DOI: 10.24996/ijs.2023.64.2.19

ISSN: 0067-2904

Assessment of Groundwater Suitability for Irrigation and Livestock Purposes in Sayed Al-Shuhadaa Agricultural City, Karbala, Central Iraq

Rafal Ghassan Mahmoud[1]*, Ayser Al Shamma'a[1], Maithem Al-Ghanimy[2]

[1]*Department of Geology, College of Science, University of Baghdad, Baghdad, Iraq*

[2]*General Authority for Groundwater, Ministry of Water Resources, Karbala, Iraq*

Received: 11/4/2022 Accepted: 8/6/2022 Published: 28/2/2023

Abstract

The study investigates the anion and cation concentrations and their distribution in the Dammam aquifer to assess the groundwater suitability for irrigation and livestock in Sayed Al-Shuhadaa, Karbala, central Iraq. It lies between longitudes 43º 29' 00" – 43° 40' 00" E and latitudes (32° 17' 00" – 32°22' 00") N. The physicochemical properties, cations and anions were measured in 14 active wells distributed in the study area. The assessment was conducted based on the sodium adsorption rate (SAR), sodium percentage (Na%), electrical conductivity (EC), total dissolved solids (TDS), and Hydrogen number (pH). Groundwater in the study area is very good for livestock and characterised by no damage, as the rate of sodium adsorption was good. The percentage of sodium and pH values are within the permissible values for irrigation, except for some wells that have high TDS and EC, which leads to an increase in salinity.

Keywords: Hydrochemistry, Dammam aquifer, Suitability of groundwater, Sayed Al-Shuhadaa agricultural city.

صلاحية المياه الجوفية للأغراض الزراعية في مدينة سيد الشهداء الزراعية ، محافظة كربلاء ، العراق

رفل غسان محمود[1]*، ايسر الشماع[1] ، ميثم الغانمي[2]

[1] قسم علم الأرض، كلية العلوم، جامعة بغداد، بغداد، العراق

[2] الهيئة العامة للمياه الجوفية، وزارة الموارد المائية، كربلاء، العراق

الخلاصة

في هذه الدراسة الحالية تم قياس تراكيز الايونات السالبة الايونات الموجبة وتوزيعها في الخزان الجوفي لتكوين الدمام ، وذلك لتقييم صلاحية المياه الجوفية لأغراض الري وتربية الماشية لمدينة سيد الشهداء الزراعية الواقعة في محافظه كربلاء –جنوب غرب العراق . تم قياس الخصائص الفيزيائية–الكيميائية لعينات المياه الجوفية من خلال اختيار 14 بئر . تم تقييم مدى ملائمة المياه الجوفية للارواء والزراعة من خلال استخدام نسبة امتزاز الصوديوم (SAR) ، النسبة المئوية للصوديوم(Na%) ، التوصيلية الكهربائية (EC) ، المواد الصلبة الذائبة الكلية (TDS) والدالة الحامضية. تتميز المياه الجوفية في منطقة الدراسة بكونها جيدة جدا للماشية، وتتميز بعدم وجود ضرر حيث كانت نسبة امتزاز الصوديوم جيدة ، والنسبة المئوية للصوديوم وقيم

*Email: rafal.ghassan1208m@sc.uobaghdad.edu.iq

الأس الهيدروجيني ضمن الحدود المسموحة لاغراض الشرب،الا في بعض الابار وذلك بسبب احتوائها على
نسب عالية من TDS و EC مما يؤدي الى زيادة الملوحة.

