Iraqi National Journal of Earth Science, Vol. 26, No. 03, 2026 (176-186)

Iraqi National Journal of Earth Science

www.earth.uomosul.edu.iq

Spatial Analysis of Groundwater Quality in the Bashiqa District and its Suitability for Drinking and Irrigation

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Received: 10 March 2025 Received in revised form: 20 April 2025 Accepted: 10 May 2025

Abstract

This study aimed to assess the quality of groundwater in the Bashiqa district of Nineveh Governorate, northern Iraq, and its suitability for drinking and irrigation. It also sought to create spatial models using Geographic Information Systems (GIS). Samples were collected from 20 wells distributed across the area during September 2024 and January 2025. The Water Quality Index (WQI) was used to assess the suitability of the water for drinking. Several indices were also used to evaluate water quality for irrigation, including SAR, KR, PI, RCS, Na%, MAR, RSC, and Wilcox and Richard plots. Significant variation was observed in the distribution of central cation and anion concentrations across the research area, attributed to the region's diverse geological formations. The WQI results for drinking water were published: During the summer, 5% of water samples were rated as excellent, 60% as good, 25% as poor, and 10% as unsuitable. In winter, 10% of water samples were rated as excellent, 55% as good, 35% as poor, and 10% as unsuitable. Several wells were found to be unsuitable for drinking, because many of the studied standards exceeded the limits set by the World Health Organization. Water quality in the area ranged from suitable to unsuitable for irrigation. The unsuitability of some wells for irrigation was attributed to high electrical conductivity values according to the Wilcox and Richard irrigation classifications.

Keywords:

Groundwater, Water Quality Index, Drinking, Irrigation.

DOI: 10.33899/injes.v26i3.60929, ©Authors, 2026, College of Science, University of Mosul.

1. Introduction

More than two billion people depend on groundwater to meet their daily needs. Groundwater provides drinking water and is used in agriculture, livestock, industry, and civil infrastructure (Ouhakki et al., 2024; Mohammed et al., 2022). Water pollution not only affects water quality but also threatens human health (Verma et al., 2020; Shehab et al., 2024). Groundwater quality results from various processes and interactions that affect it, ranging from atmospheric condensation to water extraction from wells. Temporal fluctuations in the source and composition of recharged water, along with hydrological and anthropogenic factors, can cause periodic changes in groundwater quality. Therefore, assessing groundwater quality is critical for determining its suitability for specific uses (Kateb and Al-Youzbakey, 2022; Jalal et al., 2024).

Global water supplies have recently declined in quality due to population growth, human activities, and climate change. Groundwater is particularly vulnerable to this problem, not only because it is a sustainable water resource, but also because it is the only available source of water in emergencies (Al-Gamal et al., 2025; Khattab et al., 2023). Contaminated water increases morbidity and mortality rates, while using substandard water for irrigation reduces productivity and negatively impacts soil quality over time (Al-Aarajy et al., 2023). This problem poses a significant threat to the Bashiqa District, making it imperative to continuously assess groundwater quality and implement preventive measures in the region.

The suitability of groundwater for various uses depends on its quality and the extent to which its chemical and physical properties vary. International classifications aim to verify the suitability of water for direct use. The Water Quality Index (WQI) is a valuable tool for assessing groundwater quality, as it can transform complex and large datasets into simple, easy-to-understand numbers to determine water quality levels (AL-Ahmed and AL-Elsheikh, 2024; Eti et al., 2024, 2024; Ahmed and Faisal, 2020). Our current study aims to assess groundwater quality from a spatial perspective and its potential applications for drinking and irrigation. This study used the Water Quality Index (WQI) to assess the suitability of groundwater for drinking. For irrigation, several indices were used, including NA, SAR, KR, MAR, PI, P.S., and RCS, along with the Wilcox and Richards chart.

2. Methodology

Study Area Description

The Bashiqa district is located in northern Iraq, about 10 km northeast of Mosul City. The area of the Bashiqa district is 511.47 km^2, distributed over 57 sub-districts. The research area experiences a wet spring and winter and a dry summer and fall. The study area is located between latitudes 36° 34' - 36° 20' north and longitudes 43° 32' - 43° 10' east (Fig. 1).

