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Hydrochemical Evaluation of Groundwater from Selected Wells in Al Muthana Governorate, Southern Iraq

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Abstract

The study area is part of the city of Samawa in Al Muthanna Governorate in southern Iraq. The study area is located to the west of Samawa city bounded by the north latitudes 31⁰11'-31°42' and east longitudes 44°58'- 45⁰16'and its groundwater resources are developed for supply and irrigation purposes. In order to evaluate the quality of groundwater in the study area, twenty three groundwater samples were collected and analyzed for physical and chemical parameters. Hydrochemical analysis showed that the groundwater of the study area is excessively mineralized and very hard. The increase in flow length of groundwater in the study area caused a change in water quality from bicarbonate to sulfate and chloride. The abundance of the major ions is as follows: SO_4> CL>HCO_3>$NO_3$and Na>Ca>Mg>K. The dominant type of groundwater is Na^+- sulfate. The water of the studied wells is not suitable for human drinking. Depending on TDS and EC values, most samples of the water are moderate saline class for irrigation. Most wells are good to permissible (wells No.4,14,17) and doubtful (well No. 12) for irrigation depending on Na%, while unsuitable for irrigation depending on EC (except well No. 17 which is permissible). Excellent water class (S1)for agriculture was recorded depending on SAR, except for well N0.2 which had an a good class (S2).

Keywords: Water type, groundwater, irrigation water, chemical formula.

تقييم هايدروكيميائي للمياه الجوفية لآبار مختارة من محافظة المثنى,جنوب العراق

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الخلاصه

ان منطقة الدراسة هي جزء من مدينة السماوة في محافظة المثنى جنوب العراق, وتقع بين دائرتي عرض(31⁰11¯−31°42¯) شمالًا وخطي طول(44⁰58¯− 45⁰16¯) شرقاً,وفيها تعتبر المياه الجوفية ذات أهمية كبيرة لأغراض الري والاستخدامات الأخرى. تمت دراسة ثلاث وعشرون نموذجاً للمياه الجوفية في منطقة الدراسة لمعرفة نوعية المياه وبعض المتغيرات الفيزياوية والكيماوية. بينت الدراسة أن المياه الجوفية في منطقة

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الدراسة كانت شديدة التمعدن وعسرة جداً وأن طول مسافة حركة المياه الجوفية قد غيّر نوع المياه من البيكاربونات الى الكبريتات والكلوريد.ان الانيونات السائدة هي بالترتيب: الكبريتات,الكلوريد,البيكاربونات, النترات بينما الكتيونات هي الصوديوم,الكالسيوم,المغنيسيوم, البوتاسيوم. أن غالبية المياه كانت من نوع كبريتات الصوديوم. بينت الدراسة عدم صلاحية المياه للشرب وان المياه كانت من صنف متوسط الملوحة للري اعتماداً عل قيم المواد الصلبة الذائبة الكلية والتوصيلية ألكهربائية, بينما أشارت الدراسة الى إن غالبية الآبار جيدة الى مسموحٌ بها للري (آبار رقم 4,14,17) ورديئة(بئر رقم 12) اعتماداً على نسبة الصوديوم المئوية وأن المياه ممتازة للري اعتماداً على نسبة امتزاز الصوديوم.

1: Introduction

The hydrogeological studies are considered as an important task in regions where groundwater is the only source of water , which is used for various purposes, particularly in agriculture .Therefore, the decline in the quality of groundwater occurs as a result of increasing salinity in the soil . The objectives of this research are: a- studying the hydro chemical properties of groundwater, b- determination of the quality of groundwater, c- determination of the validity of groundwater for different uses by comparing with the Iraqi and global specifications.

1-1: Study Area

The study area is located to the southern part of Iraq within Al Muthana governorate to the west of the city of Samawa and to the south of Sawa Lake, bounded by the north latitudes $31^0 11'$-$31^0 42'$ and east longitudes $44^0 58'$-$45^0 16'$(Figure-1). The study area and the surroundings are entirely covered by sedimentary rocks of Cenozoic Era, ranging in age from Early Eocene up to recent Quaternary sediment. Lithologically, the following stratigraphic sequence exists:

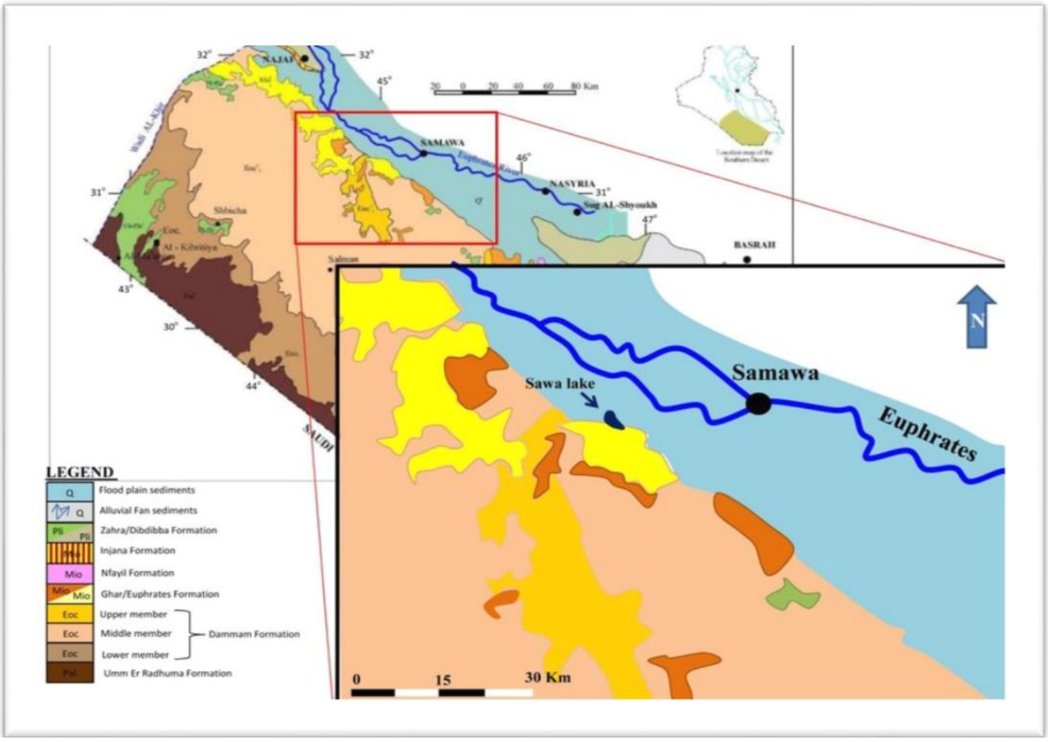

Figure 1-Geological map of the study area [1]

1-Rus formation (Early Eocene): The Rus formation corresponds to beds previously assigned to the Dammam formation [2].It comprises recrystallized limestone, which is partly silicified. In the Mesopotamian zone of south Iraq, the formation consists predominantly of anhydrite with some unfossiliferous limestone, blue shale and marl [3]. The formation is not exposed in the study area.

2-Dammam formation (Middle-Late Eocene):It is the only exposed formation of paleogene Epoch in the study area. It is comprised of limestone, dolomite, marl, and shale. Dammam formation is deposited in the carbonate inner shelf lagoon and shoal [2].

3- Euphrates formation (Early Miocene): The formation is composed of shelly, chalky, well bedded, recrystallized limestone[4].The geological conditions of this formation, represented by the abundance of openings and interstitial spaces as a result of the dissolution of limestone, contributed to the formation of this reservoir as an important groundwater reservoir.

4- Nafayil formation (Middle Miocene) : The section of Nafayil formation is of a composite type. The lower member is in Garat Nafayil south of Haditha, whereas the upper member is exposed at 3km to the west of Al-Habbania lake. The lower member of Nafayil formation is exposed in the study area in a limited location, forming Mesas and small spots that overly Euphrates formation to the east of Sawa Lake. Only the lower member of the Nafayil formation, which consists of cyclic deposits, is exposed in the study area.

5- Quaternary sediments: The quaternary deposits consist of the sediments of the plaiostocene and the Holocene. These deposits cover the study area, which are marine, river and air sediments, and their thickness ranges between 140-200 meters. These sediments are characterized by their high permeability that helps to filter surface water to the underground layers that can be reservoirs of groundwater.

1-2: Materials and Methods

The physical and chemical data for twenty three wells in Samawaharea(Figure-2,Table-1) were taken from General Commission for Groundwater and included measurements of cations (K^+ ,Na^+ ,Mg^{+2} ,Ca^{+2}) and anions (CL^-,SO_4^{-2},HCO_3^-,NO_3^-) as well as hydrogen ion concentration(PH), electrical conductivity (EC), and total dissolved solids(TDS)(Table-2).

The samples of water were collected in September 2014 (water deficit period). The samples were placed in plastic bottles with a volume of 1.5 liter after washing by distilled water and then rinsed by sample water for each well to ensure the elimination of pollutants. pH and EC were measured in the site after collecting the samples using calibrated EC-pH meter with a standard solution, while TDS was measured by the evaporation method. Water samples were analyzed to determine ions concentration in the laboratories of General Commission for Groundwater.