1. Introduction

Recently, groundwater has been considered one of the main and important natural resources due to the increasing demand for water with less surface water supply and decreasing rainfall. It has become very important to have large quantities of good quality groundwater. The study deals with the Dammam aquifer located in Karbala Governorate, where groundwater occurs within the pebbly sandstone beds, sometimes containing siltstone and mudstone beds [1]. The groundwater quantity and quality in Karbala have been studied by many researchers [2], [3], [4]; this study focused on Sayed Al-Shuhadaa agricultural city, which is a new agricultural project that lies on the west side of Karbala. For that, the groundwater's validity for irrigation is considered the most important purpose [5]. The Dammam Formation is the main aquifer in this area, where it extends west of the Euphrates River in most of the western and southern deserts [6]. The saturated thickness represents almost all the thickness of the formation, where it contains wide and expanded caves and cracks due to structural and weathering impacts [7]. The project is located near the Ain Al-Tamr area to be one of the agricultural projects supporting the local production of wheat. The project area is 5000 acres, and the most important characteristic is the use of pivotal irrigation systems of international origin. The area is expanded by adding 22 pivot sprinklers to become 36 sprinklers, each sprinkler covering 80 to 120 acres, and 22 new wells were dug.

2. Study Area:

The studied area is an agricultural project called Sayed Al-Shuhadaa agricultural city. It is located within Al-Ukhaidir area in the Ain Al-Tamar district, to the southwest of Al-Razzaza Lake and the west of the Holy Karbala province. It lies between longitudes 43º 29' 00" – 43º 40' 00" and latitudes 32º 17' 00" – 32º22' 00"N (Figure 1), occupies an area of about 50.79 Km^2. The study area lies near Wadi Al-Ubayad and Wadi Al-Rakash, ranging 35-158 m high above sea level. From a hydrogeological standpoint, the production unit in the studied area is represented by the Dammam Formation, a confined aquifer. The direction of flow runs from the west-southwest toward the east-northeast, with transmissivity (T) values ranging between (147- 781.5) m^2/day, hydraulic conductivity (K) values are ranged between 2.94 and 58.74 m/day, storage coefficient (Sc) values range between 0.000334 and 0.000406, and the specific capacity (SC) values range between (406-1083.9) m^2/day.[8].