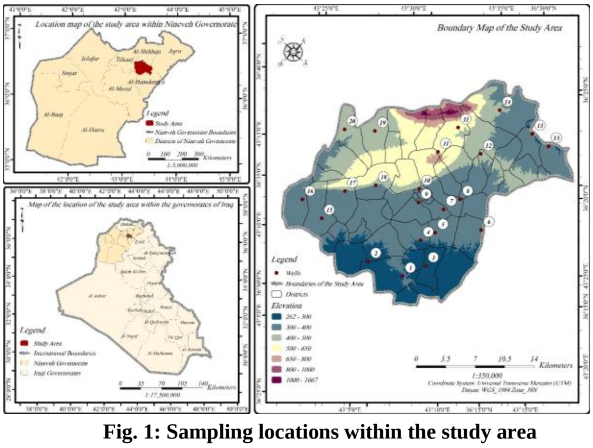


Fig. 1: Sampling locations within the study area

The research area is characterized by multiple geological formations, their characteristics shown from oldest to youngest (Fig. 2): the Pila Spi Formation (Middle-Late Eocene), which consists of limestone and occurs in the center and north of Bashiqa District; the Injana Formation (Late Miocene), which consists of a series of clays, sandstones, and marls and covers some areas in the east of the area and extends in a strip to the west, in addition to some areas in the south the; the Fatha Formation (Middle Miocene), which occurs in the center of the area, and consists of salt rocks (halites), gypsum, and anhydrite; and the Muqdadiya Formation, which consists of coarse to gravelly sandstone with high porosity and permeability and occurs in a small part in the north of the area. These formations cover the Quaternary deposits in the area, and the remaining soils are of the highest Quaternary deposits and occupy large areas of the southwestern part of the area, in addition to floodplain and slope deposits that occur in the far north of the area and a continuous strip in the center of Bashiqa District. (AL-Yousafani, 2021; Hussein and Al-Salem, 2017).

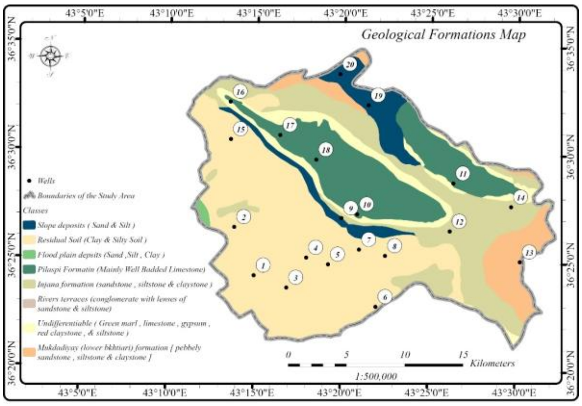


Fig. 2: Geological map of the study area with sampling sites

Sampling or Data used

Groundwater samples were collected from twenty wells used for irrigation, drinking, and animal watering in September 2024 and January 2025. The sample location coordinates were ascertained utilizing the GPS (Figure 1). pH and EC were measured on-site using Yieryi C-600A, which was pre-calibrated in the laboratory with standard solutions before testing. The concentrations of (Ca^{2+}, Mg^{2+}, Cl-, and HCO^{3-}) were measured using the titration method. The sulfate ate content was measured by precipitation using a 10% barium chloride solution. A flame photometer determined the sodium and potassium concentrations, while a UV spectrometer measured nitrate content according to standard methods (APHA, 1998). Wilcox diagrams, Richard diagrams, and Piper diagrams were created using Diagrammes v8.6. Spatial analysis maps were generated using ArcGIS Pro 3.0.2.

Water Quality Index (WQI)

Various criteria and indices derived from water's physical and chemical properties enable water quality evaluation. The WQI is a vital metric and a proficient instrument for evaluating water quality, as it consolidates various factors influencing water quality into a single number that reflects the overall state of the water. In the 1960s, Horton proposed the first mathematical model for assessing water quality, which Brown further developed in 1972. The Water Quality Index condenses and simplifies comprehensive water quality data into clear categories that express water quality (Table 1), with a lower number indicating better water quality, while a higher number signifies poorer quality. This index provides the public and decision-makers with a thorough overview of water quality. The WQI was calculated using the arithmetic weighting method used by (Al-Mashhadany, 2021; Al-Soyffe et al., 2022; Al-Aarajy et al., 2023). The arithmetic weighting of WQI used in this study is presented as follows:

1-Calculation of Unit Weight

The unit weight (Wi) values are calculated from the corresponding inverse of the standard specification (Sn) for each factor, according to the equation:

$$W_i = k/S_n \qquad (1)$$

Wi = unit weight for parameter, k = proportional constant, S_n = standard parameter value.

2- Calculation of the K value

K represents the value of the proportionality constant as in the equation (Hamma et al., 2024).

$$\mathrm{K} = 1/\sum_{i=0}^{n} \frac{1}{Sn} \qquad (2)$$

3- Calculation of Quality Rating

The quality index or sub-index (Qi) is computed using the equation provided by Brown et al. (1972).

$$Qi = 100 \times (V_0 - V_i)/(S_n - V_i) \qquad (3)$$

V_0 = measured parameter, V_i = ideal value, with V_i all parameters equal to zero except for pH, which is 7.0, S_n = denotes the permissible standard value of the parameter.

