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Hydrogeochemical Assessment of Groundwater for Irrigation and Drinking in Al-Kubba and Sherikhan Area, Northwest of Mosul City

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ABSTRACT

Understanding and managing of water reserves are based on the study of groundwater. The current study includes areas at the left side of Mosul City for the upper and lower regions of Sherikhan and Al-Kubba. Six samples are collected from wells in the study area. TDS, Temp., EC and pH are measured in the field. A laboratory analysis of the main ions (Na^{+}, Mg^{+2}, Ca^{+2}, Cl^{-}, SO_4^{-2}, HCO_3^{-}, K^{+1}) is performed. The study results show that most wells samples do not conform to the specifications of the Iraqi standards for drinking water due to the high values of most of the measured qualitative properties. The water quality index WQI reveals that most of the samples are considered as not suitable for drinking. Few heavy elements (Cd, Cr, Cu, Pb, and Co) are also examined, and each of Fe and Cu is within acceptable limits of WHO specifications, while the rest of the elements are over the acceptable limits. Irrigation tests are also examined, and each of TH, Na% and the ratio of MAR is within the acceptable limits and it refers to the suitability for irrigation of most plants that are moderately sensitive to salinity and some plants who have moderate resistance to salt. The statistical analysis shows that there is a strong correlation between calcium and bicarbonate, and between sodium and chlorine. This indicates that carbonate and sodium salts were dissolved.

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التقييم الهيدروجيوكيميائي للمياه الجوفية للري والشرب في منطقتي الكبة وشريخان، شمال غربي مدينة الموصل

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الملخص

يعتمد فهم وإدارة المخزون المائي على دراسة المياه الجوفية، وقد شملت الدراسة الحالية المناطق الواقعة في الجانب الأيسر من مدينة الموصل لمنطقتي الكبة والشريخان العليا والسفلى، وتم جمع ستة عينات من الآبار الموجودة في المنطقة. تم قياس TDS وTemp وEC وpH في الحقل، كما تم إجراء فحوصات مختبرية مثل التحاليل الكيميائية للعناصر الرئيسة والتي تشمل Na^+, Mg^{2+}, K^+, Ca^{2+}, HCO_3^-, $SO4^{2-}$, Cl^-. وأظهرت نتائج التحاليل أن غالبية عينات الآبار غير مطابقة للمواصفات العراقية للشرب. كما كشف مؤشر جودة المياه WQI أن معظم العينات غير صالحة للاستهلاك البشري. تم أيضًا فحص عدد قليل من العناصر الثقيلة، بما في ذلك Cd وCr وCu وPb وCo؛ وقد وجد ان الحديد والنحاس ضمن الحدود العراقية والعالمية، بينما بقية العناصر كانت فوق الحدود المسموحة، كما تم اجراء فحوصات الري كالصلادة الكلية ونسبة الصوديوم Na% و MAR، وقد بينت النتائج انها مطابقة للمواصفات، وحسب هذه النتائج تعتبر صالحة للري لمعظم النباتات متوسطة الحساسية للملوحة وبعض النباتات متوسطة المقاومة للملوحة. كما أوضح التحليل العاملي ومصفوفة الارتباط وجود علاقة قوية بين الكالسيوم والبيكربونات التي تمثل اذابة صخور الكربونات، كما نلاحظ علاقة قوية بين الصوديوم والكلور التي تمثل اذابة أملاح الصوديوم.

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Introduction

Due to population increase, related activities, and climate change, water resources worldwide are experiencing quality degradation (Dandge and Patil, 2021). Groundwater is a sustainable source of water, but rather as a resource, it is more vulnerable to this problem because in times of emergency, they are the only readily available source of water (Khattab et al., 2021). To preserve this resource, it is necessary to understand the mechanisms and variables affecting and regulating groundwater quality (Kale et al., 2020). Iraq is a country that experiences severe water scarcity, affecting not only drinking water but also industrial and agricultural uses. The development of life and population growth climate change and global warming have affected the rising demand for water in recent years in this country. The physical and chemical characteristics of the groundwater depend on the geological formations, through which the groundwater passes. Also, other factors control the groundwater quality such as the water-rock interactions, geological conditions, climate and topography, vegetation cover, water residence time, and anthropogenic factors (Alaarajy et al., 2023). The major sources of groundwater are rivers, irrigation canals, and rainfall. It is possible to be extracted from different layers and rock formations, whether they are sedimentary, igneous, or metamorphic rocks, where each type has its own physical, mineral, and chemical characteristics that determine the basis of the physical and chemical characteristics of groundwater (Wong et al., 2021). Many studies of groundwater in Al-Kubba and Sherikhan area have been conducted by many researchers. The last one is of Abdulqader (2013), who studied the physical and chemical properties of shallow water wells in Al-Kubba-Sherikhan area.

