Jasm [3]**
M. N. A. Al-Falahi **[4]** **Sami awad Alkubaisy [3]**
[1]*University of Anbar, Center of Desert Studies, Anbar, IRAQ.*
[2]*University of Anbar, Upper Euphrates Basin Developing Center, Anbar, IRAQ.*
*Corresponding Author: ds.bassim.zedan@uoanbar.edu.iq

Received:01/07/2025 **Revised: 12/08/2025** **Accepted: 17/09/2025** **Published: 07/12/2025**

ABSTRACT
Monitoring the quality and quantity of groundwater is crucial for the effective and sustainable management of this valuable resource. In arid and semi-aried areas, irrigation water quality and soil salinity were the main limiting factor for growing agricultural crops, increased salinity of groundwater used in dry areas with limited rainfall hinders crop diversification that can be produced. Therefore, it is important to ensure the quality of irrigation water, this study dealt with the physical and chemical composition of groundwater in a location where groundwater in the Kharayeb al-Sheikh area is considered the main source of water for irrigation of crops, The water in those places is characterized by some problems related to the quality and suitability for irrigation field crops and trees, The aim of this study is to show the chemical characteristics of groundwater used in the irrigation process and classify it according to the scheme [1] and evaluate it according to the standard specifications of the Food and Agriculture Organization of the International [2] . Water samples were obtained from the six wells located within the study area for the period between the year 2023 to 2024 and in various seasons.
The values of hydrogen ion potential (pH) of well water were ranged between (6.8-7.3), the electrical conductivity (ECe) of salts ranged between (3.9-7.4 dSm-1), and the sodium absorption rate (SAR) ranged between (7.6-16.2) Potassium (K+) (6.7- 19.8) Calcium (Ca+2)(16.1- 30.1), Magnesium (Mg+2) (9.9-22.3), Chloride (Cl-) (40.8- 56.1), Bicarbonate (HCO3 -) (8.81- 27.5) sulphate (SO4-2)(25.0- 37.9), sodium (Na+)(32.4-60.1) meql-1, and the Kelley index was (0.66-1.94), The results of the study showed variations of some chemical characteristics over a range Its suitability for irrigating crops. Well water is classified as C5S1, C5S2, C4S1, and C4S2, all of which have high salinity, the study recommends taking administrative measures when using this water.

Keywords**:** Groundwater; Western Desert; Agricultural uses; Anbar Governorate; Mapping irrigation water classes.

INTRODUCTION

Groundwater is critical for sustained economic activity, growth, food security, social and economic development, and adaptation to the impacts of climate change. However, the sustainability of this vital resource is under threat in many regions, partly due to the lack of clear management policies. In the context of global pressures on food and water supply systems, policymakers must act now to ensure that groundwater is managed responsibly across the various sectors that depend on this Reference.

In [3] divided the desert regions into three types based on the amount of rainfall, starting with extremely arid lands, which do not receive any rainfall for 12 consecutive months, to arid lands, which receive an annual rainfall of less than 250 mm, while semi-arid lands are the regions where the average rainfall ranges between 250-500 mm annually. In his study of groundwater in the Western Desert. [4] noted the predominance of sulfate ions, followed by chloride, nitrate, and bicarbonate among negative ions. Among positive ions, calcium ions predominated, followed by sodium and magnesium. He found that 45% of the water in the studied areas had a salinity less than 13.2 dS m1-, and only 13% had a salinity greater than 19.2 dS m1-, This indicates that a small percentage of well water in the Western Desert contains high amounts of salts, according to data from [5]. The study of water hydrochemistry is of great importance in agricultural production, as water cannot be completely pure in nature and has a direct impact on the growth and production of agricultural crops. It affects the productive capacity of soils through its impact on the chemical, physical, and biological properties of the soil [6]. [7]explained that knowing the quality of groundwater is no less important than knowing its existence and quantities, because the quality of groundwater differs from one region to another according to a group of factors, including the nature of the chemical and physical composition of the rocks, which is reflected in the quality of groundwater contained in each well.

[8] studied the Groundwater Quality Index (GWQI) and its uses for irrigation purposes using Geographic Information System (GIS) techniques for the Nekor-Ghiss plain (Morocco). A multi-criteria analysis based on a GIS was used to determine values for various water quality attributes. The Piper and Durov scheme Were

The study focused on the main water parameters groundwater samples, such as sodium adsorption rate (SAR), dissolved sodium percentage (Na%), residual sodium carbonate (RSC), and permeability index (PI), The majority of water samples in the study area were suitable for irrigation. Based on magnesium hazard (MH) and Kelley's ratio, 51.9% of samples were unsuitable for irrigation purposes, while 59.49% were considered good for irrigation purposes. In the study of [9], Alappuzha district, Kerala state, South India, which is mainly dependent on groundwater for agricultural needs, for irrigation purposes, an attempt is made to find out the variables controlling water quality of deep groundwater aquifers using statistical tools.

[10] considered surface water quality parameters as an important means of determining the suitability of water for irrigation. Data from 32 irrigation stations were used to calculate sodium absorption rate (SAR), sodium content (Na%), Kelly index (KI), permeability index (PI) and irrigation water quality index (IWQI) to assess surface water quality. The obtained SAR, KI and Na% values ranged from 0.10 to 9.43, 0.03 to 1.37 meqL-1 and 3.16 to 57.82%, respectively. The calculated PI values showed that 93.75% of the water samples were in the "suitable" category and 6.25% in the "unsuitable" category. The obtained IWQI values from the research area ranged from 30.59 to 81.09. In terms of irrigation water quality, 12.5% of the samples were of "good" quality, 15.62% of "poor" quality, 68.75% of "very poor" quality and 3.12% of "unsuitable" quality. Based on these values, the IWQI value was estimated based on the SAR, Na%, KI and PI values using a multiple regression model. The regression coefficient (R2) was determined to be 0.6 in the multiple regression analysis. A moderately significant relationship was detected ($P < 0.05$). A relationship was concluded between the dependent and independent variables and the statistical performance of the models was determined using statistical values such as the mean value (μ), standard error (SE), standard deviation (σ), R2, root mean square error (RMSE) and mean absolute percentage error (MAPE).