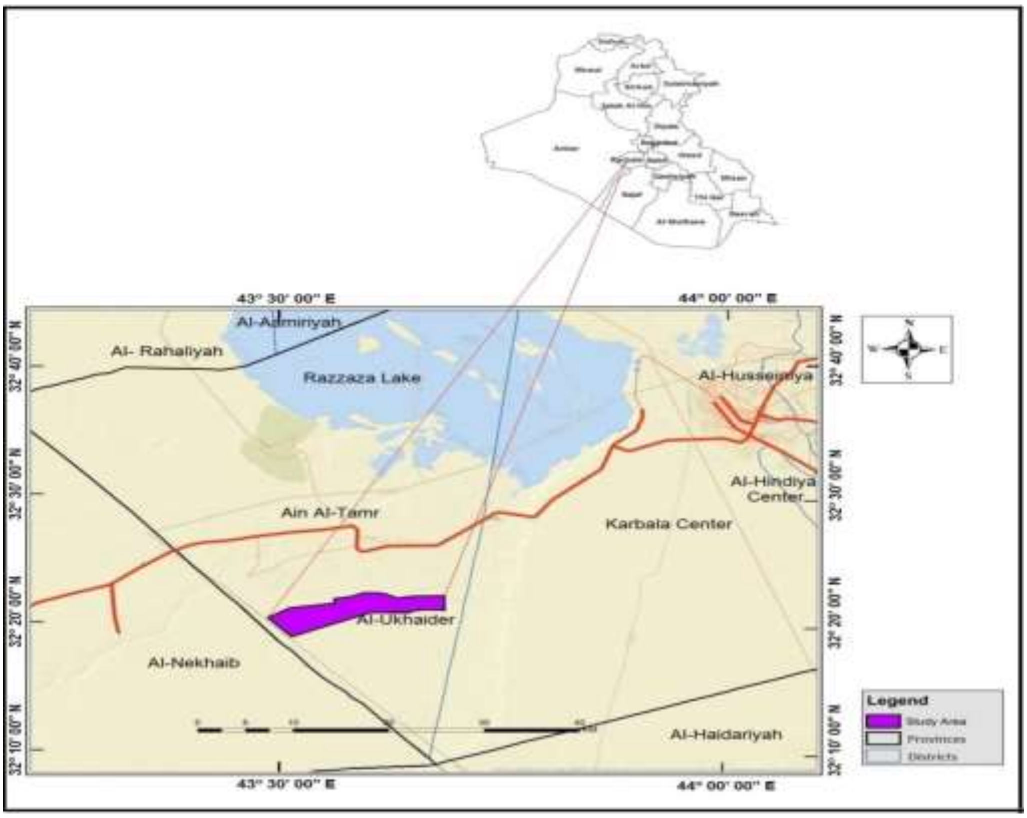

Figure 1: Location of the study area

3. Materials and Methods

Fourteen wells were used for collecting water samples from the Dammam aquifer in November 2021 (Figure 2). The main cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) and main anions (SO_4^{2-} CO_3^{2-}, Cl- and HCO_3^{-}) were analyzed. Each sample's coordinates (latitude, longitude and elevation) were recorded depending on the GPS, Garmin-78 origin. Table 1 presents the analysing methods for the various parameters.

Laboratory work is focused on chemical and physical analyses. Groundwater distributed over the area is analysed in the General Commission of groundwater laboratory. pH and EC are measured by the pH-EC meter, while TDS is measured by the TDS meter and vaporisation method depending on the standard procedure [3]. The equations below were used to check the accuracy of the result [9]. Table 1 shows the apparatus and analytical methods used to analyze those elements and variables.

Table 1: The apparatus and analytical methods used in this study

Parameter	Methods of analysis
Ca^{+2}	EDTA titrimetric
Na^{+}, K^{+}	Flame Emission Photometric
Mg^{+2}	Calculation from total hardness and calcium
HCO_3^{-}, NO_3^{-}	Technecon in volumetric
SO_4^{-2}	Nephelometry
Cl^{-}	Argentometric titration
PO_4^{3-}	Digestion And Ascorbic Acid Spectrophotometric
pH	pH meter
EC	Conductivity meter
TDS	Drying, in 105 C^{0} - (Boyd, 2000)
TH	EDTA titrimetric

$$R.D\ \% = \left| \frac{r\,\Sigma Cations - r\Sigma Anions}{r\,\Sigma Cations + r\Sigma Anions} \right| \times 100 \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

A% = 100 – R.D
Where:
R.D %: is the Relative Difference
rΣ Cations = The sum of cations concentrations (epm unit).
rΣ Anions = The sum of anions concentrations (epm unit).
A= Certainty or Accuracy