This study classifies the wells water samples according to quality, also it characterizes the physical and chemical composition of the groundwater, and it evaluates its usefulness as a source for drinking water and irrigation by knowing the extent to which the results match the specifications of the World Health Organization, in addition to knowing the extent to which heavy elements affect that water.

Geology of the Study Area

The studied wells have various depths ranging from 7 to 60 meters. The study area is located between longitudes (43°02´30.49´´E-43°04´59.3´´E) and latitudes (36°24´08.01´´N-36°24´59.93´´N). Samples are taken from six wells in the study area of the Al-Kubba and upper and lower Sherekhan regions (Fig. 1). The exposed rock units belong to the upper and lower members of the Fatha Formation (Middle Miocene), and the Injana Formation (Upper Miocene), in addition to the Quaternary sediments. The rocks of Fatha Formation, in general, are successions of anhydrite, gypsum, and rock salt intermingled with limestone, marl, and clastic rocks. As for the Injana Formation, which follows the Fatah Formation, it consists of a succession of sedimentary cycles. It grades upwards to red and lead-colored mudstone, marl, siltstone, chert and medium-coarse sandstone (Al-Rawi et al., 1993). The sandstones in this formation are characterized by their high porosity and permeability, which allows them to store groundwater and also allows water to pass into the Fatha Formation layers that lies beneath them through fracture surfaces. As for the clay rocks, they often appear red in color and have thin layers and are fragile to low in hardness (Al-Rawi et al., 1993). In addition, recent deposits cover the parts near the river represented by Quaternary sediments. Figure (1-B) is a Google Earth Image showing the locations of the samples.

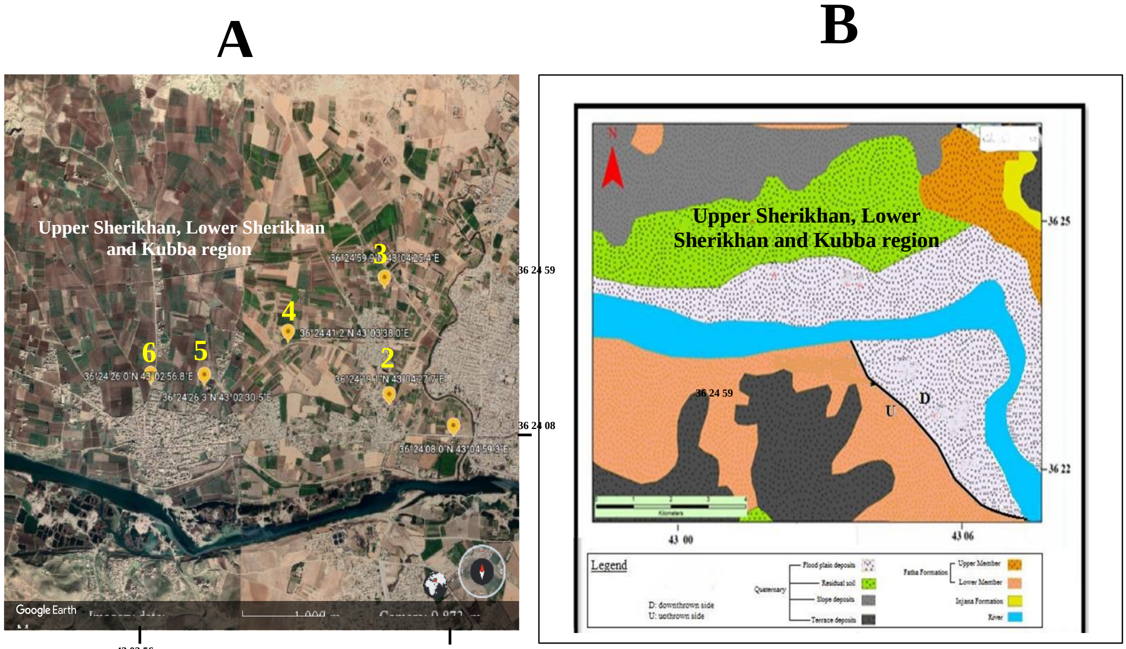

Fig. 1: A- Google Earth Image 2023; B- Geological map for the studied area (Al-Bachachi, 2014) showing the locations of samples.

