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Evaluation the ground water in kirkuk governorate for drinking and irrigation purposes.

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ABSTRACT

A field study was conducted to evaluate groundwater pollution and determine its suitability for drinking and irrigation purposes in the districts of Shawan , Alton Kopre and Dibis district in Kirkuk Governorate. Samples were collected from fifty-two wells during September 2023. The chemical concentration of groundwater (pH, EC, TDS, T.H,Ca^{+2}, Mg^{+2}, K^{+}, Na^{+} SO_4^{-2}, CO_3^{-2}, HCO_3^{-}, NO_3^{-}, PO_4^{-3}, Cl^{-}) were analyzed, also mathematical model WQI was measured to evaluate Water quality for irrigation and drinking. ArcGIS 10.4.1 software was used for figure spatial distribution of parameters.

The results showed that the chemical characteristics of the well waters are within the permissible limits except of total hardness (T.H.) and electrical conductivity (EC), as 50.02% and 2.13% of the water in the study wells exceeded the permissible limits for drinking and irrigation in terms of hardness and electrical conductivity, respectively. Concerning dissolved cations, 13.67% of the total area exceeded the permissible limits for drinking only for calcium ions, and 25.71% exceeded the permissible limits for drinking and irrigation for magnesium ions; as for potassium ions, 4.35% of the study wells exceeded the permissible limits for irrigation. While the dissolved (Anions) ions for all well water was within the permissible limits, with the exception of sulphate, phosphate, and nitrate ions, as 99.89% of the study well water was within the permissible limits for drinking, with the exception of wells W3 and W31, but all of them are suitable for irrigation with regard to sulphate ions. As for phosphate ions, 99.96% of the study well water exceeded the permissible limits for drinking only, while 46.82% was not suitable for irrigation regarding nitrates.

Keywords: groundwater, WQI, EC, Kirkuk, water hardness.

INTRODUCTION

Groundwater is the second leading source of water for humans all over the world. Water reaches the surface of the earth through springs or by drilling wells. It is one of the important sources that humans resort to for drinking, agriculture, and industry. **[**1] explained that the amount of groundwater depends on the amount of rainwater seeping below the surface of the earth, which is considered the main source of groundwater in addition to other sources. The study of the hydrochemistry of groundwater is a function of the rocky nature lithology and the mineral composition of the aquifers [**1**] Groundwater constitutes about 71.7% of the potable water in the world [2**,**3]. Because it is underground, its pollution is difficult to detect or control and requires a relatively high cost to treat it [4]. In addition, it is the source that can control water withdrawal according to demand [5]. The mineral content of groundwater is one of the important features that distinguish it from surface water, and this content varies according to the geological nature of the area through which groundwater passes or settles. Water pollution is defined as any chemical or physical change in the quality of water that, directly or indirectly, negatively affects living organisms or makes the water unsuitable for the required uses. Most of the Citizens of Kirkuk Governorate depend on well water to meet daily and agricultural needs, and this water is exposed to sources of pollution. Different pollutions resulting from the use of chemical pesticides, fertilizers, building waste, and wastewater flowing from homes, in addition to the spread of oil refineries in various places in the governorate, which may lead to air and soil pollution, and from there it may move to groundwater, causing it to be contaminated with the residues of those additives that include carrier chemical compounds such as or heavy metals and some harmful ions. Hence, this study aims to evaluate the quality of well water spread across the study area and prepare figures of the distribution of its chemical characteristics using Geographic Information Systems (GIS) techniques.

Materials & Methods

2.1. Sample Collection

The study was conducted on a many of groundwater wells spread in Dibis ,Shwan and Alton kopre areas within the administrative boundaries of Kirkuk Governorate. The study area extends between of latitude (35º26' 31 '' -35 º 56' 49'') N and longitude (44º45' 32 '' -43 º 50' 42'') E, with an area of (183402.13) hectares. In order to determine the suitability of this water for drinking and irrigation purposes, the following steps are followed:

2.1.1. Field Work:

Water samples were collected from fifty-two wells randomly distributed in the study area during the dry season (summer) in September (2023). After running the well water pump for several minutes, water samples were taken to conduct physical and chemical analyzes using clean plastic bottles washed with the sample water several times. times before filling them, and determined their locations using GPS and Google Earth Fig (1).

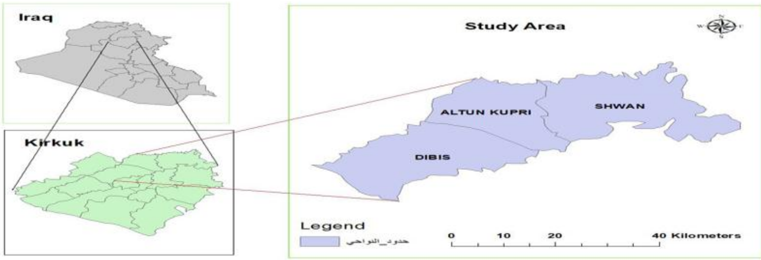

Fig (1) locations of the studied wells.

2.1.2. Laboratory work:

After bringing the samples to the laboratory, they were placed in a refrigerator at a temperature of 4°C to prevent fungal growth until chemical analysis were conducted (Table1).

Table (1): Chemical analyses of well water in the study area.