4- Calculation of WQI

The following equation expresses WQI:

$$\mathrm{WQI} = \sum_{i=1}^{n} Q_i W_i / \sum_{i=1}^{n} W_i \qquad (4)$$

Table 1: Drinking water quality classifications according to WQI (Brown et al., 1972; Horton, 1965; Jadoon et al., 2024).

WQI	Water class
0-25	Excellent
26-50	Good
51-75	Poor
75-100	Very Poor
>100	Unsuitable

Water suitability assessment for irrigation

Multiple indices assessed the appropriateness of water for irrigation applications (Table 3), including EC, SAR, KR, PI, Na%, MAR, RSC, PS, and graphical methods (Richard and Wilcox diagram).

Table 2: Indicators used to evaluate the suitability of water for irrigation

Parameter	Equation	Reference
Sodium Absorption Ratio (SAR)	$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$	(Richards, 1954)
Sodium Percentage (Na%)	$\%Na = \frac{Na}{Na + K + Mg + Ca} \times 100$	(Wilcox,1955)
Kelly Ratio (KR)	$KR = \frac{Na}{Ca + Mg}$	(Kelly,1940)
Permeability Index (PI)	$PI = (\frac{Na + \sqrt{HCO_3}}{Na + Mg + Ca})$	(Doneen,1964)
Magnesium Absorption Ratio (MAR)	$MAR = \frac{Mg \times 100}{Ca + Mg}$	(Raghunath,1987)
Residual Sodium Carbonate (RSC)	$\mathrm{RSC} = (HCO_3 + CO_3) - (Ca + Mg)$	(Eaton,1950)
Potential Salinity (PS)	$PS = Cl + \sqrt{SO_4}$	(Doneen,1964)

3. Results and Discussion

Water quality parameters

The results from the research area's physical and chemical analysis of groundwater are presented (Tables 3 and 4). Tables 3 and 4 show the water quality parameters for the Summer and winter seasons, including the maximum, minimum, average, standard deviation, and permissible limits set by the World Health Organization for physical and chemical parameters (WHO, 2004). In the present research study, the pH ranged from 6.45 to 7.62 in the summer and 6.41 to 7.85 in the winter, with all samples falling within the allowed limits established by WHO regulations. The pH did not show any significant variation between sampling seasons.

Table 3: Results of the criteria evaluated during the summer, along with a comparison with the WHO recommendations for drinking water.

Summer Season					
Parameter	Minimum	Maximum	Average	SD	WHO Standards
EC (µS/cm)	396	5150	1736.5	1373.95	1400
pH	6.45	7.62	7.072	0.32	6.5-8.5
TH (mg/l)	320	2765	1023.25	705.32	500
Ca (mg/l)	32.07	545.1	196	148.78	75
Mg (mg/l)	44.8	350.56	119.68	85.31	50
Na (mg/l)	5.075	373.5	100.02	104.29	200
K (mg/l)	1	6	1.8	1.28	12
HCO3 (mg/l)	268.4	610	442.25	99.34	200
Cl (mg/l)	40	559.88	173.47	134.38	250
SO4 (mg/l)	13	2242	518.37	646.51	400
No3 (mg/l)	6.63	103.69	24.87	20.78	50

Table 4: Results of the criteria evaluated during the winter, along with a comparison with the WHO recommendations for drinking water.

Winter Season					
Parameter	Minimum	Maximum	Average	SD	WHO Standards
EC (µS/cm)	398	5190	1746.3	1331.26	1400
pH	6.41	7.85	7.2715	0.31	6.5-8.5
TH (mg/l)	280	2642	960.1	681.77	500
Ca (mg/l)	48.10	497.79	181.20	138.83	75
Mg (mg/l)	35.84	340.48	113.79	85.63	50
Na (mg/l)	7.93	344.52	93.70	95.15	200
K (mg/l)	1	5	1.85	1.50	12
HCO3 (mg/l)	231.8	549	409.31	99.78	200
Cl (mg/l)	20	489.89	159.89	129.08	250
SO4 (mg/l)	24.29	2019	490.26	594.41	400
No3 (mg/l)	8.4	95.33	24.27	18.98	50

The EC value is directly related to the concentration of salts in the water and quantifies the amount and quality of dissolved ions (Diédhiou et al., 2023). It was found that 45% of samples in the summer and 40% in the winter season exceeded the permissible limit set by the World Health Organization.