Materials and Methods

The samples characteristics (pH, EC, and TDS) were measured at the well site. While the measurements of sodium (Na^+), calcium (Ca^{+2}), magnesium (Mg^{+2}), potassium (K^+), chloride (Cl^-), sulphate (SO_4^{-2}), Bicarbonate (HCO_3), cadmium (Cd), lead (Pb), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe) were analyzed in the Directorate of Agriculture in Nineveh Governorate.

In this research, who's criteria, Iraq's drinking water specifications No. 417 (2009), and irrigation water quality standards have been used to determine the validation of the water for drinking and irrigation purposes.

Total Hardness (TH)

The total hardness of water is the sum of its calcium and magnesium concentrations in milligrams per liter (mg/l). Divalent ions, especially calcium and magnesium, are the main factors determining the total hardness values. The two elements in question are the main causes of water hardness due to their respective contributions. Total hardness is calculated using the following equation:

$$TH = 2.49Ca^{+2} + 4.1Mg^{+2} \text{……………….(1)}$$

Sodium percentage (Na^+%)

Elevated levels of salt reduce the permeability of the soil, endangering plants as the chemical hurts their leaves (Hakim et al., 2009). The following relationship is used to calculate the sodium percentage:

$$Na\% = \left[\frac{(Na^+ + K^+)}{Ca^{2+} + Mg^{+2} + Na^{+2.} + K^+}\right] \times 100 \text{ ……… (2)}$$

Sodium adsorption ratio (SAR)

The following formula has been used to determine the rate of sodium absorption:

$$SAR = \frac{Na^+}{\sqrt{\frac{(Ca^{+2} + Mg^{+2})}{2}}} \text{ ………..(3)}$$

Magnesium absorption ratio (MAR)

The following formula can be used to determine the risk of magnesia in agricultural irrigation water:

$$MAR = \left[\frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}}\right] \times 100 \text{………(4)}$$

The water quality index (WQI)

The (WQI) is computed using all the parameters below and based on World Health Organization standards to determine whether the well water in the study area is suitable for drinking and civil uses (WHO, 2008) according to the following equation (Gupta and Misra, 2018):

$$WQI = \sum Qi\ X\ Wi / \sum Wi \text{ ………(5)}$$

$$Qi = 100\ X\ (Vm - Vi) / (Vs - Vi) \text{ ……………… (6) (for each parameter)}$$

Where: *WQI* is water quality index; *Qi* is Qualitative evaluation of parameter *i*; *Wi* is the relative weight of the parameter *i*, *Wi= 1 / Vs*; *Vm* is the measured value of the parameter *i*; *Vs* is the standard value of the parameter *i*; *Vi* is the virtual value of parameter *i* equals to zero.

Statistical analysis

SPSS program is used to perform factor analysis and correlation coefficient for the main water quality elements. The importance of factor analysis in the current study is highlighted in knowing the extent to which the groundwater of the studied area is affected by the type of rocks passing through it, and knowing the relationship of these components and elements with each other, which reflects the extent to which water is affected by these rocks.

Heavy elements

Heavy elements are defined as those whose densities are more than five times the density of water. They are known as heavy elements; each has an atomic number greater than (20). They are materials of natural origin and are spread in nature very widely and move in the environments continuously from one place to another (Ram Kumar et al., 2000). These elements split into two groups. The first group is called the "basic heavy elements", and they are essential for building the body of an organism through biological processes and they work as cofactors in the body's enzymatic system. Their excess has a detrimental impact, and their presence is crucial. These elements are chromium, cobalt, iron, nickel, magnesium, zinc, calcium, and silicon. The second group, which is known as non-essential heavy elements, includes elements that are toxic in any amount and are not needed for the body's vital functions. These elements are silver, cadmium, lead, and other non-essential elements. Since they do not break down, they will always be floating about in the water and are therefore considered hazardous contaminants. They can enter the body through polluted food, air, or water and accumulate causing damage over time (Kennedy et al., 1999). Additionally, they endanger the well-being of people, animals, and plants when their concentration levels rise. Heavy metals levels are quite low in the aquatic environment.