NO	Parameter	Methods
1	PH	pH -meter
2	EC	EC -meter
3	TDS	TDS 3meter– PPm
4	T.H	EDTA titrimetric method
5	Ca^{+2}	EDTA titrimetric method
6	Mg^{+2}	EDTA titrimetric method
7	Na^{+}	Flame photometer Method
8	K^{+}	Flame photometer Method
9	Cl^{-}	EDTA with $AgNO_3$
10	SO_4^{-2}	Vercent method
11	Co_3^{-2}	EDTA with HCl
12	HCO_3^{-}	EDTA with HCl
13	NO_3^{-}	Uv-1 100 Spectrophotometer with wave length 220nm
14	PO_4^{-2}	Yellow Molpedat Vandat by Spectrophotometer

2.2. Work

The suitability of groundwater for drinking and agricultural use was determined according to the standards of the World Health Organization (WHO) and the International Agricultural and Food Organization (FAO), respectively (Table 2).

Table 2: Global determinants of drinking water and irrigation.

No	Physical & chemical properties	Unit	WHO (2006 , 2003)	FAO (2015)	WHO (2011&2017)	FAO)2023(
1	Temp	C°	15-35	-	-	-
2	pH	-	6.5-9.5	8.56.5-	8.5	-
3	EC	s/cm- ds.m^{-1}µ	400	3	1500	-
4	TDS	-	-	2000	1000	-
5	T.H	mg.l^{-1}	500	-	500	-
7	Turb	NTU	5	-	-	-
8	Ca	mg.l^{-1}	75	400	200	-
9	Mg	mg.l^{-1}	100	60	150	-
10	Na	mg.l^{-1}	200-250	900	400	-
11	K	mg.l^{-1}	10-12	2	12	-
12	Cl	mg.l^{-1}	45-250	1100	600	-
13	SO_4	mg.l^{-1}	400	1000	400	-
14	Co_3	mg.l^{-1}	-	100	-	-
15	HCO_3	mg.l^{-1}	-	600	500	-
16	NO_3	mg.l^{-1}	50	10	50	-
17	PO_4	mg.l^{-1}	0.4	2	-	-

2.3. Water Quality Index (WQI)

To calculate the water quality index, three steps are required as mentioned by [6].
First step: A weight (wi) is assigned to each of the chemical parameters (pH, EC, TDS, T.H, Ca, Mg, Na, K, SO_4, HCO_3, NO_3, Cl) based on their tangible effects on health / their relative importance in overall quality Water for drinking purposes. The highest weight of 5 is assigned to the parameters that have significant effects on water quality and their importance in quality, and 1 is assigned as the minimum for the parameter that is considered harmless, meaning SO_4, NO_3, Cl, and TDS were given the maximum value (5). In contrast, K ions were given the minimum value (1) depending on its importance. Slim table (3).
The second step: Calculate the relative weight (Wi) for each parameter using equation (1).
The third step: The quality rating scale (qi) for each parameter is calculated by dividing its concentration in each water sample by its respective standard according to the standard specification, then multiplying the result by 100 using equation (2).
Step Three: Calculate the Water Quality Index (WQI) for each sample using equation (3).

$$Wi = \frac{wi}{\sum_{i=1}^{n} wi} \qquad \text{……….(1)} \qquad Qi = \left(\frac{ci}{si}\right) * 100 \qquad \text{……….(2)}$$

$$WQI = \sum_{i=1}^{n}(Wi * Qi) \qquad \text{……….(3)}$$

Since:
Wi: relative weight. **wi:** the weight of each parameter. **n:** number of transactions. **Qi:** quality rating. **Ci:** concentration of each chemical parameter in each water sample.
Si: Standard value according to [7] $mg.l^{-1}$.
The WQI index is classified according to Table (4).

Table (3): Water quality standards and assigned and relative weight value.

NO	Chemical properties	Drinking guidelines $mg.l^{-1}$ ،2011)WHO(	Assigned Weight (wi)	Relative Weight (Wi)
1	pH	8.5	4	0.10811
2	EC (μS/cm)	1500	4	0.10811
3	TDS ($mg.l^{-1}$)	1000	5	0.13514
4	T.H as $CaCO_3$ ($mg.l^{-1}$)	500	2	0.05405
5	Ca ($mg.l^{-1}$)	200	2	0.05405
6	Mg($mg.l^{-1}$)	150	2	0.05405
7	Na($mg.l^{-1}$)	400	2	0.05405
8	K ($mg.l^{-1}$)	12	1	0.02703
9	SO_4 ($mg.l^{-1}$)	400	4	0.10811
10	HCO_3	500	3	0.08108
11	NO_3 ($mg.l^{-1}$)	45	5	0.13514
12	Cl ($mg.l^{-1}$)	600	3	0.08108
			37∑	0.999≈1

Table (4): Groundwater Quality Index (WQI) classes according to [6].