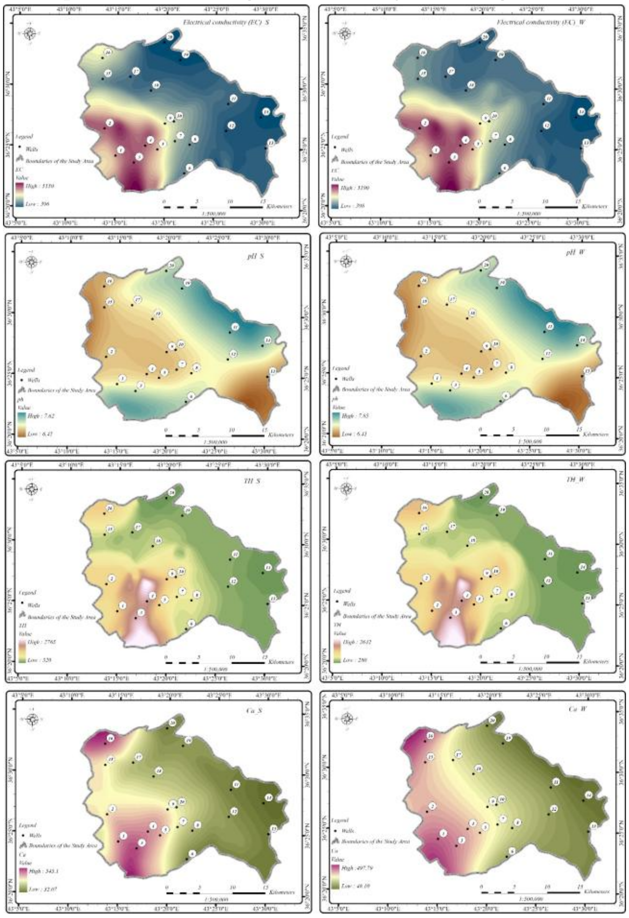
Calcium and magnesium are closely related to water hardness. They are standard components of surface and groundwater, and calcium concentrations in the study area ranged between (32.07-545.1) mg/L in summer and (48.10-497.79) mg/L in winter. Magnesium concentrations ranged between (44.8-350.56) mg/L in summer and (35.84-340.48) mg/L in winter. Water hardness is attributed to various dissolved mineral ions, primarily calcium and magnesium cations (Krishnan and Saravanan, 2022). The TH value ranged from 320 mg/L to 2765 mg/L in the summer and from 280 mg/L to 2642 mg/L in the winter. The calcium and magnesium values in most samples exceeded the WHO limits.

Sodium values ranged between (5.075-373.5) mg/L in the summer season and (7.93-344.52) mg/L in the winter season, with 85% of samples within the WHO recommended limits. Sodium is the dominant cation present in most natural waters. Sodium is a prevalent ion in groundwater, found in substantial amounts in both surface and subsurface water sources. It also plays a vital role in the creation and formation of most minerals and rocks (Abdelshafy et al., 2019). Potassium is a natural element. However, its concentration is lower than that of calcium, magnesium, and sodium. The maximum concentration was set at 6 mg/L during the summer and 5 mg/L in the winter.

Analysis of HCO_3 concentrations indicates that all sites evaluated exceed the WHO drinking water standard of 200 mg/L. Elevated concentrations result from reactions in water containing carbon dioxide as it passes through geological formations (Ishaku et al., 2015; Naveen et al., 2017). Chloride is an indicator of water salinity. When mixed with sodium, it gives water a salty flavor (Karroum et al., 2019). Chloride values ranged between (40-559.88) mg/L in the summer season and (20- 489.89) mg/L in the winter. The study results showed that 75% of the samples were within the recommended drinking limits. Sulfate concentrations ranged between (13-2242) mg/L in the summer and (24.29-2019) mg/L in the winter. The WHO standard for sulfate concentrations is 400 mg/L, with 45% of samples exceeding this limit in the summer and 35% in the winter. Figure 2 shows the spatial distribution of HCO_3, CL, SO_4, and NO_3 values. High sulfate concentrations can cause a bitter taste in water, cause laxative effects, and may corrode plumbing systems (Hyeroba and Kalin, 2024). The results of the nitrate analysis ranged between (6.63-103.69) in the summer season and from (8.4-95.33) mg/L in the winter. All the wells met acceptable drinking water standards, except for Well No. 3. The increase in contamination is due to sewage leaks, agricultural fertilizers, and livestock waste. (Wang et al., 2023).

Spatial distribution maps

The spatial distribution maps display significant variability in the physical and chemical parameters throughout the study area (Fig.3).