Results and Discussions

Analyses of the samples

The results of the chemical and physical analyses and examinations of the well water in the study area are shown in Table (1). The variation in the analyses values is due to the different depths of the wells from which the samples were taken; and therefore, this water will pass through different geological layers. The results of the analysis show that the percentage of sulfate (SO_4^{-2}) is within the Iraqi water limits and the world health organization, WHO (2006). However, we note in sample No. 2 a slight rise in the concentration of sulphates but this is still well within the limits set by the Iraqi requirements for water.

Sodium percentage ranges between (148 -11.24 ppm) in the study area. Due to penetrated rainwater into the groundwater, sodium as an element with high solubility often comes from dissolving the sedimentary rocks containing sodium chloride (NaCl), so that the sodium element is considered one of the most important elements present in the groundwater, and it is one of the main components in the rocks of the earth's crust and its percentage is about (2.8%). In some conditions, the concentration of this element reaches about (10,000) mg/l and combines with the chlorine ion forming the salt of sodium chloride (NaCl). The sodium ion in groundwater also expresses the weathering products of the Na-rich plagioclase minerals, which is one of the minerals of the feldspar group and is one of the main sources of the sodium element in groundwater (Todd, 2007).

Potassium (K^+) concentrations in the water samples are between 2.3 ppm and 5.6 ppm, which is allowable within the Iraqi drinking water standards. K^+ is one of the elements with a high adsorption capacity, and it is present well in sedimentary rocks, and feldspar minerals, which is an insoluble mineral, so the concentration of this element is usually little relative to the sodium concentration.

Bicarbonate (HCO_3^-) indicates the presence of carbonate minerals as its source is in the form of calcite (in limestone) and dolomite. The percentage of bicarbonate ranges between (176 ppm-421 ppm), and this relative heigh value indicates that the groundwater has come into contact with rocks and formations that have dissolved the carbonate minerals of the Fatha Formation.

As for the chloride ion (Cl^-), its percentage in the studied samples ranges between 28 ppm and 67 ppm, which is within the Iraqi and international drinking water specifications. The concentration of chloride ion fluctuates depending on the source and condition of the investigated water. Chloride ion concentration is related to the rate of chloride salt dissolution (NaCl).

Calcium (Ca^{+2}) percentage ranges between (240 -701 ppm), where the high concentration of calcium is noted due to the infiltrated water through gypsum and carbonate rocks (Chapelle, 2004).

Magnesium (Mg^{+2}) concentration ranges between (150-364) ppm, and when comparing this range with the Iraqi and international specifications, a significant increase in its percentage in the water wells samples is noticed. The source of magnesium is from the solubility of sedimentary dolomite rocks.

The values of the (pH) refer to the chemistry of water, and it is defined as the negative logarithm of the hydrogen ion concentration. It is a measure of the acidity or alkalinity of solutions under normal conditions of temperature and pressure. Where the pH varies according to the layers of rocks in which the groundwater is located. The degree of acidity (pH) gives an important information about the geochemical balance and the solubility of the groundwater components (Sen, 2008). All the samples have pH values between 7.09 and 7.7, which are within the acceptable range for drinking water in Iraq.

Table 1: Results of analyses of the water samples and physical and chemical parameters of groundwater for the current study, and Iraqi standards.

Parameters	EC µs/cm	pH	TDS	Ca^{+2} mgl^{-1}	Mg^{+2} mgl^{-1}	Na^{+} mgl^{-1}	K^{+} mgl^{-1}	Cl^{-} mgl^{-1}	SO_4^{-2} mgl^{-1}	HCO_3 mgl^{-1}
Iraqi standards	1400	6-8	1000	200	150	200	12	600	400	400
Well, No 1	2982	7.1	1491	701	328	148	3.9	60	20.98	421
Well, No 2	2617	7.2	1308	480	364	124	2.9	53	386	268
Well, No 3	1176	7.2	2337	360	316	105	3.4	67.3	235	262
Well, No4	1773	7.09	886	300	218	48.9	4.5	46	155	231
Well, No5	1028	7.16	515	240	158	11.24	2.3	28	82	265
Well, No 6	1720	7.77	864	280	194	83	5.6	63.8	175	176