[11] highlighted the global importance of groundwater as a source for meeting irrigation needs. Assessing the quality of groundwater in the Toshka area is essential to ensure its suitability for extensive agricultural activities in this promising region. This development relies on groundwater to address water shortages and implement major development projects in arid areas. Fifty-two samples were collected from wells in the Nubian region within the sandy aquifer in the Toshka area. Groundwater quality was assessed using hydrochemical analysis, a Piper diagram, and various indicators such as Na%, SAR, RSC, KR, MH, and PI. Hydrochemical analysis revealed an improvement in groundwater quality, attributed to continuous recharge from Lake Nasser, The Piper diagram classified most of the water samples as "secondary salinity," and nearly all wells were suitable for irrigation, with only two wells deemed unsuitable based on MH values and six wells classified based on KR values. All samples were classified as "soft." It was concluded that all samples met the WHO and FAO guidelines. Irrigation, and spatial distribution maps were shown using geographic information systems to present the interpretation of the results, The current study addresses the following:

1. An explanation of the groundwater quality status of the resources in the Kharayeb Al-Sheikh area within the arid regions of the Western Iraqi Desert.
2. Evaluation of groundwater for agricultural use according to [2] Water Quality Index approach, and classification within the [1] scheme.
3. Recommendations for addressing the problems of using these water resources are presented.

2.Methodology

Study area description

The Kharayeb ash-Shaykh area is located in western Iraq, as shown in Figure 1, and it lies between latitudes 25° 33' to 27'. 00' 19° 33' North and between longitudes 48° 42' 46.26' and 38° 42' 02.39' East with a geographical area of approximately 98.1 km2 and within the hydrological unit of the Western Desert of

Iraq [12] . The study area is surrounded from the north by the Euphrates River for a distance of 18.1 km, from the east by the Suh Al-Ghor region, from the west by part of the Al-Hajjaa Valley, and from the south by the Ramadi-Rutba highway. The inhabitants of the study area practice agriculture and animal husbandry, which is the main occupation of the citizens of the region. The Ramadi-Rutba highway extends within the center of the region. The elevation of Kharayeb ash-Shaykh is 96-181 m above sea level. Irrigation water in many areas of this study depends entirely on groundwater. It was noted that there is some agricultural investment in the study area and it is an important source of water for irrigation purposes and industrial use for quarries of construction materials for building stones and building sand in the Abu Asfia area.

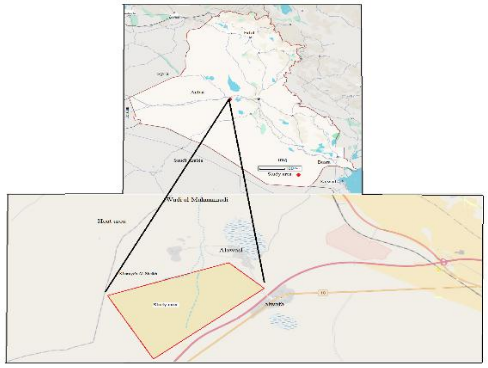

Figure 1: Location of study area within Iraqi Western Desert

Climate of Study Area

The study area belongs to the semi-desert climate zone, where the average rainfall does not exceed 100 mm per year, The aridity in the region coincides with a significant rise in temperature, averaging 24.5 degrees Celsius. The study area is characterized by being exposed to northwesterly winds, where temperatures are relatively low in the winter, and easterly winds. The natural climate of the region lies between the Euphrates River floodplain and desert areas with river valleys in the summer and rainwater drainage in the winter, Rainfall in the study area is characterized by irregularity and scarcity, and is characterized by sudden and abundant rainfall, falling in the winter months (November-December, January-February, March-April) in varying quantities, Temperature is the most important climate element, as it controls most other climate elements. The variation in temperature from one place to another or from one season to another, in turn, controls its distribution and movement system. It is the primary cause of evaporation of water bodies and the occurrence of precipitation in its various forms. Its irregular distribution is the basis for all weather conditions and daily changes, and it has a major role in the spatial distribution of living organisms on the Earth’s surface, in addition to its role in agricultural development plans, By observing the table and figure, the thermal characteristics and rainfall amounts can be analyzed, as it is characterized by a very hot and long summer due to the absence of clouds throughout the day, which exceeds 14 hours during the summer months, in addition to its continental distance, which distances it from marine influences and the nature of its continental surface, which lacks vegetation, which is characterized by dryness, while temperatures decrease in the winter during the months of (December, January, February), as temperatures reached (11.3, 9.4, 11.7°C) respectively, due to the short length of the day, which does not exceed 10 hours, and the sun’s rays falling obliquely, and the region being exposed to cold air masses [13] ,Table 1. Climatic data for the Kharayeb ash-Shaykh area,The study area is characterized by the presence of two short transitional seasons characterized by moderate temperature, as the temperature increases starting from the month of March, April, May, where the temperature was recorded at (15.5, 22.2, 27.2 °C) respectively, which represents the spring season. As for the autumn season, the temperature begins to decrease during the months of (September, October, November), where the temperature reached (29.7, 24.5, 16.3 °C) respectively. As for the monthly averages of maximum temperatures, we note a decrease in the rates in the winter season in January, where the lowest average was recorded at 15.1 °C. With the spring season, the maximum temperature rates begin to rise until they reach 43.6 °C due to the vertical fall of the sun’s rays, the low relative humidity, and the dry winds on the study area. In the autumn season, starting from the month of September, the maximum temperatures begin to decrease to 32.8 °C in October and 22.4 °C in November. The table shows the monthly rates of relative humidity in the study area, where it is noted that it varies due to differences in temperature and rainfall, The lowest rate of relative humidity reached 18% in June, and the highest rate in January, with a value of 67%, where rainfall and low temperatures occur. As for the rainfall, it is within the Mediterranean system, as rainfall begins from October until March. The winter season, which includes the months of December, January, and February, receives amounts of (21.0, 22.0, and 19.0 mm), respectively. While the amount of rain is in the spring season, which includes the months of March, April, and May, as the amounts recorded are 18.0, 12.0, and 3.0 mm, respectively. As for the summer season, there is no rainfall in the months of June, July, and August, due to the non-arrival of the Mediterranean lows, in addition to the presence of hot, dry tropical air masses that are characterized by dryness. In the autumn season, it begins. The Mediterranean depressions are back in activity, and God willing, rain will fall during the month of September. Figure 2 shows the monthly average rainfall (mm) and the average monthly maximum and minimum temperatures.