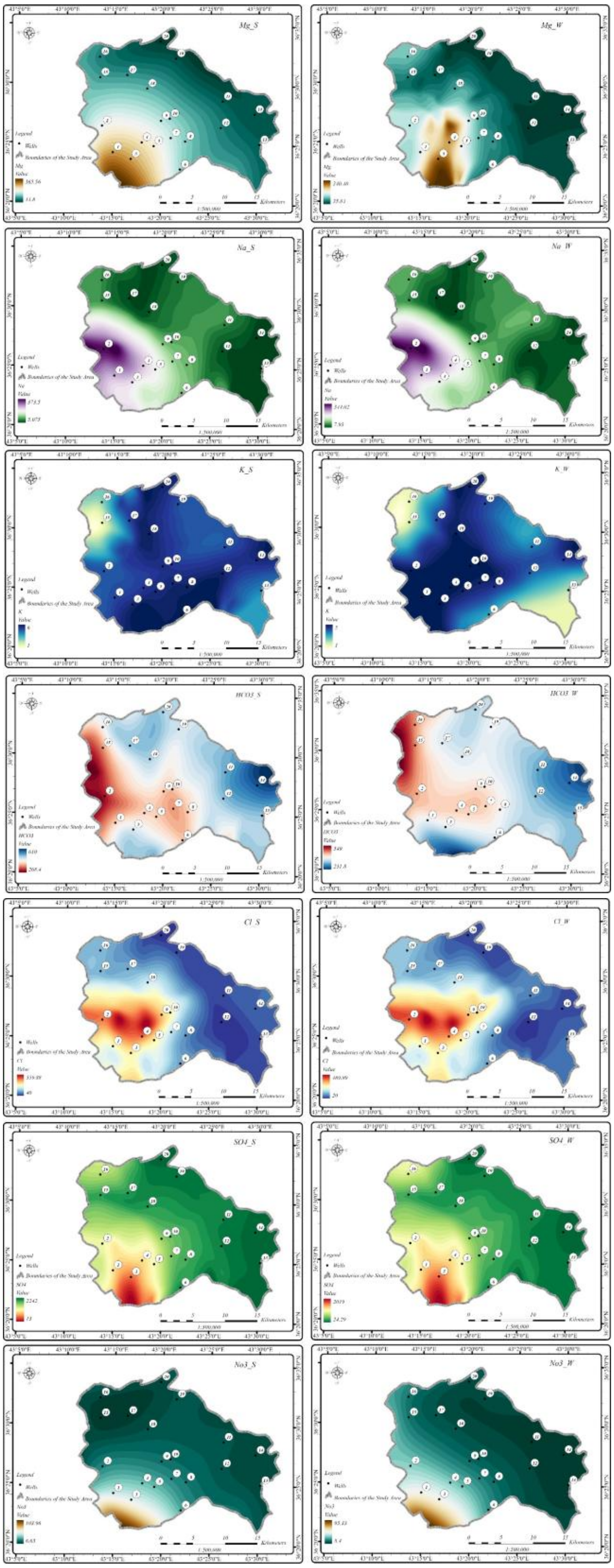


Fig. 3. Spatial distribution of groundwater quality parameters in Bashiqa District in summer (left) and winter (right).

Water classification using the Piper diagram

The chemical compositions of groundwater are classified using the Piper diagram. This diagram illustrates the variability among groundwater samples. It comprises two triangular regions at the bottom and a central diamond-shaped region. Hydrochemical facies aid in determining the origin and classification of different water types. The hydrochemical facies of groundwater clarify the relationship between anions (Cl, SO_4, and HCO_3) and cations (Ca, Mg, Na, and K) and their respective behaviors. The process of geochemical evolution is classified into six distinct kinds of water (Fig. 4) (Krishnan and Saravanan, 2022; Nag and Das, 2017). The groundwater in the research area was classified as Ca-HCO_3, Mixed Ca-Mg-Cl, and Ca-Cl (Fig. 3).

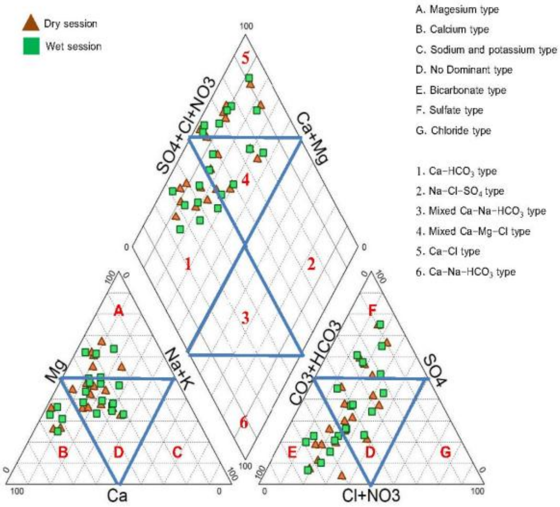


Fig. 4: Piper diagram showing the classification of groundwater samples in summer and winter.

Water Quality Index (WQI) for Drinking Water

The WQI indicates that the maximum value was 117.02 during the summer season and 110.71 in the winter season at sampling point 3, while the lowest WQI value was 22.68 in the summer season at sampling point 20 and 22.14 in the winter season at sampling point 14 (Table 5). Figure 5 shows that the northern and northeastern regions were suitable for human consumption.