Suitability for irrigation purposes

The results of parameters evaluating the suitability of water for irrigation purposes are as follows:

1: Electrical conductivity and TDS

In the studied region, electrical conductivity varies from 1028 to 2982 µs/cm (Table 2). The internationally approved classifications to determine the suitability of water for agricultural uses are mentioned in table (3). The varying salt concentrations in the water are a result of the several geological layers that cut across the region. Figure (2) represents Wilcox diagram showing the rating of groundwater samples based on EC and sodium percent, the samples range according to this figure from good to permissible for irrigation uses.

Table 2: Classification of irrigation water according to electrical conductivity and sodium percentage for the study area (Wilcox, 1955).

Samples	E.C µs/cm	Na%	Type of water
1	2982	12.9	Doubtful to unsuitable
2	2617	13	Doubtful to unsuitable
3	1176	13.8	Good to permissible
4	1773	9.3	Good to permissible
5	1028	3.29	Good to permissible
6	1720	15.74	Good to permissible

Table 3: Internationally approved classifications to determine the suitability of water for agricultural uses (Train, 1979).

Salinity (EC) ds. m^{-1}	Dissolved salts (TDS) mgl^{-1}	Chloride (Cl) (mgl^{-1})	U.S. Salinity Laboratory (U.S.S.L)	Scientific Division of the United Nations (UNESCO)	American Technical Advisory Committee (NATC)
less than 0.75	less than 500	less than 400	low salinity	no problem	Suitable for use with any agricultural crop on any soil type
1.5-0.75	1000 -500	1000 -400	medium salinity	the issue will worsen	Suitable for watering some salt-tolerant crops on well-drained soils.
3.00 -1.5	3000-1000		high salinity		Suitable for irrigating salt-tolerant crops if the soil is maintained and has enough drainage.
7.00 -3.00	5000 -2000	1000 or more	very high salinity	major difficulty	It can be used to cultivate some crops with proper drainage.
More than 7.600	more than 5000				Even if good-draining soil is available, it cannot be used to grow crops.
pH					**8.5 – 5.5**

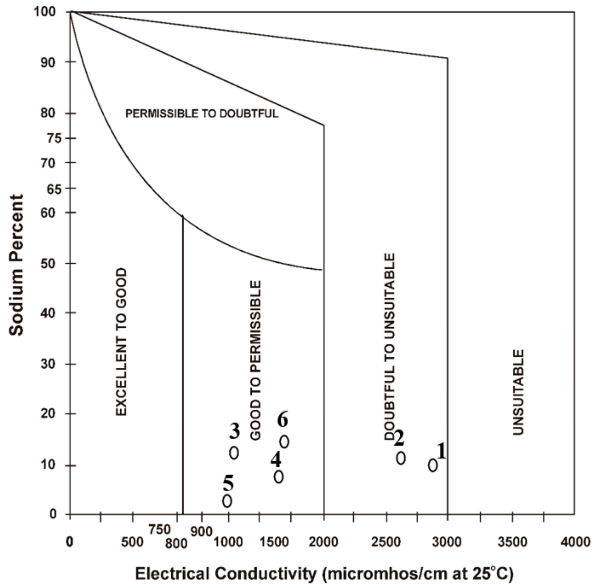

Fig. 2. Wilcox diagram showing the rating of groundwater samples based on EC and sodium percent.

2: Total Hardness (TH)

The total hardness of the examined water samples ranges between 1245 to 3090 (Table 5), which is suitable for watering some salt-tolerant crops on well-drained soils (Todd, 1980).

3: Sodium percentage (Na%)

The range of sodium percentages is between 3.29 and 15.74% (Table 5); therefore, all the samples fall within acceptable range for irrigation (Table 3). Elevated levels of salt reduce the permeability of the soil, endangering plants as then chemical hurts their leaves. It is deemed suitable for irrigation according to Wilcox (1955).

4: Sodium adsorption ratio (SAR)

The ratio of SAR for the analyzed samples ranges between (0.796-8.64) meq/l (Table 5), which is excellent (with a little or no hazard) (Table 4).