Table 1: Climate data for Kharayeb ash-Shaykh area

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature °C*	10.3	13	18.4	24.1	30.2	34.7	37.1	37.2	32.9 °C	26.8	17.3	11.9
Min. Temperature °C	6.2	8	12.3	17.5	23.3	27.9	30.4	30.2	26.2	20.9	12.6	7.9
Max. Temperature °C	15.1	18.3	24.1	30	36.2	40.9	43.5	43.6	39.4	32.8	22.4	16.5
Precipitation / Rainfall	22	19	18	12	3	0	0	0	0	8	18	21
Humidity (%)	67%	56	38	31	23	18	19	20	25	34	53	65
Rainy days (d)	3	3	2	2	1	0	0	0	0	1	2	3
avg. Sun hours (hours)	8.1	9.3	10.5	11.6	12.5	12.9	12.7	12.0	11.2	10.2	8.8	7.9

* Source: https://en.climate-data.org/asia/iraq/al-anbar-Ramadi[14]
(Data: 1991-2021. Average temperature °C, minimum and maximum temperature °C, rainfall mm, relative humidity, rainy days, Data: 1999-2019: average sun hours))

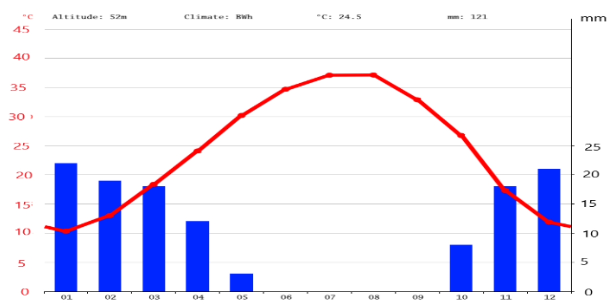

Figure 2: Monthly average rainfall (mm) , monthly average maximum temperature (°C)

Geology and Geomorphology of Study Area

The map in Figure 2 shows the geological formations on the surface, extending from the Miocene to the Holocene [15] , Lithologically, the study area includes carbonates and marls, according to [16] ,The distribution of these sediments and other geological formations is as follows:

Euphrates (upper member) Formation:

Depositional environment (shallow active).

Consists of basal conglomerates, dolomite, Cretaceous limestone, and limestone, with granular limestone, dolomite, and dolomite.

Fatha (Nafayil Bebs) Formation:

The marine environment and crater formation layers are higher than four gravel deposits in the sections near Euphrates River, They consist of cyclic rock sequences of mudstone (marl), limestone, gypsum, gypsum, limestone, and mudstone.

Residual soil

This is the main soil type in the study area, generally covering flat and gently sloping areas, with gravel being present (0-53.7%), often with a sub-circular to sub-angular shape. Calcite and dolomite are the major constituent minerals, less abundant than limestone and marl. Sand constitutes 7.4-72.5% of the soil. Fine particles, including both silt and clay, constitute 5-90.2% (YASIN, 1990) [17].

Valley Fill (Holocene):

Deposits extend along the entire course of Wadi al-Muhammadi and its branches. The valley is filled with sediment, the main components being gravel and coarse sand. The gravel consists of limestone, dolostone, and silicate sandstone, rounded in shape and ranging in size from a few centimeters to 35 cm, but may reach more than 50 cm and, very rarely, up to 100 cm. The depth varies along the course and even in adjacent areas, reaching up to 8 m, but averaging 2–5 m.

Depression Fill Sediments (Holocene):

The sediments consist mainly of clay and silt within the low-lying areas and range in thickness from 0.5–1.5 m.

Gypcrete:

The locations of this crust vary across the section. It is devoid of simple application, and its thickness ranges between 0.3 and 2.5 m. It contains cracks and veins of secondary bodies, with diameters ranging between 0.5 and 2 cm, extending to the bottom of the underlying layers. These cracks, which are deposited within them, may have resulted from drought,

Quaternary sediments: These consist of the following:

- Pleistocene river sediments.
- Pleistocene-Holocene foothill sediments.
- Pleistocene-Holocene residual soil deposits.
- Pleistocene-Holocene valley sediments.
- Pleistocene-Holocene floodplain deposits.
- Pleistocene-Holocene depression deposits.
- Organic soil deposits, which are secondary sandy loam deposits of gypsum and tar.
- Sabkha deposits, which are Holocene saline clay deposits, Figure 3. Geological map of the study area.