No	Classes	WQI values	Water quality status	Possible usage
1	I	< 50	Excellent	Drinking, irrigation, and industrial
2	II	50.1-100	Good	Drinking, irrigation, and industrial
3	III	100.1-200	Poor	Irrigation and industrial
4	IV	200.1-300	Very poor	Irrigation
5	V	>300.1	Unsuitable for drinking	Proper treatment required before use

Results and Discussion
3.1. Chemical Properties of Water
3.1.1. pH
The results Fig (2) also showed that there are two classes of pH in the well water of the study area. The first class is suitable for drinking and irrigation according to the standards of the World Health Organization [8,9] (6.5-9.5) and the standards of the Food and Agriculture Organization [10] (6 -8.4) in most parts of the study area, while the second type is suitable for drinking only in some northern parts of the study area, for an area of 12.27 and 183,389.85 hectares, with a percentage of 99.99% and 0.01%, respectively.

Fig (2): pH of well water in the study area.

3.1.2. Electrical Conductivity (EC)

The results fig (3) also showed that there are three types of The electrical conductivity of well water in the study area is according to the standards of the World Health Organization [7,11] and the standards of the Food and Agriculture Organization [10]. The first type is good water for drinking and irrigation. It is located in the eastern parts of the study area and has an area of 114,107.79 hectares, with a percentage of 62.22%, while the type The second is water suitable for irrigation only. It is located in the western parts of the study area and has an area of 65,387.38 hectares, with a percentage of 35.65%. It is classified as highly mineralized water that exceeds the permissible limits for drinking because it gives the water an unpleasant taste [12, 13]. As for the third category, water is unsuitable for drinking and irrigation. It occupies limited areas in the center of the study area, with an area of 3906.96 hectares, with a percentage of 2.13%.

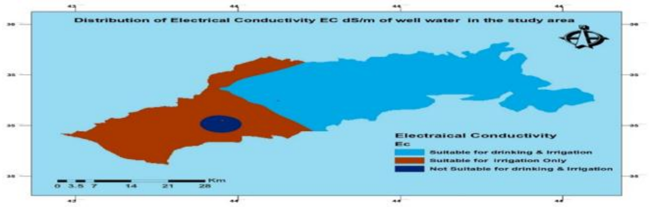

Fig (3): Electrical conductivity (EC) of well water in the study area.

3.1.3. Total Dissolved Solid (TDS)

The results fig (4) also showed that all of the well water in the study area did not exceed the permissible limits for drinking and irrigation according to WHO standards [7] (1000) mg.L^{-1} and FAO standards **[**10] (0-2000) mg.L^{-1} in all parts of the study area.

3.1.4. Total Hardness (T.H)

The results fig (5) also showed two types of total hardness of well water in the study area. The first type is suitable for drinking only and does not exceed the permissible limits according to the standards of the World Health Organization [7] (500) mg. L^{-1} and occupies the eastern regions and parts of the center of the study area, while the second type is very hard water that is not suitable for drinking and irrigation, according to [14] and occupies parts of the northeastern and western regions of the study area, with an area of 91,746.07 and 91,656.06 hectares, with a percentage of 49.98% and 50.02% over straight.

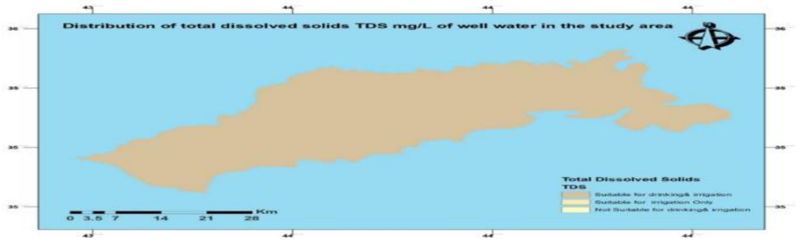

Fig (4): Total dissolved salts (TDS) of well water in the study area.

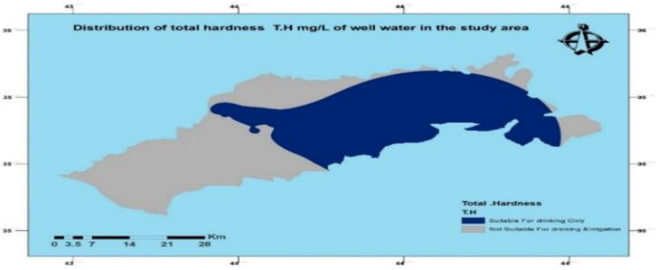

Fig (5): Total hardness (T.H) of well water in the study area.

Table (5): Chemical characteristics of well water in the study area.