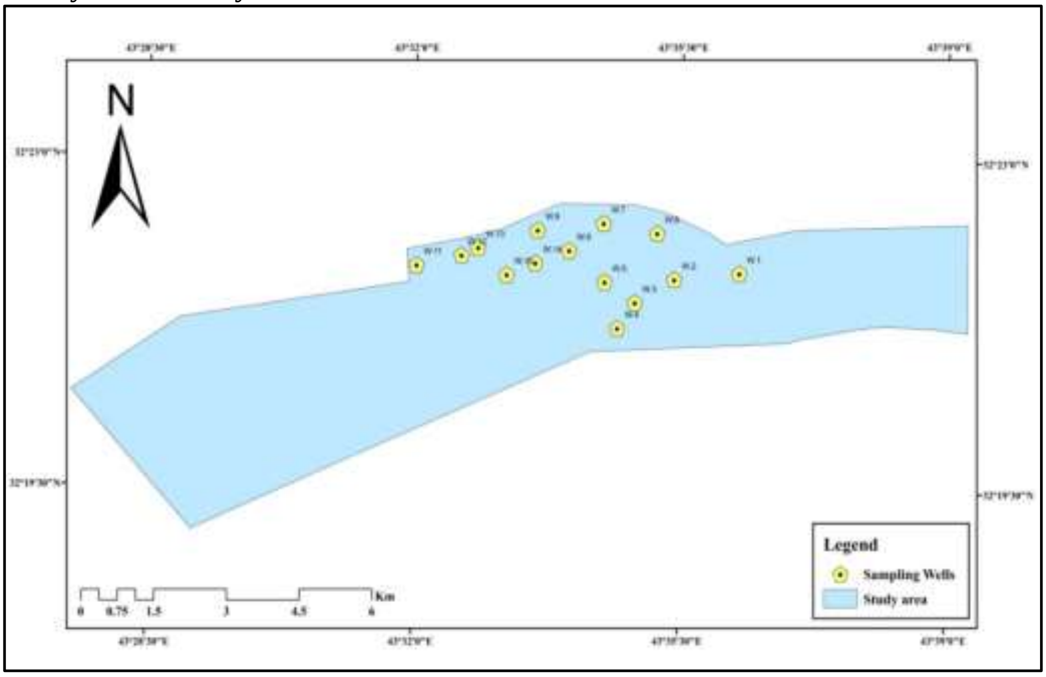

Figure 2: Location of the wells sampled.

4. Result and Discussion

When U ≤ 5%, the results could be accepted for interpretation, but if 5% ≤ U≤ 10%, the results are acceptable with risk. If the value U% > 10%, the results are independent. The results of all tested samples are accepted for the hydrochemical interpretation (Table 3).

Table 2: The accuracy classification and relative difference based on [10]

Relative Difference (R.D %)	Accuracy (A %)	Acceptability
R.D. % equals or less than 5%	A% equals or larger than 95%	Certain
R.D.% between 5% and 10 %	A% between 90% and 95%	Probable certain
R.D.% larger than 10 %	A% less than 90%	Uncertain

Table 3: Groundwater samples results' accuracy for the study wells

Well No.	R.D %	A%
1	2.3	97.7
2	6.6	93.4
3	1.4	98.6
4	5.4	94.6
5	1.7	98.3
6	1.8	98.2
7	0.3	99.7
8	3.6	96.4
9	3	97
10	5.6	94.4
11	7.6	92.4
12	5.3	94.7
13	6.2	93.8
14	1.9	98.1

4.1. Physical analysis

According to the physical characteristics of the samples (Table 4), the temperature value of groundwater samples ranged from 25.6ºC to 28.7 °C, with an average of 26.8°C during November 2021. The pH value ranges between 7.12 and 7.25, indicating that the water is neutral to slightly alkaline [11]. The EC varied from 2570 to 3430 µs/cm, reflecting slightly mineralised water [12]. The TDS varies from 1715 and 2230 ppm meaning slightly brackish [13], whereas the total hardness (TH) ranges between 743.2 and 1127.6 mg/l representing very hard water [13].

Table 4: The physical parameters of the groundwater in the study area

Parameters	Total calculated solids	Total dissolved solids	Electrical conductivity	pH	Temperature	Total hardness
Unit	(mg/L)	(mg/L)	(µs/cm)		(°C)	(mg/L)
1	1699.4	1718	2660	7.18	26,6	795.4
2	1770.5	1792	2780	7.17	26.2	972.3
3	2193.3	2230	3430	7.17	25.7	1110.7
4	1994.2	2020	3120	7.17	25.6	1127.6
5	1982.2	1945	3010	7.14	26.8	1054.9
6	1694.6	1715	2650	7.12	26.7	783.7
7	1944.1	1965	3040	7.13	27.6	983.0
8	1713.2	1735	2680	7.19	25.9	808.6
9	1694.2	1720	2660	7.25	28.2	790.4
10	1705.4	1726	2680	7.15	27.1	897.1
11	1771.4	1785	2770	7.19	27.7	972.3
12	1795.3	1820	2810	7.2	28.7	888.8
13	1725.1	1750	2700	7.16	27.1	919.4
14	1641.8	1660	2570	7.2	26.1	743.2