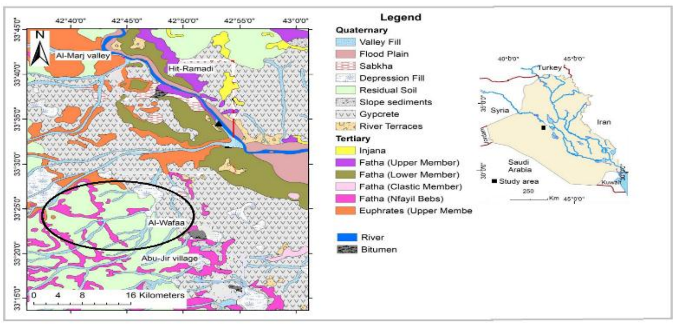

Figure 3:The Geological map of study area showing geological formations

.

Fieldwork:

Six wells and springs within the study area were identified and their geographic coordinates determined using a GBS device. Water samples were collected at a rate of three samples every three months (seasonally) from each of the six wells for the year 2023-2024 using sterile, sealed plastic bottles, Electrical conductivity and pH were estimated locally using field instruments, Drops of formalin were added and stored in a field refrigerator until transported and preserved to the laboratories of the Desert Studies Center at Anbar University, Groundwater samples were collected from six wells within the study area, including shallow wells, artesian springs, and deep wells, during March 2023. pH and electrical conductivity (EC) were measured using digital measuring devices and electrical conductivity directly in the field, The samples were transported, stored in a cooler, and transported from the field to the laboratory. The collected water samples were analyzed for the major ions: Ca, Mg, Na, K, HCO_3, CO_3, SO_4, and Cl, for chemical analyses according to the methods described in [17], calculating the sodium adsorption ratio (SAR) values according to [18] , classifying well water according to [1] , and evaluating the studied well water according to the Food and Agriculture Organization of the United Nations (FAO) standards for water classification [2] ,Table 3 shows the criteria used in the evaluation process, Figure 4 shows the methodology of the current study, which includes groundwater sampling, analysis, and comparison of the results obtained with national and international standards, statistical analysis of the various characteristics, modeling, and indicators, the spatial distribution of sample sites, the various characteristics, and the water quality index using geographic information systems. Table 2 shows the coordinates and elevation of the sites above sea level.

Table 2 Explains the location of wells relative to latitude and longitude

No.	N	E	Height above sea level m
1	33˚ 24ˈ 38.63□	42˚ 47ˈ 06.8□	100
2	33˚ 23ˈ 56.91□	42˚ 37ˈ 59.92□	156
3	33˚ 23ˈ 25.79□	42˚ 41ˈ 55.18□	132
4	33˚ 23ˈ 04.59□	42˚ 45ˈ 24.27□	114
5	33˚ 23ˈ 15.17□	42˚ 49ˈ 36.13□	104
6	33˚ 18ˈ 46.68□	42˚ 39ˈ 09.24□	137

[18] and [21] introduced another factor for evaluating the quality and classification of water for irrigation purpose based on the concentration of Na^+ with Ca^{2+} and Mg^{2+}, which can be calculated using the equation.

$$KI = \frac{Na^+}{Ca^{2+} + Mg^{2+}}$$

(All ion concentrations are expressed in $meqL^{-1}$), KI > 1 indicates excess level of Na^+ in the water so water with KI ≥ 1 is recommended for irrigation, whereas water with KI ≥ 1 is not recommended for irrigation due to the risk of alkali formation [22] , [23] .

Table 3 Criteria for the assessment of well water according to FAO standards) [2]

Nature of the problem	**value of minimum use**		
	None	**Slight Moderate**	Sever restriction of use
Salinity value (EC) dS m-1	>0.7	0.7 – 3	< 3
Total dissolved salts ppm	450	450 – 2000	< 2000
Sodium adsorption ratio	Electrical conductivity EC		
0 – 3	< 0.7	0.7 – 0.2	>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	5 – 2.9	> 2.9
Side effect of ions			
Sodium (meqL-1) natural irrigation	3 >	3 – 9	< 9
Chloride (meqL-1) surface irrigation	4 >	4 – 10	< 10
Other incidental effects			
Nitrate (meqL-1) NO3- N	0.5 >	5 – 30	< 30
Bicarbonate (meqL-1)	1.5 >	1.5 – 8.5	< 8.5
pH	6.5 – 8.4		

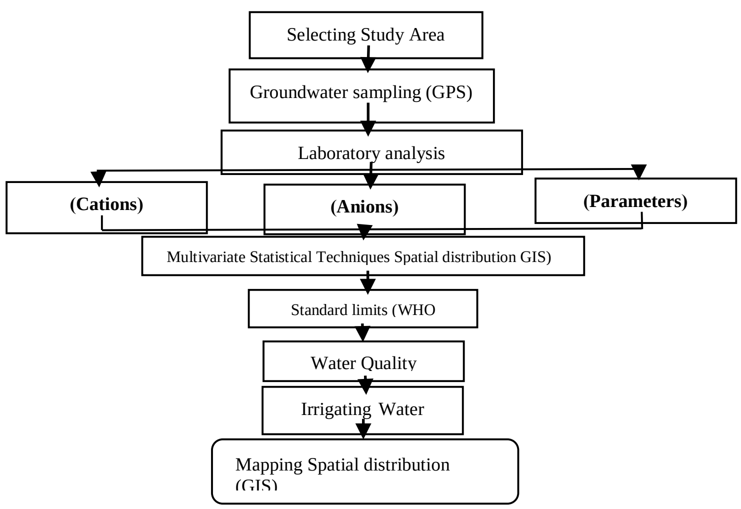

Figure 4. Research methodology of current study.