NO. Well	PH	EC dS.m^{-1}	TDS mg.l^{-1}	T.H mg.l^{-1}	NO. Well	PH	EC dS.m^{-1}	TDS mg.l^{-1}	T.H mg.l^{-1}
W1	7.3	3.19	145.83	1880.86	W30	8.3	0.8	364.58	388.26
W2	7.5	3.33	155.82	1975.16	W31	8	0.9	402.54	371.60
W3	7.5	2.76	132.85	1802.79	W32	8.4	0.96	430.51	482.62
W4	7.8	3.32	156.82	2052.62	W33	8.4	0.71	321.63	1021.13
W5	7.5	3.37	156.82	1719.82	W34	8.1	1.02	472.46	399.47
W6	7.54	3.38	165.81	2136.09	W35	8.1	0.61	289.67	554.73
W7	7.5	3.39	165.81	1442.23	W36	8.3	0.65	303.65	343.93
W8	7.6	3.7	177.80	2108.36	W37	8.2	0.64	297.66	305.08
W9	7.5	3.5	165.81	2063.92	W38	8.3	0.66	311.64	388.33
W10	7.6	3.2	155.82	1692.04	W39	8.5	0.43	210.76	249.63
W11	7.6	3.7	189.78	2441.26	W40	8.4	0.41	199.77	266.27
W12	8.1	0.5	247.72	349.52	W41	8.1	0.49	230.74	277.35
W13	8.5	0.49	249.71	277.36	W42	8.4	0.45	216.75	249.60
W14	7.9	0.43	207.76	221.93	W43	8.3	0.86	386.56	388.28
W15	8.3	0.55	262.70	310.70	W44	8.1	0.92	425.51	360.57
W16	8.4	0.63	303.65	332.89	W45	8.5	0.53	251.71	138.62
W17	8.1	0.47	346.60	421.68	W46	8.5	0.57	270.69	221.87
W18	8.2	0.49	233.73	277.38	W47	8.2	0.44	209.76	227.35
W19	8.1	0.48	230.74	282.93	W48	8.3	0.54	253.71	255.19
W20	8.3	0.69	322.63	338.42	W49	8.1	0.92	433.50	371.67
W21	7.6	1	490.44	399.44	W50	8.2	0.92	433.50	360.58
W22	8	1.06	511.42	532.65	W51	8.4	0.42	196.78	205.23
W23	7.9	1.15	566.35	221.80	W52	8.5	0.39	187.79	221.86
W24	8.3	1.76	860.02	1104.25	Min	7.3	0.39	132.85	138.62
W25	8.6	0.4	199.77	316.18	Max	8.6	3.7	860.02	2441.26
W26	8.1	0.65	309.65	393.82	Range	1.3	3.31	727.17	2302.64
W27	8.2	0.49	223.74	288.45	Average	8.08	1.24	290.42	694.01
W28	8.3	0.67	315.64	288.45	SD	0.34	1.13	133.53	680.96
W29	7.8	0.75	348.60	366.11	CV	4.25	90.95	45.98	98.12

Dssolved (Cation) ions

3.2.1. Calcium ions Ca^{+2}

The results Fig (6) also showed that there are two types of well water in the study area in terms of its content of calcium ions. The first type is suitable for drinking and irrigation and does not exceed the permissible limits according to the standards of the World Health Organization [7] (200) mg. L^{-1} and FAO standards [15] (400) mg. L^{-1} in most parts of the study area, while the second type is suitable for irrigation only and occupies the western parts of the study area with an area of 158,323.94 and 25,078.19 hectares, with a percentage of 86.33% and 13.67%, respectively.

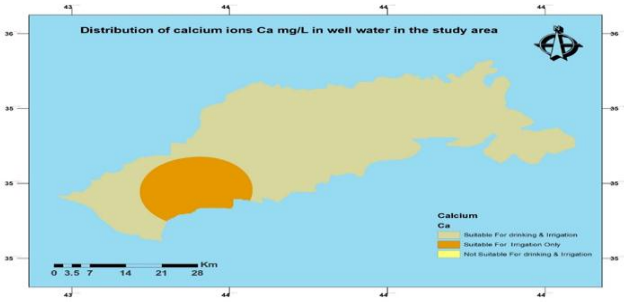

Fig (6): Distribution of calcium ions (Ca^{+2}) in well water in the study area.

3.2.2. Magnesium ions Mg^{+2}

The results fig (7) also showed that there are three types of well water in the study area in terms of its content of magnesium ions. The first type is suitable for drinking and irrigation and does not exceed the permissible limits according to the standards of the World Health Organization [7] (150) mg.l^{-1} and the standards of the Food and Agriculture Organization [15] (60) mg.l^{-1} and occupies the southern regions and separate parts of the center of the study area, with an area of 44216.15 hectares and a percentage of 24.11%, while the second type is suitable for drinking only and occupies the northern and eastern regions of The study area has an area of 92,028.35 hectares, with a percentage of 50.18%. As for the third category, it is not suitable for drinking and irrigation and occupies the western regions of the study area, with an area of 47,157.62 hectares, with a percentage of 25.71%.

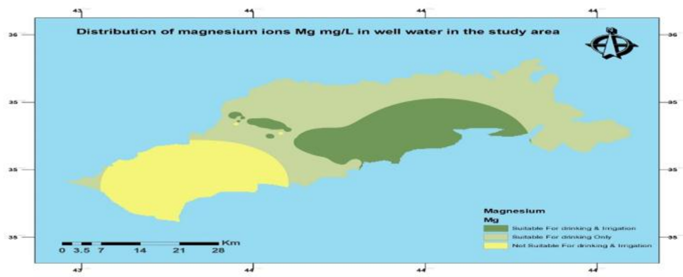

Fig (7): Distribution of magnesium ions (Mg^{+2}) in well water in the study area.

3.2.3. Sodium Ions Na^{+}

The results Fig (8) also showed that all the well water in the study area did not exceed the permissible limits for drinking and irrigation according to World Health Organization standards. [7,8, 9] (250-400) mg.L^{-1} and the standards of the Food and Agriculture Organization [15] (900) mg.L^{-1} in all parts of the study area.