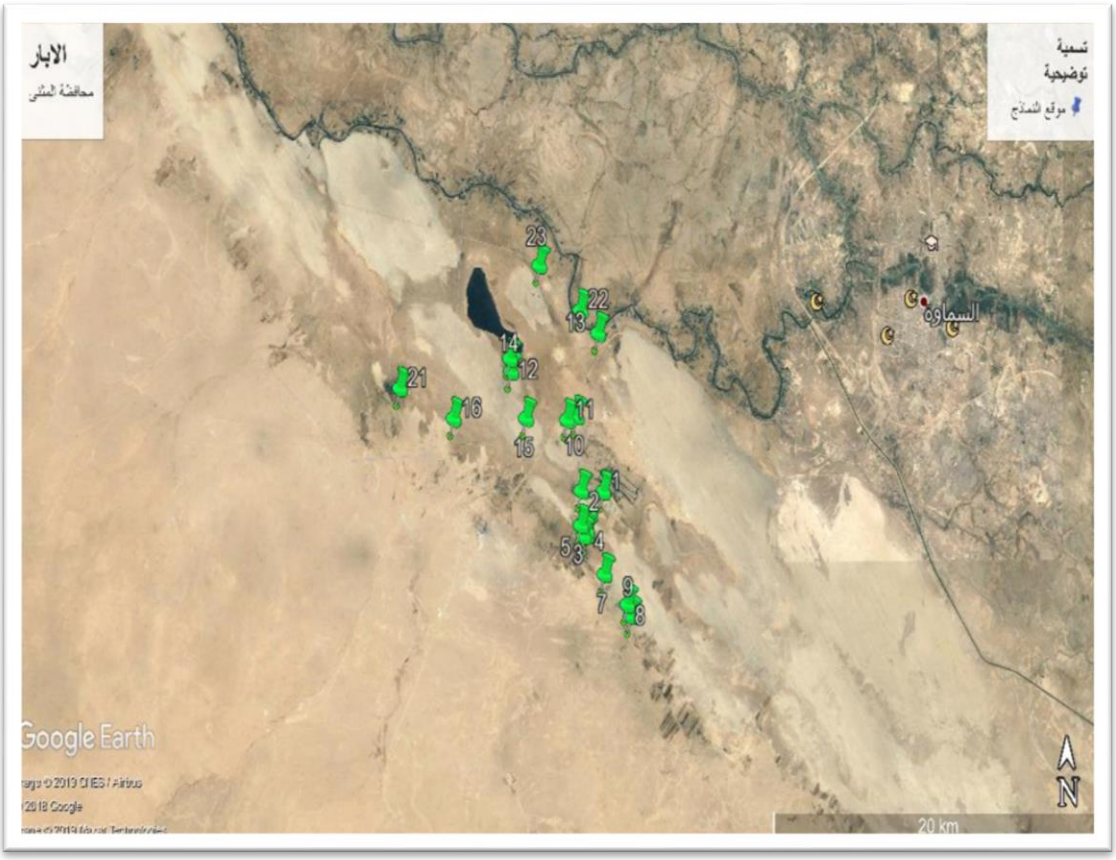

Figure 2-Location map showing sampling sites

Table 1-Groundwater samples and their coordinates

Well no.	Location name	District	Well Depth	Geo-x (Latitude)	Geo-y (Longitude)
1	Mamlaht Alsamawa/3	Al Salman	65	$45^{0}\,04^{'}$	$31^{0}14^{'}$
2	Abd Alhadi Shageel	Al Salman	56	$45^{0}03^{'}$	$31^{0}14^{'}$
3	Mohamed Sabaa Banian	Al Salman	73	$45^{0}03^{'}$	$31^{0}13^{'}$
4	Ean Algathari	Al Salman	6	$45^{0}04^{'}$	$31^{0}13^{'}$
5	Salem Sharaa Mohamed	Al Salman	20	$45^{0}03^{'}59^{''}$	$31^{0}13^{'}06^{''}$
6	Raheem Sharaa Mohamed	Al Salman	75	$45^{0}03$	$31^{0}13^{'}$
7	Fares Zmeait Khwelan	Al Salman	40	$45^{0}04^{'}$	$31^{0}12^{'}$
8	Khaled Saud Ali Anad	Al Salman	90	$45^{0}05^{'}32^{''}$	$31^{o}11^{'}27^{''}$
9	Ayed Sajet Musa/1	Al Salman	94	$45^{o}05^{'}40^{''}$	$31^{o}11^{'}11^{''}$
10	Bakan Shalaga Abu Algeg	Al Salman	55	$45^{o}03^{'}37^{''}$	$31^{o}15^{'}53^{''}$
11	Kayfya Hamed Abu Algeg	Al Salman	80	$45^{o}03^{'}\,15^{''}$	$31^{o}15^{'}49''$
12	Magayer Abadi Manfi	Al Healal	45	$45^{o}01^{'}$	$31^{o}17^{'}$
13	Ayoub Shadad	Al Salman	60	$45^{o}04^{'}$	$31^{o}17^{'}$
14	Mahmeat Sawa Altabiaea/1	Al Healal	40	$45^{o}01^{'}$	$31^{o}16^{'}$
15	Hazim Karem Lazam	Al Salman	50	$45^{o}01^{'}$	$31^{o}15^{'}$
16	Majbal Mzher Madeuf	Al Salman	80	$44^{o}58^{'}$	$31^{o}15^{'}$
17	Anad Shawael Darman	Al Rameatha	6	$45^{o}16^{'}$	$31^{o}42^{'}$
18	Fadel Awad Mohamed	Al Salman	80	$45^{o}40^{'}$	$30^{o}47^{'}$
19	Mohamed Awad Mohamed	Al Salman	84	$45^{o}39^{'}$	$30^{o}47^{'}$
20	Abd Alsada Farhan Samary	Al Salman	85	$45^{o}39^{'}$	$30^{o}46^{'}$
21	Abdul Wahed Abdul Hur	Al Salman	7	$44^{o}56^{'}$	$31^{o}16^{'}$
22	Satar Moueizy	Al Salman	48	$45^{o}03^{'}$	$31^{o}18^{'}$
23	Ali FatnanHasaun	Al Salman	71	$45^{o}02^{'}$	$31^{o}19^{'}$

Table 2-Physical and chemical values for water samples in the study area

Well No.	pH	EC µs/cm	TDS ppm	K^+ ppm	Na^+ ppm	Mg^{+2} ppm	Ca^{+2}ppm	CL^- ppm	SO_4^{-2} ppm	HCO_3^- ppm	NO_3^- ppm
1	7.42	5670	3773	31	528	160	380	750	1395	335	2
2	7.31	17550	14244	75	1384	373	802	2202	2256	1342	9
3	7.1	6270	4500	86	610	145	350	250	670	920	12
4	7.71	4090	3800	12	216	141	280	841	790	204	7.1
5	7.5	7090	5044	12	622	177	362	735	1461	514	2
6	7.16	4150	2968	79	410	127	291	547	1002	451	5
7	7.16	7390	5279	10	800	240	450	1063	1739	583	9
8	7.22	7830	6437	120	550	164	350	791	1367	510	2.3
9	7.62	8010	8700	19	803	249	489	1060	1780	549	9
10	7.22	5930	4000	9	578	157	365	790	1300	425	8
11	7.2	5220	3863	6	569	142	260	529	1039	565	4
12	7.15	4450	3342	14	680	100	190	568	1200	410	4
13	7.1	6330	4600	86	610	145	380	950	670	920	12
14	7.18	4230	3700	85	480	138	300	650	1123	460	2
15	7.15	4060	3650	100	459	137	296	620	439	470	4
16	7.81	6420	4760	98	569	160	329	681	1408	490	2.1
17	7.13	1307	1290	15	133	87	129	242	551	68	7
18	7.6	5310	3890	98	568	160	334	681	1415	490	3
19	7.15	5120	3714	119	540	160	335	722	1325	510	2
20	7.14	6730	4821	99	590	173	340	691	1540	501	2.1
21	7.16	11640	9000	78	1154	337	621	1598	2251	1098	1.2
22	7.51	5970	4110	95	565	165	336	680	1412	489	3.5
23	7.24	12520	9850	79	1154	337	622	1597	2258	1095	1.2
Rang.	7.1-7.81	1307-17550	1290-14244	6-120	133-1384	87-373	129-802	242-2202	439-2285	68-1342	1.2-12
Mean	7.3	6664	5188	61.9	633.5	181	373	836	1321	582	4.9