4. Result and Discussion

Water Content of Cations and Anions:

Table 4 shows chemical properties of main important ions in stating the water condition in study area and the statistical relationships of those properties, Among the cations, Ca^{+2} is a major component, its content ranged between (11.3 - 28.1) at a rate of 19.0 $meql^{-1}$, and concentration of Mg^{+2} ranged from (11.3 - 28.1) at a rate of 19.0 $meql^{-1}$, The sources of magnesium in groundwater are magnesium-bearing minerals present in rocks ,The contents of Na^+ and K^+ in groundwater of the wells of the study area ranged between (32.4 - 60.1) and (6.7 - 19.8) respectively, [23] , the sodium content is considered from good to permissible. As for the standards of the US Salinity Laboratory [1] , sodium is considered (doubtful) at these values, while potassium is considered (permissible). The amount of HCO_3^{-2} varies between The studied wells were (8.81 - 27.5) $meql^{-1}$, while Cl^- was in the range (40.8 - 156.1 $meql^{-1}$), Bicarbonate (8.81 - 127.5 $meql^{-1}$) and Sulphate in the range (8.81 - 37.9 $meql^{-1}$).

Table 4 : Chemical characteristics and statistical data of the well water studied

Properties *	Units	Well. 1	Well. 2	Well.3	Well. 4	Well. 5	Well. 6	Min.	Max.	Mean	SD
pH	-	7.0	7.1	6.9	6.8	7.2	7.3	6.8	7.3	7.0	0.18
EC	dSm^{-1}	5.9	6.1	5.8	7.4	3.9	3.6	3.9	7.4	5.4	1.44
TDS	mgl^{-1}	4720	4880	4640	5920	2496	2304	2304	5920	4160	1440.3
(Na^+)	$meql^{-1}$	50.5	50.1	40.0	60.1	32.4	50.2	32.4	60.1	43.7	11.7
Potassium(K^+)	$meql^{-1}$	6.7	8.5	16.7	8.8	19.8	12.9	6.7	19.8	13.2	4.72
Calcium(Ca^{+2})	$meql^{-1}$	21.7	30.1	17.0	16.1	27.0	20.0	16.1	30.1	21.9	5.07
Magnesium(Mg^{+2})	$meql^{-1}$	20.9	11.3	28.1	14.9	22.1	16.9	11.3	28.1	19.0	5.42
Chloride(Cl^-)	$meql^{-1}$	40.8	56.1	45.4	42.2	45.2	41.2	40.8	56.1	45.1	5.21
HCO_3^{2-}) Bicarbonate(	$meql^{-1}$	22.9	18.8	21.3	20.1	18.9	27.5	18.8	27.5	21.5	2.99
Carbonate(CO_3^-)	$meql^{-1}$	-	-	-	-	-	-	-	-	-	-
Sulphate(SO_4^{-2})	$meql^{-1}$	35.9	25.0	32.9	37.9	35.5	30.6	25.0	37.9	32.9	4.25
SAR	-	11.2	11.1	8.5	15.4	6.6	11.9	7.6	16.2	-	-
Na^+%	-	58.0	59.4	56.0	69.0	58.0	64.0	-	-	-	-
KI	-	1.19	1.21	0.89	1.94	0.66	1.40	-	-	-	-

*EC: Electrical conductivity, TDS: Total dissolved solids, SAR: Sodium adsorption ratio , KI: Kelley ratio, SD: Standard Deviation

Water Use for Agriculture:

Water quality problems in irrigation include high salinity and excessive toxic elements. High salinity occurs when salts accumulate in the soil. Water contains high concentrations of certain elements that delay or even eliminate the growth of some plants, such as total salinity, chlorides, and sodium, which are common toxic substances.

To better understand the suitability of water for agricultural use, there are important factors that must be taken into account, including the sodium adsorption ratio (SAR), sodium hazards, and the percentage of sodium (Na%). Knowledge of water evaluation is very important and has been used to assess the suitability of water for irrigation to avoid negative effects on soil and plant productivity. Groundwater quality assessment for agricultural use is based on total dissolved solids (TDS), EC, SAR, and major ion concentrations, chemical analysis results presented in Table (4) illustrate the values and ranges of the characteristics included in the assessment and classification of groundwater quality. This data is used to determine its suitability for agricultural use, as follows:

pH:

The pH values of the wells studied ranged from 6.8 to 7.3, with an average of 7.0, which tends to be neutral. These values are considered within the permissible limits for agricultural use.

Salinity:

The salinity values of water samples in the Kharayeb Al-Sheikh area ranged from 3.9 to 7.4 dSm-1, with an average of 5.4 dSm-1 and a standard deviation of 1.44. The salinity in Well No. 4 was the highest among the wells studied, while the lowest value was in Well No. 6, which is higher than the limits recommended by the Food and Agriculture Organization of the United Nations (FAO) for water classification [2].

Total Dissolved Solids (TDS):

The total dissolved solids concentration in water samples from the study area ranged from 2304 to 5920 mg/L, which is higher than the recorded TDS levels, Further investigations revealed average TDS values of 4160 mgL^{-1}, which are considered high concentrations obtained in the current study.

Sodium Desorption Ratio (SAR):

The SAR values varied from well to well, with the lowest value being 6.6 in Well 5 and the highest value being 11.9 in Well 6. According to the American Salinity Laboratory standards [1], the SAR was rated as "Excellent" to "Good."

Kelly Index (KI):

The Kelly Index has a range of (0.66-1.94). KI > 1 indicates an excess level of Na+ in the water. Therefore, water with a KI ≥ 1 is recommended for irrigation, while water with a KI ≥ 1 is not recommended for irrigation due to the risk of alkalinity [22], [23].