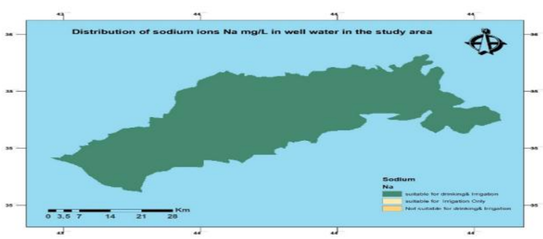

Fig (8): Distribution of sodium ions (Na^{+}) in well water in the study area.

3.2.4. Potassium Ions K

The results shown in fig (9) showed that there are two types of well water in the study area in terms of its potassium content. The first class is suitable for drinking and irrigation and does not exceed the permissible limits according to the standards of the World Health Organization [7,8,9] (10-12) mg.L^{-1} and the standards of the Food and Agriculture Organization [15] (2) mg.L^{-1} in Most parts of the study area, while the second category is suitable for drinking only in separate areas in the middle of the study area, for an area of 175428.66 and 7973.47 hectares, with a percentage of 95.65% and 4.35%, respectively, as all the water from the study wells was within the permissible limits for drinking and irrigation, except for the wells. The following levels, W1, W2, and W14, exceeded the permissible limits for irrigation, but by a small percentage, as they amounted to (3.9, 3.12, 3.51) mg.l^{-1}, respectively.

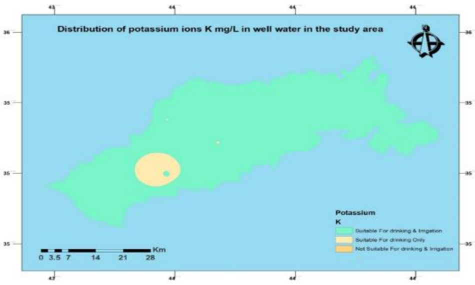

Fig (9): Distribution of potassium ions (K^+) in well water in the study area.

Dissolved (Anion) ions

3.3.1. Chloride ions Cl^{-1}

The results fig (10) also showed that all the well water in the study area is suitable for drinking and irrigation and did not exceed the permissible limits according to World Health Organization standards [7,8,9].] (250-600) mg.L^{-1} and FAO standards [16] (250) mg.L^{-1} in all parts of the study area.

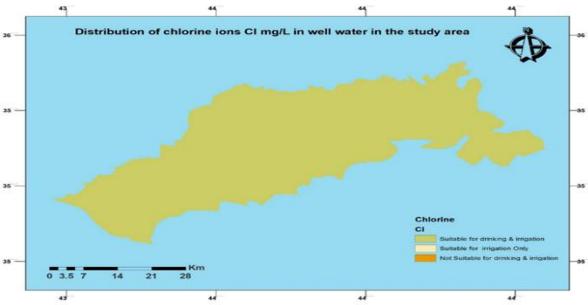

Fig (10): Distribution of chloride ions (Cl^-) in well water in the study area.

3.3.2. Sulphates ions SO_4^{-2}

The results fig (11) also showed that there are two types of well water in the study area in terms of its content of sulfate ions. The first type is suitable for drinking and irrigation and does not exceed the permissible limits according to the organization's standards. World Health [7,8,9] (400) mg.L^{-1}, except for the two wells W3 and W31, exceeded the permissible limits, but by a small percentage, as they reached (415.58) (681.98) mg.L^{-1}, respectively, and the standards of the Food and Agriculture Organization [16] (500) mg.L^{-1} with the exception of well W31, which amounted to (681.98) mg.L^{-1} in most parts of the study area, while the second type is suitable for irrigation only in a limited area in the middle of the study area and for an area of 183,205.76, 196.37 hectares, with a percentage reaching 99.89%. and 0.11%, respectively.

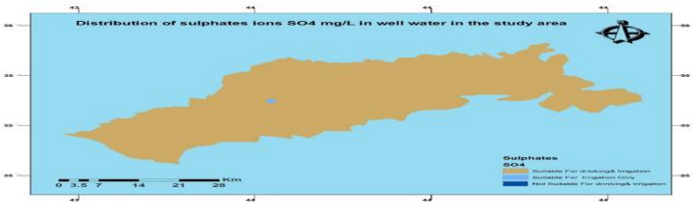

Fig (11): Distribution of sulfate ions (SO_4^{-2}) in well water in the study area.

3.3.3. IonsCarbonate CO_3

The results Fig (12) also showed that all well water in the study area is suitable for irrigation and did not exceed the permissible limits for irrigation according to the standards of the Food and Agriculture Organization [15] (0-100) mg.L^{-1} in all parts of the study area.

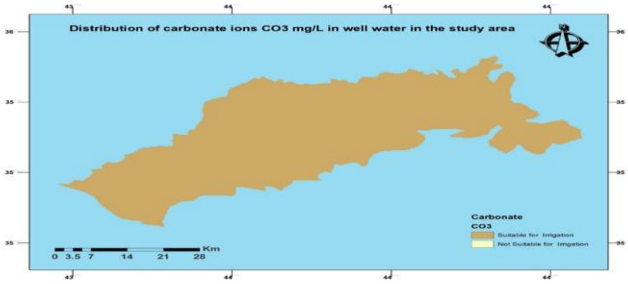

Fig (12): Distribution of carbonate ions ($CO_3^{=}$) in well water in the study area.