Table 4: Sodium adsorption ratio classification (Todd, 1980).

Sodium Hazard class	SAR (meq/l)	Remarks
C1	0-10	Excellent (little or no Hazard)
C2	10-18	Good (Appreciable hazard but can be used with appropriate management
C3	18-25	Doubtful (Unsatisfactory for most of the crops)
C4	>25	Unsuitable (Unsatisfactory for all the crops)

5: Magnesium absorption ratio (MAR)

When the percentage of MAR is greater than 50, it is deemed unsuitable for irrigation; however, when it is less than 50, it is deemed suitable for irrigation. (Szabolcs, 1964). The levels of magnesium absorption ratio in the water of the study area have been calculated and given in table (5).

Table 5: Results of total hardness, sodium percentage, SAR, and magnesium ratio of the study area.

Well No	TH ppm	Na%	SAR	MAR
1	2982	12.9	6,523	31.9
2	2687	13	8.64	43
3	2192	13.8	5.7	46,7
4	1640	9.3	3	42
5	1245	3,29	0.796	39.7
6	1492	15.74	5.39	40.9

Water quality Index (WQI)

Water quality index (WQI) has been used based on parameters and chemical analysis of water in the wells of the study area, and the classification of the groundwateris according to the classification of Gupta and Misra (2018). Table (6) shows the standard (Vs) values for the coefficient according to the standards of the World Health Organization (WHO, 2008). Table (7) displays the values of (Qi) for each chemical parameter, and table (8) represents the relative weight for chemical laboratories. Table (9) represents the values of the qualitative evaluation product multiplied by the relative weight of each chemical coefficient certified in water quality coefficient calculations for study well samples. The studied well water samples are classified according to WQI from bad to not suitable for drinking. Depending on the results of calculating the water quality index, the wells water samples are not suitable for drinking.

Table 6: Standard chemical specifications (Vs) (milligrams/liter) of water for human use according to WHO (2006).

EC µs/cm	pH	TDS mg/l	Ca^{+2} mgl⁻¹	Mg^{+2} mgl⁻¹	Na^{+1} mgl⁻¹	K^{+1} mgl⁻¹	Cl^{-1} mgl⁻¹	SO_4^{-2} mgl⁻¹	HCO_3 mgl⁻¹
1400	8.5	1000	400	50	200	55	250	400	400

Table 7: Qualitative evaluation of chemical parameters (Qi).

Parameters	EC µs/cm	pH	TDS mg/l	Ca^{+2} mgl⁻¹	Mg^{+} mgl⁻¹	Na^{+1} mgl⁻¹	K^{+1} mgl⁻¹	Cl^{-1} mgl⁻¹	SO_4^{-2} mgl⁻¹	HCO_3 mgl⁻¹
Well, No 1	213	6.67	149.1	934.66	656	74	7.09	24	5.24	105.25
Well, No 2	186.92	13.33	130.8	640	728	62	5.27	21.2	96.5	67
Well, No 3	84	13.33	233.7	480	632	52.5	6.18	26.9	58.75	65.5
Well, No4	126.6	6	88.6	400	436	24.45	8.18	18.4	38.75	57.75
Well, No5	73.428	10.67	51.5	320	316	5.62	4.18	11.2	20.5	66.25
Well, No 6	122.85	51.33	86.4	373.33	388	41.5	10.18	25.5	43.75	44

Table 8: Relative weight of the parameter (Wi).

pH	EC µs/cm	TDS mg/l	Ca^{+2} mgl⁻¹	Mg^{+2} mgl⁻¹	Na^{+1} mgl⁻¹	K^{+1} mgl⁻¹	Cl^{-1} mgl⁻¹	SO_4^{-2} mgl⁻¹	HCO_3 mgl⁻¹	Summation
0.0007	0.117	0.0010	0.0133	0.0200	0.0050	0.0182	0.0040	0.0025	0.0025	0.1842

Table 9: Results of multiplying (Wi * Qi).