Groundwater Evaluation for Irrigation:

It is noted from the results of Table 4 that the electrical conductivity values of the well water in the study area ranged between 3.9 and 7.4 dSm^{-1}, with significant differences between the electrical conductivity values of these well water. Well No. 6 showed the lowest average for this characteristic, 3.9 dSm^{-1}, compared to Well No. 4, which showed the highest average value, 7.4 dSm^{-1}. Regarding the qualitative effect of the dominance of positive ions, the following were observed: > Ca^{+2}> Mg^{+2}> K^{+} Na^{+}, As for negative ions, the following were observed: > SO_4^{-2}> HCO_3 Cl-. The values of all wells were distributed according to the [1] diagram to indicate the classification of these groundwater's and their suitability for agriculture in these arid regions of the Western Iraqi Desert. Wells 1, 2, and 4 are classified as C5S2 (the use of this water requires plants that are resistant to salt, excellent drainage, and frequent drainage). and intensive management) i.e. within the very high salinity and low sodicity, while well No. 3 is within the C5S1 category, while well 5 is within the C4S1 category, and well 6 is within the C4S2 category. Figure 6 shows the water categories and the degrees of the determinants for the studied water categories. As for the evaluation of Good and Permissible. The reason for the low values of the sodium absorption ratios in the well water is due to the dominance of the concentration of divalent ions of calcium and magnesium over the sodium concentration in these waters. The presence of calcium and sulfate dominance in the studied water is due to the geological formations in the region where dolomite, gypsum, limestone and emery rocks are found, and this is consistent with what was observed by [4] and Alalwany. ,2007[25] In their study of groundwater in the western region of Iraq, which is found within recent sediments, they found that the low concentration of magnesium compared to the concentration of calcium is due to the slow dissolution of dolomite, in addition to the widespread presence of limestone in the formations of the region, [26], Figure 5. Predictive distributions of some characteristics of well water in the study area. that water, based on [2] ,Table 3 and according to the results of Table 4, those waters showed that all the wells were evaluated from the salinity characteristic within a specific factor (Severe) as well as TDS, while from the SAR characteristic, all the wells were between(6.6-15.4) .

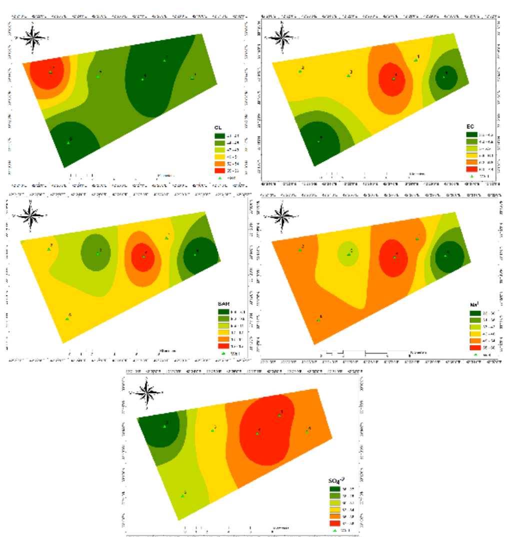

Figure 5: Predictive distributions of some well water characteristics in the study area -ArcGIS. 2021. [27]

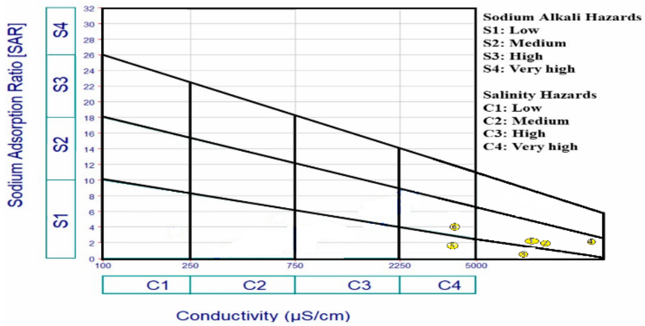

Figure 6:USSL diagram for irrigation purposes

Statistical relationship of measured characteristics:

Use the [28] program and get the results listed in Table 5,It is noted from Table 5 that there is a negative correlation between pH and EC (-0.909) and TDS (-0.90369). pH was positively correlated with HCO_3 (0.71813), potassium, and calcium. EC was positively correlated with TDS, sodium, chloride, magnesium, sulfate, and, to a lesser extent, calcium. It was negatively correlated with carbonates and potassium.

Table 5 shows the correlation matrix between the characteristics of the well water.

*	pH	EC	TDS	Na^+	K^+	Ca^{+2}	Mg^{+2}	Cl^-	HCO_3^{-2}	SO_4^{-2}
pH		-	-	-	0.2557	0.0787	-	-	0.7181	-
EC	-		0.996	0.6275	-	0.2450	0.4965	0.5046	-	0.4846
TDS	-	0.996		0.6336	-	0.2625	0.5437	0.5537	-	0.5425
Na^+	-	0.6275	0.6336		-	0.1925	-	0.2043	-	0.5139
K^+	0.2557	-	-	-		-	0.0494	-	-	-
Ca^{+2}	0.0787	0.2450	0.2625	0.1925	-		-	0.7398	0.1981	0.5187
Mg^{+2}	-	0.4965	0.5437	-	0.0494	-		0.4338	-	0.5291
Cl^-	-	0.5046	0.5537	0.2043	-	0.7398	0.4338		-	0.5968
HCO_3^{-2}	0.7181	-	-	-	-	0.1981	-	-		-
SO_4^{-2}	-	0.4846	0.5425	0.5139	-	0.5187	0.5291	0.5968	-	

At a significance level of 0.05 *

Figure 7 shows the distribution of wells and their characteristics within the BIPLOT model, which demonstrates that 73.26% of the total variance between wells is due to individual characteristics, Well 1 can be evaluated based on sulfate ions, Well 2 based on sodium and then calcium. Well 3 is evaluated based on magnesium ions, while Well 4 is evaluated based on TDS and EC, and to a lesser extent, chloride. Figure 6 also shows that Wells 5 and 6 may be the best wells, as they avoid salinity and sodicity.