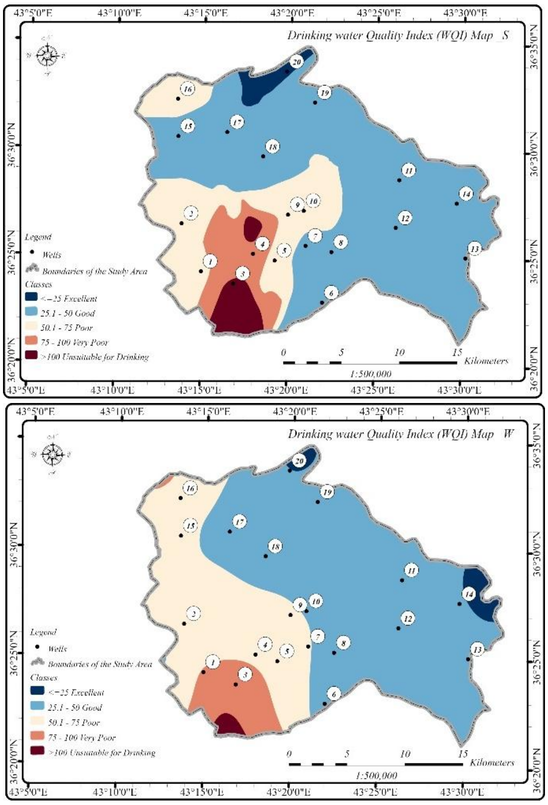


Fig. 5. Spatial distribution map of groundwater quality index in Bashiqa district.

Water Quality Assessment for Irrigation

Sodium percentage (Na%) is a significant element in groundwater, particularly when present in elevated concentrations in irrigation water, as it can cause soil degradation and diminish agricultural productivity (Subramaniyan et al., 2024). Wilcox introduced sodium percentage (Na%) for irrigation applications, predicated on the sodium concentration in groundwater (Wilcox, 1955). The sodium content ranged from 2.14 to 34.46% in the summer and from 3.06 to 35.54% in the winter (Table 7). The Wilcox 1955 graph correlating sodium to electrical conductivity indicates that most groundwater samples are categorized within the "excellent to Unsuitable" range (Fig. 6).

Table 5: WQI values for groundwater drinking water.

Well No.	WQI summer season	WQI winter season	Water class
1	58.33	59.06	Poor
2	65.14	58.85	Poor
3	117.02	110.71	Unsuitable for drinking
4	107.80	103.51	Unsuitable for drinking
5	46.16	53.88	Good in the summer season, poor in the winter season
6	37.65	36.52	Good
7	40.09	49.04	Good
8	40.35	37.14	Good
9	61.50	54.77	Poor
10	61.09	56.45	Poor
11	33.51	35.97	Good
12	25.66	25.61	Good
13	31.60	31.95	Good
14	25.93	22.14	Good in the summer season, Excellent in the winter season
15	35.81	48.24	Good
16	63.50	72.82	Poor
17	25.77	27.58	Good
18	39.74	39.64	Good
19	37.88	32.85	Good
20	22.68	23.25	Excellent

Table 6: Areas of each type of groundwater quality index.

No.	Classes	Summer season		Winter season	
		Area_ Km^2	Per cent %	Area_ Km^2	Per cent %
1	<=25 Excellent	11.2818	2.20575	25.5858	5.00239
2	25.1 - 50 Good	324.382	63.4212	305.894	59.8067
3	50.1 - 75 Poor	115.567	22.595	124.635	24.3679
4	75 - 100 Very Poor	41.0808	8.03187	41.433	8.10075
5	>100 Unsuitable for Drinking	19.1605	3.74615	13.9234	2.72223

Water Quality Assessment for Irrigation

Sodium percentage (Na%) is a significant element in groundwater, particularly when present in elevated concentrations in irrigation water, as it can cause soil degradation and diminish agricultural productivity (Subramaniyan et al., 2024). Wilcox introduced sodium percentage (Na%) for irrigation applications, predicated on the sodium concentration in groundwater (Wilcox, 1955). The sodium content ranged from 2.14 to 34.46% in the summer and from 3.06 to 35.54% in the winter (Table 7). The Wilcox 1955 graph correlating sodium to electrical conductivity indicates that most groundwater samples are categorized within the "excellent to Unsuitable" range (Fig. 6).

Table 7: The various indices for groundwater categorization are appropriate for irrigation applications.