4.2. Chemical analysis

The groundwater samples were chemically analyzed (Table 5). It was found the following:

- Ca^{2+} ion concentration ranges from 178 to 224 ppm with an average of 193.42 ppm
- Mg^{2+} concentration varies between 72 and 146 ppm, with an average of 105.64 ppm

- Na^{+2} concentration ranges from 253 to 297 ppm with a 267.07 ppm as average.
- K^{+} content restricts between 2 and 1 ppm with an average of 9) ppm.
- Cl^{-} concentration varies between 346 and 599 ppm with an average of 436.07 ppm.
- The concentration of $SO_4^{=}$ ranges from 520 to 760 ppm, with 574.71 ppm as an average.
- HCO_3^{-} concentrations ranged from 183 to 239 ppm, with 222.57 ppm as an average.

Table 5: Results of the hydrochemical analysis of groundwater in the study area

Well No.	Unit	Calcium	Magnesium	Sodium	Potassium	Chloride	Bicarbonate	Sulphate
W. 1	ppm	190	78	261	11	355	226	578
	epm	9	6.39	11.34	0.28	10	3.7	12.04
W. 2	ppm	190	121	266	2	418	239	534
	epm	9	9.91	11.56	0.17	11.77	3.91	11.12
W. 3	ppm	224	134	297	12	538	228	760
	epm	11.2	10.98	12.91	0.3	15.15	3.37	15.83
W. 4	ppm	211	146	284	10	599	194	550
	epm	10.55	11.96	12.34	0.25	16.87	3.18	11.45
W. 5	ppm	200	135	273	8	588	183	595
	epm	10	11.06	11.86	0.2	16.56	3	12.39
W. 6	ppm	187	77	260	10	352	226	582
	epm	9.35	6.31	11.3	0.25	12.49	3.7	12.04
W. 7	ppm	191	123	266	9	593	210	552
	epm	9.55	10.08	11.56	0.23	16.7	3.44	11.5
W. 8	ppm	192	80	263	11	357	228	582
	epm	9.6	6.55	11.43	0.28	10.05	3.73	12.125
W. 9	ppm	188	78	260	10	353	226	579
	epm	9.4	6.39	11.3	0.25	9.94	3.7	12.062
W. 10	ppm	178	110	255	7	407	228	520
	epm	8.9	9.01	11.08	0.17	11.46	3.73	10.83
W. 11	ppm	190	121	266	7	418	239	530
	epm	9.5	9.91	11.56	0.17	11.77	3.91	11.04
W. 12	ppm	206	91	277	13	371	239	598
	epm	10	7.45	12.04	0.33	10.45	3.91	12.45
W. 13	Ppm	182	113	258	7	410	231	523
	epm	9.1	9.26	11.21	0.17	11.54	3.78	10.89
w.14	Ppm	179	72	253	9	346	219	563
	epm	9	9.098	11.13	0.17	11.49	3.75	10.85
IQS,2009	ppm	150	100	200	_____	350	450	400
WHO,2011	ppm	150	125	200	12	250	250	250

5. Suitability of groundwater for different purposes

There are various purposes for groundwater, including agriculture, irrigation, and livestock. The chemical content of water utilized for the agriculture, irrigation and livestock is measured, and it is essential to analyze the water for the purposes above by comparing their results to the allowed limits [14]

5.1. Suitability of groundwater for agriculture

The significance of assessing irrigation appropriateness for groundwater arises from the vast impact that water quality has on soil and plant systems, which, in turn, impacts agricultural productivity [14]. Plant tolerance to TDS and EC in irrigation water varies by plant type and quality.[13]. Depending on the classification of (Tood, 2007) [15], all the studied water samples are accepted for most types of crops [14] (Table 6)

Table 6: Classification of Todd for crops tolerance based on the relative concentrations of salt for agricultural purposes