2-Results and Discussion

2-1: Physical Parameters

Hydrogen ion concentration (PH): It is the reciprocal of the logarithm (base 10) of the hydrogen ion concentration in moles per liter .pH is one of the most important operational quality parameters of water [5].Neutral water has a pH value of 7.0 , alkaline water is more than 7.0 and acidic water has less than 7.0 . Most groundwater has pH values between 5.0-8.0 but it is usually in the range of 6.5-8.5 [6]. pH value in the water of study area ranged between 7.1-7.81 with a mean value of 7.3. Most wells were weakly alkaline 7.2-7.6.

Electrical conductivity (EC):It is the ability of $1cm^3$ water to conduct an electric current at a standard temperature of $25C^{\circ}$ and measured in micro Siemens per centimeter (µ.s\ cm), depending on the total amount of soluble salts [7].The variation of conductivity gives important information about the evolution of water quality. EC represents a good evidence to determine the mineralization degree of water [8]. The EC values in groundwater of the study area ranged between 1307-17550 µ.s\cm with a mean value of 6664 µ.s\cm. Water samples are classified as being of excessively mineralized water (Table-3).

EC(µS\cm)	Mineralization	The Study area
<100	Very weakly mineralized water(granite terrains)	
100-200	Weakly mineralized water	
200-400	Slightly mineralized water (limestone terrains)	
400-600	Moderately mineralized water	

600-1000	Highly mineralized water	
>1000	Excessively mineralized water	Range(1307-17550)

Total Dissolved Solids (TDS): It is a measure of the total amount of minerals dissolved in water and is a very good parameter in the evaluation of water quality [9], also reflecting salinity [10].It is measured by parts per million (ppm) or milligrams per liter (mg\L) units. The TDS values in the groundwater of the study area ranged between 1290-14244 ppm with a mean of 5188 ppm. TDS content of groundwater may increase by movement of water through rocks containing soluble minerals matter, while it is concentrated by evaporation [11].

Total hardness (TH): Hardness of water is a measure of the capacity for precipitating soup. The primary components of hardness are calcium and magnesium. Hardness is measured by ppm or mg/l units according to the following equation:

$TH = 2.497Ca^{+2} + 4.115Mg^{+2}$ [12]

where Ca^{+2} and Mg^{+2} are the concentrations of ions in ppm. Water is classified into several types according to its total hardness, as in Table 4.

Table 4-Classification of water according to Total hardness

Tood 2007[13]		Boyd 2000[14]	
Degree of hardness in ppm	Term	Quality of water	Degree of hardness in ppm
0 <TH ≤60	Soft	Soft	50≤TH
60 <TH≤120	Moderately hard	Moderately hard	50<TH≤150
120<TH≤180	Hard	Hard	150<TH≤300
180<TH	Very hard	Very hard	300<TH

TH values in the study area ranged between 680-2939ppm with a mean value of 1679ppm , which indicates that all samples are of very hard water.

2-2: Chemical Analysis

Calcium ion (Ca^{+2}): Subsurface water in contact with sedimentary rocks derives most of their calcium from calcite, aragonite, dolomite, anhydrite, and gypsum [15].Some calcium carbonate is desirable for domestic water because it provides liner in the pipes, which protects them against corrosion [16]. Sewage water contains a large quantity of organic materials which, when oxidized, release quantities of CO_2, leading to an increase of Ca^{+2} [17]. Calcium concentration in water samples of the study area ranged between 129-802 ppm with a mean value of 373ppm.

Magnesium $Mg^{+2:}$ The common sources of magnesium in the hydrosphere are dolomite in sedimentary rocks; olivine, biotite, hornblende, and augite in igneous rocks; and serpentine, talc, diopside, and tremolite in metamorphic rocks. Magnesium is found in lower concentrations than calcium in natural water due to slow dissolution of dolomite together with the greater abundance of calcium in the earth's crust [15]. Magnesium ions concentration in groundwater of the study area ranged between 87-373 ppm, with a mean value of 181ppm.

Sodium Na^{+} : Sodium is the most abundant among the alkali elements, and makes up 2.6% of the earth's crust being the sixth most abundant element over all. The essential source of most sodium in natural water is from the release of dissolvable products during the weathering of plagioclase and feldspars. In areas of evaporatation deposits, the dissolve of halite is also important. Clay minerals may, under proven conditions, release large quantities of commutable sodium [18]. Sodium is a significant factor in assessing water for irrigation and plant watering, where high levels affect soil structure and the plant's ability to take up water [19]. Sodium concentration is important in classifying irrigation water, because sodium reacts with soil to reduce its permeability [13]. Sodium concentration the in study area ranged between 133-1384 ppm with a mean value of 633.5 ppm.