Parameters	Range	Classification	No. of samples			
			Summer	%	Winter	%
Electric Conductivity (EC)	<250 µS/cm	Excellent	Nil	0	Nil	0
	250–750 µS/cm	Good	6	30	5	25
	750–2250 µS/cm	Permissible	8	40	9	45
	2250–5000 µS/cm	Doubtful	5	25	5	25
	>5000 µS/cm	Unsuitable	1	5	1	5
Sodium Adsorption Ratio (SAR)	< 10 meq/l	Excellent	20	100	20	100
	10 - 18 meq/l	Good	Nil	0	Nil	0
	18 - 26 meq/l	Fair	Nil	0	Nil	0
	> 26 meq/l	Poor	Nil	0	Nil	0
Na%	<20	Excellent	14	70	14	70
	20-40	Good	6	30	6	30
	40-60	Permissible	Nil	0	Nil	0
	60-80	Doubtful	Nil	0	Nil	0
	> 80	Unsuitable	Nil	0	Nil	0
Potential Salinity (PS)	< 7meq/l	Good	13	65	13	65
	7 - 15 meq/l	Moderate	7	35	7	35
	> 15 meq/l	Not recommended	Nil	0	Nil	0
Permeability Index (PI%)	> 75%	Suitable	Nil	0	Nil	0
	25-75	Good	14	70	14	70
	< 25%	Unsuitable	6	30	6	30
Residual Sodium Carbonate (RSC)	<1.25 meq/l	Safe for irrigation	20	100	20	100
	1.25 - 2.5 meq/l	termed marginal	Nil	0	Nil	0
	> 2.5 meq/l	Unsuitable for irrigation	Nil	0	Nil	0
Kelly's Ratio (KR)	< 1	Suitable	20	100	20	100
	> 1	Unfit for irrigation	Nil	0	Nil	0
Magnesium Adsorption Ratio (MAR%)	< 50 %	Excellent	12	60	11	55
	> 50 %	Harmful to soil	8	40	9	45

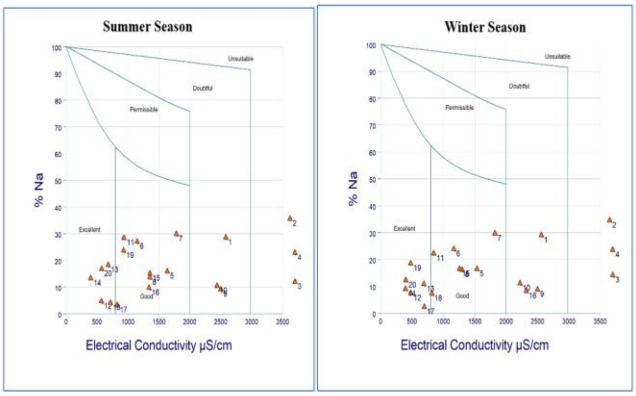


Fig. 6. Wilcox diagram (NA%) illustrating groundwater suitability for irrigation during the summer season (left) and winter season (right).

The sodium adsorption ratio (SAR) is essential for evaluating the appropriateness of irrigation water. Elevated SAR can adversely affect soil composition, compaction, penetration, and the growth of crops (Djoudi et al., 2023;

Jadoon et al., 2024). This study found that all groundwater SAR values were safe (SAR < 10) during Summer and winter. The Richard diagram enables the categorization of water according to its appropriateness for irrigation purposes, specifically assessing salinization risk represented on the x-axis by conductivity (denoted as C) and alkalinization represented on the y-axis by sodium absorption ratio (denoted as S) (Fig. 7).

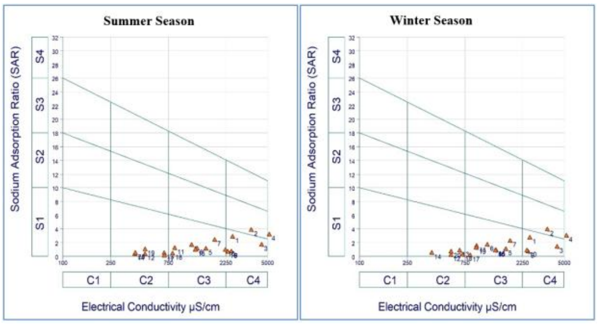


Fig. 7. Richard diagram (SAR) illustrating groundwater suitability for irrigation during the winter season (left) and summer season (right).

Permeability Index (PI): The permeability index is crucial for evaluating irrigation water quality and soil permeability. The amounts of sodium, calcium, magnesium, and bicarbonate influence it. The permeability index is assessed to determine water movement in the soil (Nag and Das, 2017). Based on the permeability index, groundwater samples can be classified as suitable, good, or unsuitable. It was found that 30% of the samples in the study area were unsuitable, and 70% were good. (Table. 8).

Table 8: Water quality for irrigation according to Richards' classification (Richards, 1954).