Crop Division	Crops of low tolerance for salt, EC (µS /cm)	Crops of medium tolerance for salt, Ec (µS /cm)	Crops of high tolerance for salt, Ec (µS /cm)
Fruits	0 to 3000 Strawberry, Pear, Almond, Plum Orange, Limon, Apple, Peach Apricot	3000 to 4000 Olive, Pomegranate, Cantaloupe, Figs,	4000 to 10,000 Date palm
Vegetables	3000 to 4000 Radish, Celery, Green beans	4000 to 10,000 Tomato, Onion, Cucumber, Peas, Cauliflower, Carrot, Potatoes, Bell pepper, Cabbage, Broccoli, Sweet Corn Lettuce	10000 to 120,000 Garden beets and Spinach
Field Crops	4000 to 6000 Field beans	6000 to 10,000 Corn (field), Rice, Sunflower, Wheat,	10,000 to 16,000 Sugar beet, Barley, Cotton

5.2. Validity of Groundwater for the irrigation

Water suitability for irrigation is determined by the kind and salt content dissolved in water and their influence on crop development and growth [15]. The mineral content in the water, the type of plants and the soil nature determine the viability of irrigation [16].

Parameters below were used to determine the water suitability for irrigation areas:

1- Sodium adsorption ratio (SAR)
2- Sodium Carbonate residual (RSC)
3- Permeability (PI)
4- Sodium percentage (Na%)

The ratio of Sodium Adsorption (SAR)

It is defined as the Sodium ions ratio to the Mg and Ca ions by milliequivalent/litre. It is a critical metric for the evaluation of soil alkalinity or alkali hazard; while using groundwater for irrigation, the following equation [15] is used to calculate SAR:

$$SAR = \frac{rNa}{\sqrt{r(Ca+Mg)/2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

SAR: Sodium adsorption ratio

rCa^{+2}, rMg^{+2} and rNa+: Ions concentrations (epm)

Groundwater is classified as an excellent due to SAR values (less than 10), as in (Table 8)

Table 7: SAR-based classification of irrigation water

Level	SAR	Hazard
S1	Less than10	No harmful influence from the Na^{+}.
S2	10 to 18	Sodium hazard in fine-textured soils with high CEC can be utilised in .sandy soil with good permeability
S3	18 to 26	Most soil sand additives, such as gypsum, will negatively impact and will .be required to exchange sodium ions
S4	More than 26	invalid for irrigation.

Sodium Percentage (Na %);

For irrigation, groundwater was assessed based on the soluble sodium percentage (SSP) and the sodium percentage (Na%). The high Na concentration in the water indirectly affects plant development and soil quality [15]. Na buildup and possible damage to soil structure, infiltration, and aeration may occur when irrigation water has more than 60% Na content.
The following equation can be used to calculate the Na%:

$$\text{Na\%} = \frac{\text{rNa+rK}}{\text{rCa+rMg+rK}} * 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where the ions' concentrations are described in epm

Table 8: Parameters Na%, RSC, PI, and SAR for groundwater in the study area

Sample	SAR	Na%	RSC	PI
1	3.247	18.041	-11.69	49.620
2	3.094	21.658	-15	44.4285
3	3.160	24.216	-18.81	42.022
4	3.035	24.573	-19.33	40.525
5	3.009	23.14	-18.06	41.288
6	3.195	17.886	-11.96	49.0487
7	3.026	21.894	-16.19	43.009
8	3.185	18.289	-12.42	48.445
9	3.184	17.966	-12.09	48.813
10	3.026	20.279	-14.18	44.882
11	3.040	21.657	-15.5	43.711
12	3.249	19.853	-13	47.532
13	3.025	20.658	-14.58	44.485
14	3.188	17.155	-11.26	49.882

Table 9: Classification of the irrigation water based on [17]

EC µs\cm	TDS ppm	SAR	Na%	pH	Water Quality
250	175	3	20	6.5	Excellent
250-750	175-525	3-5	20-40	6.5-6.8	Good
750-2000	525-1400	5-10	40-60	6.8-7	Permissible
2000-3000	1400-2100	10-15	60-08	7-8	Doubtful
>3000	>2100	>15	>80	>8	Unsuitable