Well number	EC µs/cm	pH	TDS mg/l	Ca^{+2} mgl⁻¹	Mg^{+2} mgl⁻¹	Na^{+1} mgl⁻¹	K^{+1} mgl⁻¹	Cl^{-1} mgl⁻¹	SO_4^{-2} mgl⁻¹	HCO_3 mgl⁻¹	Summation
1	0.1491	0.7803	0.1491	12.43	13.12	0.37	0.129	0.096	0.0131	0.263	28.4886
2	1.30844	1.559	0.1308	8.512	14.56	0.31	0.0959	0.0848	0.2412	0.167	26.93
3	0.0588	1.559	0.2337	6.384	12.64	0.262	0.11247	0.1076	0.1468	0.163	21.66
4	0.0886	0.702	0.086	5.32	8.72	0.1222	0.1488	0.0736	0.00968	0.144	15.41
5	0.0514	1.248	0.051	4.256	6.32	0.0281	0.076	0.0448	0.05125	0.1656	12.29
6	0.0859	6.0056	0.864	4.965	7.76	0.2075	0.1852	0.102	0.109375	0.11	20.38

Table 10: Water quality index (Ahsan et al., 2023).

Drinking water quality scale	Type of water for drinking
0-25	Very good
26-50	good
51-75	bad
76-100	Very bad

100<	Not suitable for drinking

Table 11: Water quality index (WQI) for the study area.

Well number	WQI	Type of water
1	154.65	Not suitable for drinking
2	146.19	Not suitable for drinking
3	117.58	Not suitable for drinking
4	83.65	Very bad
5	66.72	bad
6	110.64	Not suitable for drinking

Heavy elements

The analysis data of the heavy elements are shown in Table (12). The lead (Pb) levels range from (0.0066-0.07497 ppm) but are still near the WHO's safe limit (0.05 ppm). Lead is one of the few naturally abundant elements, and its concentration varies across the earth's crustal layers. Groundwater contains negligible levels of lead. About the element cadmium (Cd), its values range between (0.03463–0.1275 ppm). Its concentrations in the first, second, and third samples are close to the permissible specifications, but in the fourth, fifth and sixth samples they are greater than the standards of the world health organization. An excess of cadmium in the body can cause several health problems including a halt in normal growth, a shift in blood composition (leading to anemia), higher blood pressure, and enlarged heart muscle (Weng et al., 2007). Regarding the iron element (Fe), its values vary between 0.1807 and 0.3889 ppm, which are close to the requirements of the World Health Organization. The presence of iron at concentrations higher than 1 mg/l alters the taste and color of water and hurts the liver and digestive system. When compared to the World Health Organization's recommended limits, the chromium (Cr) concentration in this study is much higher with a range of 0.0628 to 0.0810 ppm. The instrument's detection limit for copper (Cu) is not reached, (about 0.13 ppm). The amount of cobalt (Co) ranges from 0.0705 -0.1092 ppm which is higher than the standards set by the World Health Organization.

Table 12: Results of the heavy metal analyses for the studied samples.

	Cu ppm	Fe ppm	Cd ppm	Cr ppm	Pb ppm	Co ppm
WHO's Standards	0.13	0.3	0.0003	0.005	0.001	0.005
Well, No 1	Nil	0.2556	0.06104	0.0628	0.01311	0.0705
Well, No 2	Nil	0.1807	0.03463	0.0725	0.07151	0.0797
Well, No 3	Nil	0.2051	0.05477	0.0654	0.03060	0.0891
Well, No 4	Nil	0.3889	0.08708	0.0810	0.07497	0.0910
Well, No 5	Nil	0.2635	0.09724	0.1035	0.03541	0.0949
Well, No 6	Nil	0.2227	0.1275	0.1654	0.00663	0.1092

Statistical analysis

The results of the statistical analysis accomplished for the major groundwater quality parameters are as follows:

1: Correlation Coefficient

The correlation coefficient shows how much there is a linear relationship between two variables. The correlation coefficient's value can be either positive or negative, which shows how much there is a direct or inversely relationship. If the correlation coefficient is 1, the points will form a straight line. If it is zero, however, the points will spread out in a circle around the origin point. Results of correlation coefficient show that sodium and potassium have a positive relationship with Cl, which indicates their presence in the form of sodium potassium salts as shown in Table (13). We notice a strong correlation between calcium and bicarbonate HCO_3^- (0.877), which represents carbonate rocks. We also notice a strong correlation between sodium and chloride (0.77) and the relation between potassium and chloride (0.552), which represent sodium and potassium salts.