Potassium K^{+} : Clay minerals, feldspar, and mica are the main sources of potassium ions, along with evaporates containing highly soluble sylvite in some sedimentary rocks. The concentration of potassium ions is less than the concentration of sodium ions in groundwater, with the reason being the lower solubility of sodium ion [20]. Potassium ion increases in groundwater due to the use of chemical fertilizers [21].Potassium plays an important role in plant growth. In every liter of human blood, there is 180-220 mg /L of potassium, and the lack of this amount, as well as increasing it, causes disturbance in the body [5]. Potassium concentration in water samples of the study area ranged between 6-120 ppm with a mean value of 61.7 ppm. High concentration of potassium in some samples of the study areais due to the effect of agricultural fertilizers.

Chloride CL^- : Chloride is a minor constituent of the earth's crust, but a major dissolved constituent of most natural water. It represents an important element in the hydrologic cycle, where its content in rain water is usually less than 10 ppm, whereas in groundwater it varies from few ppm in the snow-fed wells to high content in desert brines. Chloride ion is available in evaporated rocks and in rock minerals such as apatite and soda [22]. In addition, the treatment of water with chloride can lead to increased concentrations in the groundwater [5]. Chloride concentration in the water samples of the study area ranged between 242-2202 ppm with a mean value of 836 ppm. High chloride concentration in groundwater of the study area may be an indicator to pollution by sewage and agriculture fertilizers.

* Sulfate (SO_4^{-2}): Sedimentary rocks such as gypsum and anhydrite represent an important source of sulfate [13], while other sources are agricultural and industrial activities [23]. Sulfate concentration in the water samples of the study area ranged between 439-2285 ppm with a mean value of 1321 ppm. All water wells of the study area do not meet with the standard concentration of IQS 2009[24] (400 ppm) and WHO 2007[25](250 ppm).

Bicarbonate(HCO_3^-): The primary source of bicarbonate ion in groundwater is the melting of calcareous rocks in water, which contain the dissolved carbon dioxide of dissolved carbon, as well as the presence of hydrogen ion resulting from the dissolution of carbonic acid. Decay of organic matter may also release carbon dioxide for dissolution[26]. The concentrations of bicarbonate in the study area ranged between 68-1342ppm with a mean of 582 ppm.

Nitrate (NO_3^-): Organic matters and fertilizers represent the most common sources of nitrates in natural water; they originate from industrial and agricultural activities [27], [28]. Nitrate has a direct effect on plant growth and may cause a hazard for drinking water sources if the levels reach to 10 ppm or higher [29]. Nitrate concentration in the study area ranged between 1.2-12ppm with a mean value of 4.9ppm. Nitrate concentrations in the study area are lower than the standards values of IQS 2009[24]and WHO 2007[25] (50 ppm for both guidelines).

2-3 Water types and hydro chemical formula: Types of water are connected to the chemical and physical properties, which change relatively with respect to time and space. These changes are slow in groundwater compared with surface water [30]. Water type is very important to determine its suitability for the different uses (human, agricultural, and industrial purposes). Many classifications depend on the concentrations of main cations and anions by unit equivalent weight of ion (epm)(Table-5) or milli equivalent per liter (meq / l).

Table 5-Chemical analysis of groundwater samples in epm units.

W.No.	K^+	Na^+	Mg^{+2}	Ca^{+2}	CL^-	SO_4^{-2}	HCO_3^-	NO_3^-	RSC	Na%	SAR
1	0.79	22.9	13.3	19.0	21.1	29.6	5.4	0.02	-26.8	42.3	5.7
2	1.92	60.1	31.08	40.1	62.0	47	5.6	0.14	-65.5	46.5	10.8
3	2.2	26.5	12.08	17.5	7.04	13.9	15.08	0.19	-14.5	49.6	6.8
4	0.3	9.3	11.7	14	23.6	16.4	3.34	0.11	-22.4	27.3	2.6
5	0.3	27	14.7	18.1	20.7	30.4	8.4	0.03	-24.4	45.4	6.6
6	2.02	17.8	10.5	14.5	15.4	20.8	7.39	0.08	-17.7	44.1	5.03
7	0.25	34.7	20	22.5	29.9	36.2	8.81	0.14	-33.2	45.1	7.5
8	3.07	23.9	13.6	17.5	22.2	28.4	8.3	0.03	-22.8	46.4	6.05
9	0.48	34.9	20.7	24.4	29.8	37	9	0.14	-36.1	43.9	7.35
10	0.23	25.1	13.08	18.2	22.2	27	6.96	0.12	-24.3	44.7	6.35
11	0.15	24.7	11.83	13	14.9	21.6	9.26	0.06	-15.5	50	7.01
12	0.35	29.5	8.33	9.5	16	25	6.72	0.06	-11.1	62.6	9.9
13	2.2	26.5	12.08	19	26.7	13.9	15	0.19	-16	48	6.72
14	2.17	20.8	11.5	15	18.3	23.3	7.5	0.03	-18.9	23	5.73
15	2.5	19.9	11.41	14.8	17.4	9.1	7.7	0.06	-18.5	46.2	5.51
16	2.51	24.7	13.33	16.4	19.1	29.3	8.03	0.03	-21.7	47.7	6.41
17	0.38	5.78	7.25	6.45	6.81	11.4	1.11	0.11	-12.4	31	2.21
18	2.51	24.6	13.33	16.7	19.1	29.4	8.03	0.04	-22	47.5	6.37