3.3.4. bicarbonate Ions HCO_3

The results fig (13) also showed that all well water in the study area is suitable for drinking and irrigation according to World Health Organization standards [7] (500) mg.L^{-1} and FAO standards [15] (600) mg.L^{-1} in all parts of the study area.

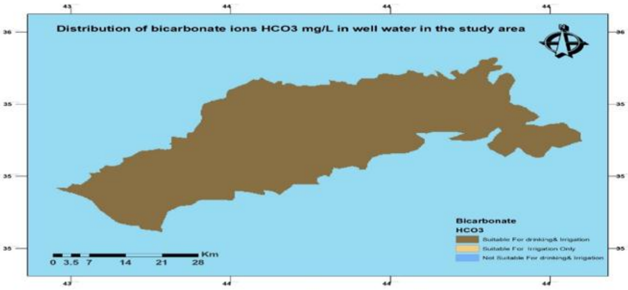

Fig (13): Distribution of bicarbonate ions (HCO_3) in well water in the study area.

3.3.5. Nitrate Ions NO_3

The results Fig (14) also showed that there are two types of well water in the study area in terms of its content of nitrate ions. The first type is valid. for drinking and irrigation, it did not exceed the permissible limits according to the standards of the World Health Organization [7,8,9] (50) mg.L^{-1} and international classifications [17,18] (22<) mg.L^{-1}. It is located in the eastern parts. of the study area, the second type is suitable for drinking only and is located in the western parts of the study area, with an area of 97526.73 and 85875.4 hectares, with a percentage of 53.18% and 46.82%, respectively.

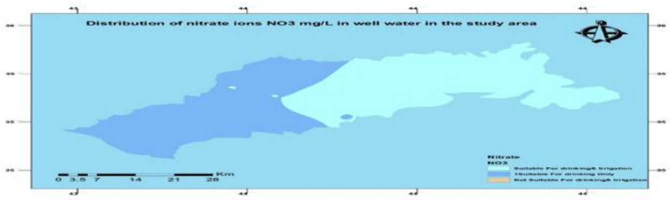

Fig (14): Distribution of nitrate ions (NO_3) in well water in the study area.

3.3.6. Phosphate Ions PO_4^{-3}

The results Fig (15) also showed that there are two types of well water in the study area in terms of its content of phosphate ions. The first type is suitable for drinking and irrigation and does not exceed the permissible limits according to the standards of the World Health Organization [8,9] (0.4) mg.L^{-1} and the standards of the Food and Agriculture Organization [15] (2-0) mg.L^{-1} in various areas of the study area. The second type is suitable for irrigation only in most of the study area and for an area of 73.64, 183,320.31 hectares. With percentages of 0.04% and 99.96%, respectivel

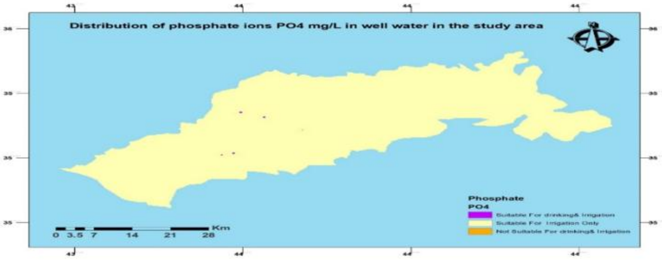

Fig (15): Distribution of phosphate ions (PO_4^{-3}) in well water in the study area.

Table (6): Concentrations of dissolved (Cation) ions in the well water of the study area.

NO. Well	Cation Dissolved ions mg.l-1				NO. Well	Cation Dissolved ions mg.l-1			
	Ca	Mg	Na	K		Ca	Mg	Na	K
W1	270.84	292.66	147.2	3.9	W30	88.8	40.46	23	0.39
W2	290.82	303.45	144.9	3.12	W31	93.24	33.72	29.9	0.39
W3	375.18	210.39	115	2.73	W32	93.24	60.69	46	0.78
W4	364.08	277.82	142.6	2.34	W33	75.48	202.30	32.2	0.39
W5	288.6	242.76	170.2	2.73	W34	59.94	60.69	39.1	0.39
W6	306.36	333.12	149.5	2.34	W35	106.56	70.13	25.3	0.39
W7	299.7	168.58	151.8	2.34	W36	68.82	41.81	32.2	0.39
W8	299.7	330.42	135.7	2.34	W37	66.6	33.72	29.9	0.39
W9	308.58	314.24	108.1	2.34	W38	71.04	51.25	27.6	0.39
W10	297.48	230.62	96.6	1.56	W39	48.84	31.02	11.5	0.39
W11	346.32	383.02	96.6	1.56	W40	53.28	32.37	9.2	0
W12	55.5	51.25	18.4	0.08	W41	57.72	32.37	9.2	0.39
W13	55.5	33.72	23	0.12	W42	55.5	26.97	11.5	0.39
W14	33.3	33.72	27.6	3.51	W43	84.36	43.16	32.2	0.39
W15	44.4	48.55	27.6	0.04	W44	71.04	44.51	52.9	1.56
W16	51.06	49.90	25.3	0.08	W45	44.4	6.74	29.9	0.39
W17	57.72	67.43	25.3	0.35	W46	48.84	24.28	32.2	0.39
W18	48.84	37.76	23	0.39	W47	68.82	13.49	23	0.78
W19	48.84	39.11	16.1	0.39	W48	44.4	35.06	29.9	0.39
W20	55.5	48.55	25.3	0.39	W49	71.04	47.20	52.9	1.17
W21	68.82	55.29	29.9	2.34	W50	68.82	45.85	55.2	0.78
W22	73.26	84.96	46	1.17	W51	46.62	21.58	23	0
W23	68.82	12.14	48.3	0.39	W52	53.28	21.58	11.5	0
W24	117.66	196.90	48.3	0.39	Min	33.3	6.74	9.2	0
W25	66.6	36.41	23	0.39	Max	375.18	383.02	170.2	3.9
W26	86.58	43.16	16.1	0.39	Range	341.88	376.27	161	3.9
W27	59.94	33.72	11.5	0	Average	117.57	97.28	50.087	0.95
W28	59.94	33.72	19.32	0.39	SD	104.68	105.33	45.81	1.026
W29	73.26	44.51	23	0.39	CV	89.032	108.27	91.48	108.02