Table 13: Correlation matrix between major water quality parameters for the study area.

		EC	pH	TDS	Ca	Mg	Na	K	Cl	SO_4	HCO_3
Correlation Coefficient	**EC**	1.000	-.156	.108	.875	.658	.774	.141	.320	.050	.613
	pH	-.156	1.000	-.205	-.356	-.340	-.016	.665	.388	.129	-.613
	TDS	.108	-.205	1.000	.422	.741	.666	-.083	.732	.284	.312
	Ca	.875	-.356	.422	1.000	.764	.855	-.072	.397	-.137	.877
	Mg	.658	-.340	.741	.764	1.000	.884	-.210	.563	.472	.526
	Na	.774	-.016	.666	.855	.884	1.000	.153	.772	.228	.548
	K	.141	.665	-.083	-.072	-.210	.153	1.000	.552	-.138	-.351
	Cl	.320	.388	.732	.397	.563	.772	.552	1.000	.244	.055
	SO_4	.050	.129	.284	-.137	.472	.228	-.138	.244	1.000	-.442
	HCO_3	.613	-.613	.312	.877	.526	.548	-.351	.055	-.442	1.000

2: Factor analysis

The statistical program SPSS is used to conduct the factor analysis of the water quality data for the study area. The results of factor analysis are seen in table (14). We can see three factors which explain 88.328% of the variance, the first factor is the largest one, it explains 39.87% of the total variation and reflects carbonate components and the electrical conductivity EC, salts as NaCl. The second factor reflects dolomite $CaMg(CO_3)_2$, which is responsible for 25.557% of the overall variation. The third factor explains 22.93% KCl and pH secondly.

Table 14: Rotated factor loadings (R-mode Factor analysis).

Parameters	F1	F2	F3
Ca	0.978	0.153	
HCO_3	0.879	-0.122	-0.420
EC	0.853		
Na	0.800	0.549	0.215
SO_4	-0.306	0.831	
TDS	0.353	0.767	
Mg	0.641	0.739	-0.174
K		-0.125	0.939
pH	-0.311		0.862
Cl	0.399	0.606	0.628
Variance ratio	**39.87%**	**25.577**	**22.93**

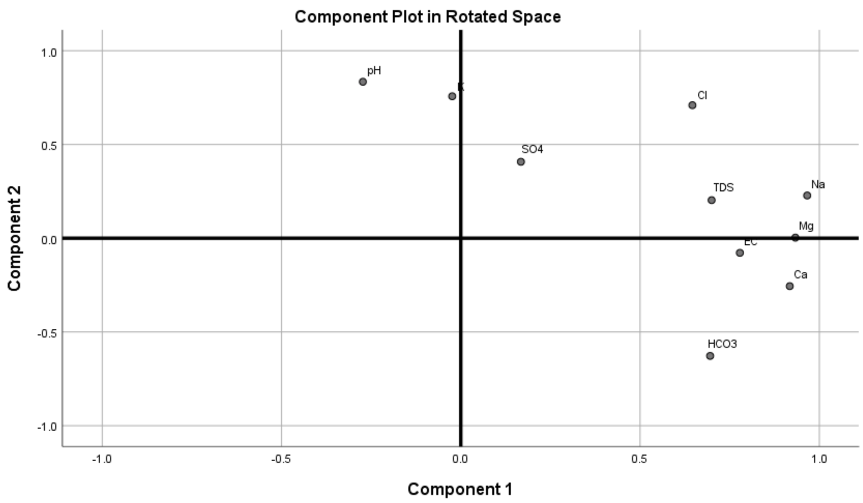

Fig. 4. Components of factors 1 and 2.

Conclusions

The groundwater in the area under study is profoundly affected by the geological strata rocks. Additionally, the principal ion concentration values in the groundwater of the straightforwardly investigated area do not fall within the acceptable ranges of the Iraqi drinking water standard. The ionic concentrations of cadmium, cobalt, the majority of the quantities of iron, and lead in the water samples are within acceptable levels; yet, this water is not appropriate for consumption.

According to the results, the well water of the studied area is classified as water suitable for growing specific types of crops with little sensitivity to salts. Well water samples are not suitable for drinking purposes. Through statistical analysis, it is noticed that the studied groundwater is influenced by carbonate, dolomite rocks, halite and sulfate salts.

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