19	3.05	23.4	13.33	16.7	20.3	27.6	8.36	0.03	-21.7	46.8	6.05
20	2.53	25.6	14.41	17	19.4	32	8.21	0.03	-23.2	47.2	6.47
21	2	50.1	28.08	31	45	46.8	18	0.01	-41.1	46.8	9.22
22	2.43	24.56	13.75	16.8	19.1	29.4	8.01	0.05	-22.5	46.9	6.28
23	2.02	50.17	28	31.1	44.9	47	17.9	0.01	-41.2	46.8	9.22
Rang.	0.15-3.07	5.78-60.1	7.25-31.08	6.45-40.1	6.81-62	11.4-47	1.11-17.9	0.01-0.19	-65.5 to -1	23-62.6	2.2-10.8
mean	1.58	27.5	15.1	18.6	23.5	27.5	8.78	1.71	-24.2	44.6	6.6

The hydrochemical formula is defined as an equivalent weight ratio for all ions having a ratio of higher than 15% in groundwater, which are arranged regularly according to the concentration of each ion, in addition to TDS and pH values. The result of this formula determines the water type . The formula (also called Kurlolov formula) was taken from Ivanov 1968[31] is:

$$TDS(mg\backslash l)\,\frac{Anions\ epm\%\ in\ decreasing\ order}{Cations\ epm\%\ in\ decreasing\ order}\ pH$$

Table-6 shows the type of groundwater in the studied area, as resulted from the use of the hydrochemical formula. It is an important measure in geochemical reactions through the flow of groundwater, where the increase in flow length will change the water quality from bicarbonate to sulfate and chloride. This could be an indicator to the length of groundwater flow [32]. We note from the results that most wells are of a sulfate water type.

Table 6-Hydrochemical formula results of groundwater samples

Well No.	Hydro chemical formula	Water type
1	$3737\,\frac{SO_4^{-2}\,(52.17)CL^-\ (37.9)HCO_3^-(9.8)NO_3^-\ (0.05)}{Na^+(40.95)Ca^{+2}(33.8)Mg^{+2}(23.7)K^+(1.3)}\ 7.42$	Na^+- Sulfate
2	$14244\ \frac{\mathrm{CL-(54.04)\ SO4-2(40.95)\ HCO3-(4.8)NO3-(0.12)}}{\mathrm{CL-(54.04)\ SO4-2(40.95)\ HCO3-(4.8)NO3-(0.12)}}7.31$	Na^+ - Chloride
3	$4500\,\frac{\mathrm{HCO3-(41.58)SO4-2(38.46)CL-(19.41)\ NO3-(0.53)}}{\mathrm{Na+(45.4)\ Ca+2(30.01)\ Mg+2(20.7)\ K+(3.7)}}\ 7.1$	Na^+ - Bicarbonate
4	$3800\,\frac{\mathrm{CL-(54.3)\ SO4-2(37.3)\ HCO3-(7.6)\ NO3-(0.26)}}{\mathrm{Ca+2(39.5)\ Mg+2(33.1)\ Na+(26.4)\ K+(0.86)}}7.71$	Ca^{+2}- Chloride
5	$5044\,\frac{\mathrm{SO4-2(51.07)\ CL-(34.2)\ HCO3-(14.13)\ NO3-(0.05)}}{\mathrm{Na+(44.9)\ Ca+2(30.07)\ Mg+2(24.5)\ K+(0.49)}}\ 7.5$	Na^+- Sulfate
6	$2968\,\frac{\mathrm{SO4-2(47.7)\ CL-(35.2)\ HCO3-(16.8)\ NO3-(0.18)}}{\mathrm{Na+(39.6)\ Ca+2(32.3)\ Mg+2(23.5)\ K+(4.49)}}\ 7.16$	Na^+ - Sulfate
7	$5279\,\frac{\mathrm{SO4-2(48.2)\ CL-(39.8)\ HCO3-(11.7)\ NO3-(0.19)}}{\mathrm{Na+(44.8)\ Ca+2(29.02)\ Mg+2925.7)\ K+(0.3)}}\ 7.16$	Na^+ - Sulfate
8	$6437\,\frac{\mathrm{SO4-2(48.1)\ CL-(37.6)\ HCO3-(14.1)\ NO3-(0.05)}}{\mathrm{Na+(41.1)\ Ca+2(30.09)\ Mg+2(23.4)\ K+(5.2)}}\ 7.22$	Na^+ - Sulfate
9	$8700\ \frac{\mathrm{SO4-2(48.7)\ CL-(39.2)\ HCO3-(11.8)\ NO3-(0.19)}}{\mathrm{Na+(43.3)\ Ca+2\ (30.3)\ Mg+2(25.7)\ K+(0.59)}}\ 7.62$	Na^+ - Sulfate
10	$4000\,\frac{\mathrm{SO4-2(47.9)\ CL-(39.4)\ HCO3-(12.33)\ NO3-(0.2)}}{\mathrm{Na+(44.3)\ Ca+2(32.1)\ Mg+2(23.07)\ K+(0.4)}}\ 7.22$	Na^+ - Sulfate
11	$3863\,\frac{\mathrm{SO4-2(47.1)\ CL-(32.4)\ HCO3-(20.19)\ NO3-(0.13)}}{\mathrm{Na+(49.7)\ Ca+2(26.1)\ Mg+2(23.12)\ K+(0.3)}}\ 7.2$	Na^+ - Sulfate
12	$3342\ \frac{\mathrm{SO4-2\ (52.3)\ CL-(33.4)\ HCO3-(14.06)\ NO3-(0.12)}}{\mathrm{Na+(61.9)\ Ca+2(19.8)\ Mg+2(17.4)\ K+(0.7)}}\ 7.1$	Na^+ - Sulfate
13	$4600\ \frac{\mathrm{CL-(47.8)\ HCO3-(26.9)\ SO4-2(24.9)\ NO3-(0.34)}}{\mathrm{Na+(44.3)\ Ca+2(31.7)\ Mg+2(20.2)\ K+(3.6)}}\ 7.1$	Na^+ - Chloride