Table (7): Concentrations of dissolved (Anion) ions in the well water of the study area.

NO. Well	Anion Dissolved ions mg.l-1						NO. Well	Anion Dissolved ions mg.l-1					
	Cl	SO_4	CO3	HCO_3	NO_3	PO_4		Cl	SO_4	CO3	HCO_3	NO3	PO4
W1	79.65	117.22	24	195.2	19.95	0.70	W30	53.1	202.46	18	366	11.66	1.29
W2	109.74	159.84	15	183	20.14	0.70	W31	60.18	681.98	24	329.4	12.100	1.01

W3	111.51	415.58	21	256.2	20.04	0.58	W32	97.35	191.81	21	280.6	13.54	1.07
W4	86.73	362.30	15	183	19.68	0.43	W33	74.34	223.78	24	311.1	8.44	1.21
W5	120.36	223.78	18	274.5	19.91	0.12	W34	53.1	191.81	30	317.2	8.23	1.21
W6	74.34	255.74	30	213.5	20.24	1.35	W35	70.8	266.4	18	268.4	7.898	2.36
W7	70.8	181.15	15	219.6	20.07	1.50	W36	53.1	298.37	24	353.8	8.99	1.35
W8	90.27	127.87	27	170.8	20.14	0.29	W37	72.57	170.50	18	481.9	9.15	0.64
W9	67.26	159.84	24	213.5	20.04	0.86	W38	53.1	149.18	9	427	8.95	1.50
W10	81.42	213.12	21	274.5	19.33	0.58	W39	81.42	159.84	9	268.4	6.37	0.92
W11	88.5	234.43	30	152.5	18.5	0.70	W40	70.8	149.18	15	286.7	5.02	1.29
W12	51.33	298.37	21	219.6	7.78	0.92	W41	106.2	149.18	24	256.2	5.23	1.21
W13	60.18	372.96	15	244	7.22	0.80	W42	74.34	159.84	27	262.3	7.97	1.65
W14	70.8	372.96	6	420.9	4.75	2.26	W43	83.19	117.22	18	189.1	7.11	0.92
W15	35.4	213.12	21	225.7	8.57	1.35	W44	115.05	149.18	21	213.5	5.39	1.21
W16	53.1	181.15	21	170.8	9.14	0.21	W45	56.64	106.56	6	262.3	5.100	1.50
W17	54.87	245.09	15	268.4	10.96	0.64	W46	60.18	127.87	21	359.9	5.88	0.64
W18	47.79	213.12	18	250.1	7.8	0.37	W47	61.95	85.25	12	262.3	7.98	1.07
W19	35.4	277.06	15	323.3	8.52	0.58	W48	46.02	138.53	18	390.4	6.01	1.07
W20	28.32	213.12	15	292.8	9.99	0.43	W49	99.12	127.87	12	311.1	5.54	0.86
W21	42.48	191.81	12	341.6	13.41	0.43	W50	79.65	117.22	6	384.3	5.72	0.80
W22	40.71	170.50	18	359.9	13.83	0.64	W51	53.1	149.18	27	341.6	6.26	1.21
W23	33.63	213.12	15	378.2	13.15	1.29	W52	90.27	138.53	6	366	4.65	1.50
W24	49.56	213.12	12	323.3	13.01	0.58	Min	23.01	85.25	6	152.5	4.65	0.12
W25	23.01	202.46	15	244	4.85	0.49	Max	120.36	681.98	30	481.9	20.24	2.36
W26	49.56	245.09	18	335.5	15.63	0.37	Range	97.35	596.74	24	329.4	15.59	2.24
W27	47.79	223.78	18	231.8	10.40	0.58	Average	66.78	210.66	18	285.29	11.076	0.93
W28	42.48	181.15	15	280.6	12.92	0.29	SD	23.32	97.86	6.17	73.23	5.301	0.48
W29	60.18	223.78	18	298.9	10.99	0.92	CV	34.91	46.45	34.30	25.67	47.86	51.42

Water quality index(WQI)

The results fig (16) showed that there are three categories of WQI for well water in the study area according to[6] and the standards of the World Health Organization[7]. The first type is excellent for drinking, irrigation and industry and is located in the eastern parts of the study area and for an area It reached 118,591.59 hectares, with a percentage of 64.66%, while the second type is good for drinking, irrigation, and industry, and occupies the western parts of the study area, with an area of 64,794.18 hectares, with a percentage of 35.33%. As for the third type is poor, suitable for irrigation and industry only, and is located in a limited part of the study area, with an area of 35.33%. 16.36 hectares, with a percentage of 0.01%.