Sodium Carbonate Residual (RSC)

A high concentration of bicarbonate in the soil may produce Mg and Ca precipitation, leading to a relative rise in Na concentration raising the hazard of sodium [17]. In the groundwater samples, all RSC values are low (Table 10). There is no thread of Na content in groundwater because the RSC values are below zero, which means the Na hazard is non-existent. The toxicity of Na is also improbable and falls below the permitted limits because all RSC values are below zero [18]. The RSC was calculated using the equation below:

$$\text{RSC} = ([CO_3^{2-}] + [HCO_3^{-}]) - ([Ca^{2+}] + [Mg^{2+}]) \quad \ldots\ldots\ldots\ldots\ldots\ldots (4\text{-}9)$$

Table 10: Irrigation water classification according to RSC values [19]

RSC	Hazard
Less than 0	None
0 to 1.25	Low, with some Mg and Ca removal from irrigation water.
1.25 to 2.50	Medium, with appreciable Mg and Ca removal from irrigation water
More than 2.50	High, with most Ca and Mg removed, leaving Na to accumulate.

Permeability Index (PI)

The soil's permeability is influenced by the long-term use of Sodium and irrigation water and soil content of Ca, Mg and HCO_3 [20]. To determine the groundwater's suitability for irrigation, [19] developed an approach to determine the PI, which depends on the concentration of the calcium, magnesium, sodium and bicarbonate ions shown in the equation below.

$$PI\ \% = \frac{Na+\sqrt{HCO3}}{Ca+Mg+Na} * 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Table 11: (PI) classification for the irrigation [20]

PI %	Class	Water quality for irrigation
Less than 25	Class-III	Unsuitable
25 to 75	Class-II	Good quality
More than 75	Class-I	Very good quality

EC and TDS

The EC and TDS are widely used to evaluate the water quality parameters because they indicate the ion contents dissolve in water. The plentiful amounts reduce the plants' osmotic activities, prohibiting sufficient ventilation. The amount of dissolved solids is estimated physically by using the TDS of an electric current. It increases with the increase of ions amount and decreases with the decrease in ion content. The Values of TDS show that all wells refer to Doubtful water for irrigation except well (3) refer to as unsuitable for irrigation, and the electrical conductivity (Ec) for all the wells is doubtful water for irrigation except wells (3, 4, 5, and 7) are unsuitable for irrigation (Table-3).

5.3. Groundwater suitability for livestock

Groundwater suitability for livestock was assessed according to the classification [12], which relies on the major anions, cations, and TDS. According to this classification, all groundwater samples are of very good category for livestock (Table 11)

Table 12: Classification of groundwater in the study area compared to standards of water quality for livestock purposes [21]

Elements and Parameters	Very good	Good	Acceptable	Can be used	Maximum limits	Average concentrations of the study period
Na^+	800	1500	2000	2500	4000	267.07
Ca^{2+}	350	700	80	900	1000	193.42
Mg^{2+}	150	350	500	600	700	105.64
Cl^-	900	2000	3000	4000	6000	436.07
SO_4^{2-}	1000	2500	3000	4000	6000	574.71
TDS	3000	5000	7000	10000	15000	1827.214
TH	1500	3200	4000	4700	54000	102.364
Unit ppm						

Conclusions

The physical and chemical properties of groundwater of the Dammam aquifer in the agricultural city of Sayed Al-Shuhada, located in the Karbala Governorate, were measured to know its suitability for agricultural purposes. Groundwater is suitable for growing various crops. It is excellent for irrigation in terms of SAR content; there is no sodium hazard in the groundwater because the residual sodium carbonate is less than zero. Due to TDS values, all groundwater samples were uncertain except well-3, which was unsuitable for irrigation. Based on Ec values, all the groundwater samples are doubtful, except wells (3, 4, 5 and 7) were unsuitable for irrigation. As for livestock, groundwater is very good for cattle drinking.