14	$3700 \frac{SO4-2(47.4)\ CL-(37.1)\ HCO3-(15.3)\ NO3-(0.06)}{Na+(42.1)\ Ca+2(30.2)\ Mg+2(23.2)\ K+(4.3)}\ 7.18$	Na^{+} - Sulfate
15	$3650 \frac{CL-(50.8)\ SO4-2(26.6)\ HCO3-(22.4)\ NO3-(0.17)}{Na+(40.9)\ Ca+2(30.3)\ Mg+2(23.4)\ K+(5.2)}\ 7.15$	Na^{+} - Chloride
16	$4760 \frac{SO4-2(51.8)\ CL-(33.9)\ HCO3-(14.19)\ NO3-(0.05)}{Na+(43.3)\ Ca+2(28.8)\ Mg+2(23.3)\ K+(4.4)}\ 7.81$	Na^{+} - Sulfate
17	$1290 \frac{SO4-2\ (58.8)\ CL-(34.9)\ HCO3-(5.9)\ NO3-(0.5)}{Mg+2(36.5)\ Ca+2(32.4)\ Na+(29.1)\ K+(1.9)}\ 7.13$	Mg^{+2}–Sulfate
18	$3890 \frac{SO4-2(51.9)\ CL-(33.8)\ HCO3-(14.15)\ NO3-(0.08)}{Na+(43.1)\ Ca+2(29.1)\ Mg+2(23.2)\ K+(4.3)}\ 7.6$	Na^{+} - Sulfate
19	$3714 \frac{SO4-2(49.0)\ CL-(36.09)\ HCO3-(14.8)\ NO3-(0.05)}{Na+(41.4)\ Ca+2(29.5)\ Mg+2(23.5)\ K+(5.3)}\ 7.15$	Na^{+} - Sulfate
20	$4821 \frac{SO4-2(53.6)\ CL-(32.5)\ HCO3-(13.7)\ NO3-(0.05)}{Na+(43.04)\ Ca+2(28.5)\ Mg+2(24.1)\ K+(}\ 7.14$	Na^{+} - Sulfate
21	$9000 \frac{SO4-2(42.6)\ CL-(40.9)\ HCO3-(16.3)\ NO3-(0.01)}{Na+(45.07)\ Ca+2(27.8)\ Mg+2(25.2)\ K+(1.7)}\ 7.16$	Na^{+} - Sulfate
22	$4110 \frac{SO4-2(51.9)\ CL-(33.8)\ HCO3-(14.14)\ NO3-(0.09)}{Na+(42.6)\ Ca+2(29.10\ Mg+2(23.8)\ K+(4.20)}\ 7.51$	Na^{+} - Sulfate
23	$9850 \frac{SO4-2(42.7)\ CL-(40.8)\ HCO3-(16.3)\ NO3-(0.01)}{Na+(45.04)\ Ca+2(27.9)\ Mg+2(25.2)\ K+(1.8)}\ 7.24$	Na^{+} - Sulfate

2-4 Usability of groundwater in the study area

Groundwater is used for several purposes depending on the type of water and its content of anions and cations that change it from one type to another. Therefore ,it is necessary to evaluate the water according to the local and world standard specifications to determine the suitability of water to the different uses like domestic , agricultural and industrial ones [12].

2-4-1 Usage of water for drinking

Groundwater forms an important source of water for drinking and other domestic purposes, especially in some arid and semi-arid regions where surface water is scarce. Iraqi drinking standards (IQS,2009)[24] and those of the world health organization (WHO,2007)[25]are used to determine the suitability of groundwater in the studied area for human drinking purposes, depending on the ions concentrations in water, TDS and other components (Table-7). Overall, it seems that the current groundwater for all studied wells is not suitable for human drinking, because levels of most of the elements not within the recommended guideline levels.

Table 7-Comparison of results of parameters of water samples with the standards of drinking water IQS, 2009)[24] and WHO, 2007[25]

Parameters	IQS 2009	WHO 2007	studied wells (range)	Suitability of the samples in the study area
pH	6.5-8.5	6.5-8.5	7.1-7.8	All samples are suitable
EC (µS/cm)	1500	1530	1307-17550	All samples are not suitable except 17
TDS(ppm)	1000	1000	1290-14244	All samples are not suitable
Ca^{+2} (ppm)	150	75	129-802	All samples are not suitable except 17
Mg^{+2}(ppm)	100	125	87-373	All samples are not suitable except 12 and 17
Na^{+}(ppm)	200	200	133-1384	Not Suitable except sample 17
K^{+}(ppm)	-	12	6-120	Only samples(4,5,7,10,11) are suitable
CL^{-} (ppm)	350	250	242-2202	All samples are not suitable except 3 and 17
SO_4^{-2} (ppm)	400	250	439-2285	All sample are not Suitable
NO_3^{-} (ppm)	50	50	1.2-12	All samples are suitable

2-4-2 Water suitability for irrigation and agricultural purposes

These uses depend upon several factors such as sodium adsorption ratio (SAR), residual sodium carbonate (RSC), EC, TDS, and sodium concentration percentage (Na %).

One of the important classifications of the irrigation water depends on the salinity (EC&TDS)[33] as shown in (Table-8).