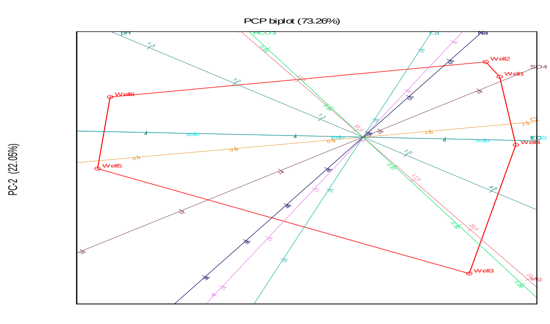

Figure7 : Biplot analysis of properties in six wells

Geochemical Properties:

When interpreting the results based on the geochemical properties of the well water in the study area, as shown in Figure 8, which is known as the Piper Trainer diagram [29] and used in the geochemical evaluation of groundwater by [30], it is clear that the tested water, in terms of the main wave ions, is of a quality dominated by Ca^{+2}, Mg^{+2}, and Na^+, In terms of negative ion group, it is HCO_3^-, Cl^-, and SO_4^{-2}, with a predominantly basic characteristic. A visual representation of the average concentrations of the main ions was projected onto the diagram, revealing that the water in the wells is of the types that fall under the dominant hydrochemical facies of groundwater: NaCl type, Mixed CaMgCl type. Figure 7 illustrates the Piper diagram .

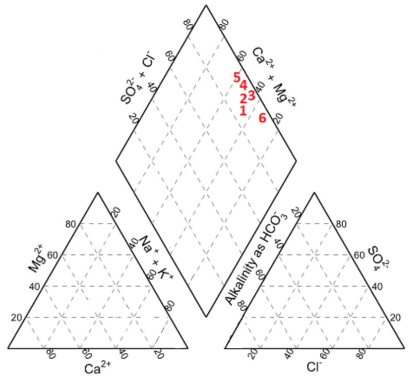

Figure 8: Piper diagram groundwater samples.

Conclusions

The research results demonstrated an understanding of groundwater quality, as well as being a useful tool in water quality management, analytical tools, and decision-making processes for future agricultural development in these desert areas.

Laboratory analysis results showed that the water in the study area is classified as highly saline and moderately sodic, most of which, according to international classifications, are extremely hazardous and require intensive management if used for agricultural purposes.

The study proposes, in the absence of water management, the transfer of water from the Euphrates River via water pipelines, estimated at a distance of 18.1 km, to mitigate the negative consequences of this saline water, which is the primary cause of land degradation and salinization.

Recommendations

Based on the results of this study, we recommend the following:

1. When using these lands, the quality of the water in the study area and its salinity should be taken into consideration.
2. Develop management methods and modern irrigation technologies to reduce the salinity of this water and its impact on crop productivity.
3. Conduct further research studies on this important resource, given the drought conditions in these areas.
4. Select appropriate and saline-tolerant crops and trees within the region.

Acknowledgments

The research team thanks the administration of Anbar University and the Desert Studies Center for preparing the practical requirements for field activities for the study.

References

[1].Richards, L.A. (1954) Diagnosis and improvement of saline and alkaline soils. U.S. salinity Lab.Staff, U.S.D.A. Handbook No.60 Washington,D.C.160.

[2].F. A. O. (1989) Quality of Water for agriculture. Paper No. 29 (Rev. 1). Ayers, R. S. and D. W. Westcott. Rome. Italy.

[3].Peveril, M., (1953) The Vegetation region distribution according to amount of precipitation.(C.F.)Guest,1966.

[4].Thalen, D.C .P. (1979) Ecology and Utilization of Desert shrub- rangelands In Iraq . ph.D. thesis . Netherlands.

[5].Parsons , R . M . (1955) Groundwater Resources of Iraq . Dulaimliwa . Baghdad. Vol .10. p.12 .

[6].Chow, V.T. (1964) Handbook of Applied Hydrology. McGraw-Hill Book Company, New York.

[7].Hussein, Y. A. (1985) Groundwater in the Western Plateau of Iraq and its Sensing Aspects. Master's Thesis. College of Arts, University of Baghdad(in Arabic).

[8].Elkhalki S, Hamed R, Jodeh S, Ghalit M, Elbarghmi R, Azzaoui K, Hanbali G,Ben Zhir K, Ait Taleb B, Zarrouk A and Lamhamdi A . (2023) Study of the quality index of groundwater (GWQI) and its use

for irrigation purposes using the techniques of the geographic information system (GIS) of the plain Nekor-Ghiss (Morocco). Front. Environ. Sci. 11:1179283.doi: 10.3389/fenvs.2023.1179283.

[9].Joji , V. S. (2024) Analysis of Chemical Characteristics of Fluoride-Rich Waters in Deeper Coastal Aquifers of Alappuzha District, Kerala State, South India for Domestic and Irrigation Purposes . Ground Water Contamination in India .

[10]. Sayiter Y., Can B. K. (2019) Estimation of irrigation water quality index with development of an optimum model: a case study. Environment, Development and Sustainability .

[11]. Aly, Marwa M, Fayad Shymaa AK, Abd Elhamid Ahmed MI. (2024) Assessment of groundwater suitability for different active ties in Toshka district, south Egypt. Journal of Groundwater Science and Engineering, 12(1): 34-48.

[12]. Sissakian, V.K. (2012) Calcrete development in Darbandi Khan – Sartaq Bammu Area, NE Iraq. Scientific notes. Iraqi Bull. Geol. Min., Vol.8, No.1, p. 93 – 98.

[13]. Al-Shalash, Ali Hussein (1988) Climate of Iraq. Basra: University of Basra(in Arabic).

[14]. climate-data (2021) org/asia/iraq/al-anbar-Ramadi.

[15]. Sissakian, V. & Buthaina, S. (2007) Stratigraphy of the Iraq western desert. Iraqi Bul, Geol, Min.(Special Issue, Geology of Iraqi Western Desert): 51- 124.

[16]. Sissakian, V.K..and Al-Khalidi, Z.B., (2012) The Lithological Map of Iraq. Iraqi Bull. Geol. Min., Vol.8, No.3, p. 1 – 13.