References

[1] N. H., Al-Basrawi, "Hydrogeology of Razzaza lake Iraq's western desert", Ph.D. dissertation. (Unpublished), Univ. of Baghdad, Baghdad Iraq, 1996.

[2] S.A. Ibrahim, and A. M. Al-Shammaa, "Hydrochemistry of shallow groundwater in western Karbala city, Central part of Iraq", *Iraqi Bulletin of Geology and Mining*,vol.8, no.3, pp. 91-107. 2012.

[3] M. A., Al-Ghanimy, "The hydrogeology of Dammam aquifer in the west and southwest of Karbala city", M.Sc. thesis, Univ. of Baghdad, Baghdad, Iraq, 2013.

[4] M. A., Al-Ghanimy, "Hydrogeological condition of the main productive aquifers with advanced techniques such (GIS) in Karbala-Najaf plateau, Iraq". Ph.D. dissertation. Univ. of Baghdad, Baghdad, Iraq, 2018.

[5] A.M., Barawari, "Studied Geological board of Karbala", The General Company of geological survey and mineral. Internal report, 1995.

[6] S. B., Al-Jawad, and S., Khilail, "Report on definition study of groundwater exploitation regions for agriculture purposes in Iraq", (unpublished), ministry of irrigation. Iraq, 2001.

[7] M. M., Al-Shamari, "Groundwater Evaluation for Dammam Formation in South Razzaza Lake", M.Sc. thesis, Univ. of Baghdad, Baghdad, Iraq, 2014.

[8] M. R., Hashim, "Hydrogeological study of Al-Saqy project, Karbala Governorate, Iraq", M.Sc. thesis. (Unpublished), Univ. of Baghdad, Baghdad, Iraq, 2021.

[9] J.D., Hem, "*Study and Interpretation of the Chemical Characteristics of Natural Water", 3rd Ed., US Geol. Surv*., 1989.

[10] K.D., Stoodly, T. Lewis, and C.L., "*Staintion, , Applied Statistical Technique*", *London: John Wiley and Sons*, 1980

[11] G., Matthess, "The Properties of Groundwater, Department of Environmental Science", *International Journal of Geosciences* **,** vol.7 , no.10, 2016

[12] M., Detay, "*Water Wells- implementation, maintenance and restoration*", *London: John Wiley and Sons*, 1997.

[13] D. K., Todd, "*Groundwater hydrology*", *2nd Ed., New York: Jhon Wiley and Sons, Inc*. 1980.

[14] M. A., AL-Janabi, "Hydrochemistry of the unconfined aquifer and the relationship of unsaturated zone sediments on the groundwater quality in Tikrit-Samara basin", Ph. D. dissertation, (In Arabic), Univ. of Baghdad, Baghdad, Iraq, 2008.

[15] D. K., Todd, "*Groundwater hydrology*" *3rd Ed., India: John Wiley and Sons, Inc*., 2007.

[16] Z., Qannam, "A hydrogeological, hydrochemical and environmental study in Wadi AL-Arroub drainage basin, south west Bank, Palestine", DAAD, vol. 9, 211 p. 2003.

[17] C. M., Don, "A grows guide to water quality", University college station, Texas, 1995.

[18] J. W., Van Hoorn, "Quality of irrigation water, limits of use and predication of long-term effects, Salinity Seminar, Baghdad", Irrigation and Drainage paper No.7, FAO, pp. 117-135. 1970.

[19] L. D., Doneen, "Water Quality in Agriculture", Department of Water Science and Engineering, University of California, Davis, 1964.

[20] A. J., Turgeon, "Irrigation Water Quality", College of Agricultural sciences, Pennsylvania State University, USA. 2000.

[21] M. E., Altoviski, "*Handbook of hydrogeology", Gosgeolitzdat, Moscow, USSR*, (in Russian), 1962