Water CIass	Index	Water CIass	Index
Admissible	C3S1	Excellent	C1S1
Margional	C3S2	Good	C1S2
Margional	C3S3	Admissible	C1S3
Poor	C3S4	Poor	C1S4
Poor	C4S1	Good	C2S1
Poor	C4S2	Good	C2S2
V Poor	C4S3	Margional	C2S3
V Poor	C4S4	Poor	C2S4

The Kelly ratio (KR) signifies the excess of sodium relative to calcium and magnesium. The Kelly ratio evaluates the suitability of groundwater for irrigation (Nag and Das, 2017). This investigation demonstrates that all samples are appropriate for irrigation in both summer and winter.

Potential Salinity (PS): Slightly soluble salts precipitate and accumulate in soil when irrigation water is used for several consecutive years, causing severe soil damage (Al-Saffawi et al., 2021). PS values ranged from 1.74 to 20.24 during the summer and from 1.74 to 20.24 during the winter.

Magnesium adsorption ratio (MAR%): High magnesium levels in groundwater negatively affect some soil properties. This can transform fertile, productive soil into alkaline and saline soil, reducing crop productivity (Al-Aarajy et al., 2023). The results of the sample analysis showed that 60% in summer and 55% in winter were excellent for irrigation.

Residual Sodium Carbonate (RSC) is an irrigation criterion, representing the degree of calcium and magnesium deposition within the soil profile. It is one means of expressing the damage caused by sodium, which destroys the soil structure and thus affects plants, especially leaves, burning them and reducing plant productivity (Ahmad et al., 2020; Kumari and Rai, 2020). The results indicated that the water in the study area is safe for irrigation.

4. Conclusion

The groundwater quality in the Bashiqa district was evaluated to assess its suitability for human consumption and irrigation. The chemical and physical investigation findings indicated that most groundwater quality metrics in the region exceeded WHO standards for potable water. Using the groundwater quality index (WQI) and spatial distribution maps, it was found that the southern and southeastern regions were unsuitable for drinking. In contrast, the study area's northern, northeastern, and central regions were suitable for drinking. As for irrigation, the water quality ranged from suitable to unsuitable according to irrigation water quality indicators. The unsuitability of some wells for irrigation is attributed to high electrical conductivity values, as confirmed by the Wilcox and Richard classifications.

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Iraqi National Journal of Earth Science, Vol. 26, No. 03, 2026 (176-186)

Iraqi National Journal of Earth Science

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التحليل المكاني لنوعية المياه الجوفية في ناحية بعشيقة ومدى ملاءمتها للشرب والري

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تاريخ الاستلام: 17 اذار 2025 تاريخ المراجعة: 20 نيسان 2025 تاريخ القبول: 19 ايار 2025

تاريخ النشر الالكتروني: 01 تموز 2026

الملخص

تهدف هذه الدراسة إلى تقييم جودة المياه الجوفية ومدى ملاءمتها للشرب والري في ناحية بعشيقة بمحافظة نينوى شمال العراق. كما سعت إلى إنشاء نماذج مكانية باستخدام نظم المعلومات الجغرافية (GIS). جُمعت عينات من 20 بئرًا موزعة في المنطقة خلال شهري سبتمبر 2024 ويناير 2025. تم استخدام مؤشر جودة المياه (WQI) لتقييم مدى ملاءمة المياه للشرب. كما تم استخدام العديد من المؤشرات لتقييم جودة المياه للري، بما في ذلك SAR وKR وPI وRCS و%Na وMAR وRSC ومخططات Wilcox و Richard. لوحظ تباين كبير في توزيع تركيزات الكاتيون والأنيون الرئيسية داخل منطقة البحث، ويعزى ذلك إلى التكوينات الجيولوجية المتنوعة في المنطقة. نُشرت نتائج مؤشر جودة المياه (WQI) لمياه الشرب على النحو التالي: خلال فصل الصيف، تم تصنيف 5٪ على أنها ممتازة، و60٪ على أنها جيدة، و25٪ على أنها سيئة، و10٪ على أنها غير مناسبة. خلال فصل الشتاء، صُنِّفت 10% من عينات المياه على أنها ممتازة، و55% جيدة، و35% رديئة، و10% غير صالحة. والسبب في عدم صلاحية بعض الابار للشرب بسبب تجاوز معظم المعايير المدرسة للحدود التي وضعتها منظمة الصحة العالمية. وتراوحت جودة المياه في المنطقة بين مناسبة وغير مناسبة للري. ويُعزى عدم ملاءمة بعض الآبار للري إلى ارتفاع قيم الموصلية الكهربائية حسب تصنيفات Wilcox و Richard للري.

الكلمات المفتاحية:

المياه الجوفية، مؤشر نوعية المياه، الشرب، الري.

DOI: 10.33899/injes.v26i3.60929, ©Authors, 2026, College of Science, University of Mosul.