Chapman, H.D. and Pratt, P.F. (1961) Methods of analysis for soils, plants and waters. University of California, Los Angeles, 60-61, 150-179.

[17]. YASIN, M. J. (1990) SOME GEOTECHNICAL PROPERTIES OF SOILS IN THE HADITHA AREA, W. IRAQ. BULLETIN Of the International Association of ENGINEERING GEOLOGY .

[18]. Al-Zubaidi, A. H., Abdul Aziz Al-Barzanji, Afaf S. (1981) Evaluation of different methods for estimating gypsum. In gypsum soils in Iraq. Iraqi Agricultural Sciences Journal, Volume (16).

[19]. Kelly, W. P. (1963) Use of saline irrigation water. Soil Sci. 95, 355–391. doi: 10.1097/00010694-196306000-00003.

[20]. Paliwal KV . (1967) Effect of gypsum application on the quality of irri gation water. Madras Agric J 59:646–647.

[21]. Ramesh K, Elango L . (2012) Groundwater quality and its suitability for domestic and agricultural use in Tondiar River Basin, Tamil Nadu, India. Environ Monit Assess 184(6):3887–3899.

[22]. Karanth KR . (1987) Groundwater assessment development and manage ment. Tata McGraw Hill Publishing Company Ltd., New Delhi, p 725.

[23]. Wilcox, L.V. (1948) The quality of water for irrigation use. US Dep. Agric. Technol. Bull, 40, 962.

[24]. Alalwany, AbdulKarem Ahmed. (2007) The effect of agricultural exploitation on the characteristics of soil and natural vegetation of some desert oases in western Iraq. Doctoral thesis. Anbar University College of Agriculture.

[25]. AlDulaimy, Abdel Saleh (2000) Structural and geological structure of Anbar Governorate. Encyclopedia of Anbar civilization. Anbar University - Center for Desert Studies.

[26]. ArcGIS. (2021) https://deskt op.arcgis.com/en/arcmap/10.4/get-started/setup/arcgis-desktop-quick-start-guide.htm.

[27]. Pearson, Karl (2023) Pearson correlation coefficient program.

[28]. Piper,A.M. (1944) A graphic procedure in the geo-chemical interpretation of water analyses. American geophysical Union Transactions 25,914-923.

دراسة هيدرولوجية لتقييم نوعية المياه الجوفية وملاءمتها لأغراض الري في منطقة خرايب الشيخ باستخدام نظم المعلومات الجغرافية ضمن الصحراء الغربية، العراق

عبدالكريم احمد العلواني[1] **فاضل مخلف حسين[1]** **محمد حاتم محمد عبدالرزاق [1]**

باسم احمد زيدان[1] **ميادة صفاء جاسم [1]** **منير ناجي الفلاحي[2]**

سامي عوض محمد[1]

[1] جامعة الانبار , مركز دراسات الصحراء.

[2] جامعة الانبار , مركز تنمية حوض ,عالي الفرات.

الخلاصة

إن مراقبة نوعية وكمية المياه الجوفية أمر بالغ الأهمية للإدارة الفعالة والمستدامة لهذا المورد المهم في المناطق الجافة وشبه الجافة، ان نوعية مياه الري وملوحة التربة العامل المحدد الرئيسي لنمو المحاصيل الزراعية، كما أن زيادة ملوحة المياه الجوفية المستخدمة في المناطق الجافة ذات الأمطار المحدودة تعيق تنوع المحاصيل التي يمكن إنتاجها ،تناولت هذه الدراسة التركيب الفيزيائي والكيميائي للمياه الجوفية في موقع منطقة خرايب الشيخ المصدر الرئيس لمياه ري المحاصيل، وتتميز المياه في تلك الأماكن ببعض المشاكل المتعلقة بنوعية وملاءمة ري المحاصيل الحقلية والأشجار، وتهدف هذه الدراسة إلى إظهار الخصائص الكيميائية للمياه الجوفية المستخدمة في عملية الري وتصنيفها وفقًا للمخطط [1] وتقييمها وفقًا للمواصفات القياسية لمنظمة الأغذية والزراعة الدولية [2]، تم الحصول على عينات المياه من الآبار الستة الواقعة ضمن منطقة الدراسة للفترة ما بين عامي 2023 و 2024 وفي مواسم مختلفة، تراوحت قيم جهد أيون الهيدروجين (***pH***) لمياه الآبار بين (6.8–7.3)، وتراوحت الموصلية الكهربائية (***ECe***) للأملاح بين (3.9–7.4 ***dSm−1***)، وتراوحت معدل امتصاص الصوديوم (***SAR***) بين (7.6–16.2)، والبوتاسيوم ***(K+)*** (6.7–19.8)، والكالسيوم ***(Ca+2)*** (16.1–30.1)، والمغنيسيوم ***(Mg+2)*** (9.9–22.3)، والكلوريد ***(Cl−)*** (40.8–56.1)، والبيكربونات ***(HCO3−)*** (8.81–27.5)، والكبريتات ***(SO4−2)*** (25.0–37.9)، والصوديوم (***meqL−1) (32.4-60.1) Na+***، وكان مؤشر كيلي (0.66–1.94) أظهرت نتائج الدراسة اختلافات في بعض الصفات الكيميائية على مدى ملاءمتها لري المحاصيل صنفت مياه الآبارالمدروسة إلى الاصناف ***C5S1***، و***C5S2***، و ***C4S1***، و***C4S2***، وجميعها ذات محتوى ملحي عالي، توصي الدراسة باتخاذ إجراءات إدارية عند استخدام هذه المياه.

الكلمات المفتاحية: المياه الجوفية؛ الصحراء الغربية؛ الاستخدامات الزراعية؛ محافظة الانبار ؛ رسم خرائط اصناف مياه الري.