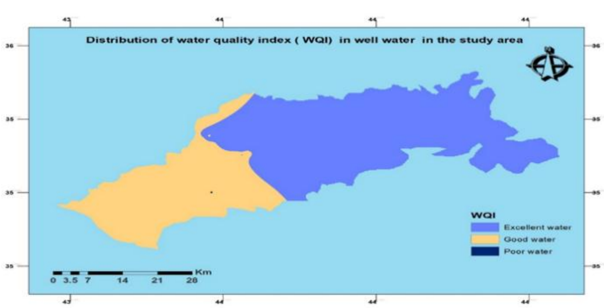

Fig (16): WQI distribution of well water in the study area.

Table (8): WQI values for well water in the study area.

NO. Well	WQI	NO. Well	WQI
W1	88.7	W30	45.3
W2	93.3	W31	58.8
W3	93.5	W32	49.3
W4	100.3	W33	55.7
W5	92.1	W34	46.3
W6	99.6	W35	45.3
W7	84.0	W36	44.2
W8	97.4	W37	42.0
W9	95.7	W38	42.3
W10	88.2	W39	33.8
W11	105.6	W40	33.1
W12	39.3	W41	34.1
W13	40.8	W42	34.2
W14	40.9	W43	40.0
W15	37.2	W44	41.8
W16	37.6	W45	31.2
W17	42.4	W46	35.6
W18	36.0	W47	31.5
W19	38.7	W48	36.1
W20	41.1	W49	42.9
W21	47.9	W50	43.4
W22	51.6	W51	33.1
W23	47.7	W52	33.2
W24	73.4	Min	31.2
W25	34.6	Max	105.6
W26	45.1	Range	74.43
W27	36.7	Average	52.80
W28	39.9	SD	23.08
W29	43.0	CV	43.71

Conclusion

From the results of the study, it appeared that the WQI Water Quality Index revealed 64.66% of the study area was of excellent quality, suitable for drinking, irrigation, and industry, but, 35.33% was of good quality, also suitable for drinking, irrigation, and industry, and 0.01% was of poor (low) quality, suitable for irrigation industry perposes.

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تقييم المياه الجوفية في محافظة كركوك لأغراض الشرب والري.

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الخلاصة

أجريت دراسة ميدانية لتقييم تلوث المياه الجوفية وتحديد صلاحيتها للأغراض الشرب والري في ناحيتي شوان والتون كوبري وقضاء الدبس في محافظة كركوك**.** جمعت العينات من اثنان وخمسون بئراً خلال شهر سبتمبر 2023، التركيز الكيميائي للمياه الجوفية (***pH***،***EC*** ، ***TDS***،***T.H***، Ca^{+2}، Mg^{+2}، K^{+}، Na^{+}، Cl^{-1} ، SO_4^{-2}،CO_3^{-2}، HCO_3^{-}، NO_3^{-}، PO_4^{-3}) ، كما أستخدم موديل الرياضي***WQI*** لتقييم نوعية المياه للشرب **.**تم استخدام برنامج ***ArcGIS 10.4.1*** لتحديد التوزيع المكاني للمؤشرات**.**

أظهرت النتائج أن الصفات الكيميائية لمياه تلك الآبار تقع ضمن الحدود المسموح بها باستثناء صفتي العسرة الكلية (***T.H***) والإيصالية الكهربائية (***EC***) إذ إن 50.02 %، 2.13 %من مياه آبار الدراسة تجاوزت الحدود المسموح بها للشرب والري بالنسبة للعسرة وللإيصالية الكهربائية على التوالي.

أما بالنسبة للكاتيونات الذائبة فقد تجاوزت 13.67 % من إجمالي المساحة الحدود المسموح بها للشرب فقط بالنسبة للأيونات الكالسيوم ، و 25.71 % تجاوزت الحدود المسموح بها للشرب والري بالنسبة لأيونات المغنسيوم ، أما بالنسبة لأيونات البوتاسيوم فقد تجاوزت ***4.35***% من آبار الدراسة الحدود المسموح بها للري .بينما الأيونات الذائبة (السالبة) كانت لجميع مياه الآبار ضمن الحدود المسموح بها باستثناء أيونات الكبريتات والفوسفات والنترات ، إذ إن 99.89 %من مياه آبار الدراسة ضمن الحدود المسموح بها للشرب باستثناء البئرين ***W3*** و***W31*** لكن جمعيها صالحة للري بالنسبة لأيونات الكبريتات ،أما بالنسبة لأيونات الفوسفات فقد تجاوزت 99.96 % من مياه آبار الدراسة الحدود المسموح بها للشرب فقط ، في حين46.82% غير صالحة للري بالنسبة للنترات

الكلمات المفتاحية: المياه الجوفية، ***WQI***،***EC*** **,** عسرة الماء**.**