Table 8-classification of water for irrigation and agriculture purposes

Water class	**EC µS/cm**	**TDS ppm**	**Type of water**	**Samples of the Study area**
Non-Saline	<700	<500	Drinking and irrigation water	
Slightly Saline	700-2000	500-1500	Irrigation Water	17
Moderate Saline	2000-10000	1500-7000	Primary drainage water and groundwater	1,3,4,5,6,7,8,9,10,11,12,13, 14,15,16,18,19,20,22
Highly Saline	10000-25000	7000-15000	Secondary drainage water and groundwater	2,21,23
Very highly Saline	25000-45000	15000-35000	Very saline groundwater	
brine	>45000	>35000	Sea water	

Comparing with this standard, the groundwater samples of the study area are moderate saline .
Residual sodium carbonate (RSC): A high concentration of bicarbonate in irrigation water may lead to the precipitation of calcium and magnesium in the soil and thus to a relative increase of sodium concentration. Therefore, the sodium hazard will increase [34]. The bicarbonate hazard is expressed by RSC which was introduced by Eaton, 1950[35], as follows:

$RSC = (CO_3^{-2} + HCO_3^{-})-(Ca^{+2}+Mg^{+2}).$

Where all ions are measured by the equivalent weight (epm)(Table-5).RSC values in the study area ranged between -65.5 to -11 epm with a mean of -24.2. According to the classification of Eaton, 1950,[35] (Table 9), all the samples of groundwater in the study area are safe for irrigation.

Table 9-Classification of irrigation water based on RSC values (Eaton, 1950)[35]

RSC (epm)	Water type	Area study
<1.25	Safe	All samples(negative values)
1.25-2.5	Marginal	
>2.5	Unsuitable	

Soluble sodium percentage (Na %) and EC: Sodium content is commonly expressed in terms of sodium percentage. Increasing sodium ion ratio in irrigation water will affect soil efficiency, where it leads to a decrease in its porosity and permeability, and thus will affect the plant growth or stunted growth. Na% value is calculated according to the following equation:

$Na\% = (rNa + rK / rCa + rMg + rNa + rK) \times 100$ [12]

Where all ionic concentrations (rNa, rK, rCa, rMg) are expressed in epm Na% values in the study area ranged between 23-62.5 with a mean of 44.6. The classification of Tood ,1980 [12], for irrigation water based on Na% and EC values (Table-7) was adopted in this study, while the results of this study are explained in Table-10.

Table 10-The results according to the classification of Todd (1980)[12] for irrigation water based on Na % and EC.

Water class	Na%	Study area	EC µS/Cm	Study area
Excellent	<20		<250	
Good	20-40	Well no. 4,14,17	250-750	
Permissible	40-60	Most samples	750-2000	Only sample no. 17
Doubtful	60-80	Well no.12	2000-3000	
Unsuitable	>80		>3000	All samples except 17

Sodium adsorption ratio (SAR): The two most common water quality factors that influence the normal rate of infiltration are the salinity of water and the relative concentrations of sodium versus magnesium and calcium ions in the water, known as the SAR. It is an important parameter for determining the suitability of water for agriculture, because it is a measure of alkali /sodium hazard [36]. Karanth, 2008[37], defines SAR of water as:

$$SAR = \frac{Na^{+}}{\left\{\sqrt{(Ca^{+2} + Mg^{+2})/2}\right\}}$$

where Na^{+}, Ca^{+2} and Mg^{+2} are concentrations of ions in epm units. High values of SAR imply a hazard of sodium replacing absorbed calcium and magnesium , a situation that is ultimately damaging to soil structure[22]. There are four classes of water for agriculture depending on SAR value according to Subramain ,2005[36]. All samples in the study area had a SAR value that is lower than 10 except sample No.2 (10.8),whereas the range was between 2.2-10.8 epm and the mean was 6.6epm. These results indicate an excellent water class(S1) for agriculture(Table-11).

Table 11- Alkalinity hazard classes of water (Subramain, 2005)[36]

SAR (epm)	Alkalinity hazard	Water class	Representing samples
<10	S1	Excellent	All samples (except no.2)
10-18	S2	Good	Sample no.2
18-26	S3	Doubtful	
>26	S4	Unsuitable	

2-4-3: Groundwater uses for livestock: Samples of the study area were evaluated for livestock and poultry used by the classification proposed by Altoviski (1962)[38] (Table-12).

Table 12-Specifications of water samples for livestock consumption according to Altoviski (1962)[38].

Parameters (ppm)	Very good water	Good water	Acceptable water for use	Can be used	High limits	Study area (range)
Na^{+}	800	1500	2000	2500	4000	133-1384
Ca^{+2}	350	700	800	900	1000	129-802
Mg^{+2}	150	350	500	600	700	87-373
CL^{-}	900	2000	3000	4000	6000	242-2202
SO_4^{-2}	1000	2500	3000	4000	6000	439-2285
TDS	3000	5000	7000	10000	15000	1290-14244
TH	1500	3200	4000	4700	54000	680-2939

Over all, it seems that the current groundwater for all studied wells is suitable to use for livestock purposes ,but the degree of suitability is different from well to another, ranging between very good to acceptable for use according to Altoviski 1962[38] classification.

2-4-4 Water suitability for industrial purposes: Water samples for the study area were determined for industrial purposes by using Hem(1985)[22] classification (Table-13).

Table 13-Water quality standards for industrial purposes[22]

Industry type	Ca^{+2} ppm	Mg^{+2} ppm	CL^{-} ppm	HCO_3^{-} ppm	SO_4^{-2} ppm	NO_3- ppm	TH ppm	TDS ppm	pH
Cement	-	-	250	-	250	-	-	600	6.5-8.5
Wood	100	50	500	250	100	5	900	1000	6.5-8
Leathers	-	-	250	-	250	-	-	-	6-8
Soft drinks bottling	100	-	500	-	500	-	-	-	-
Fruit icing	-	-	250	-	250	10	250	500	6.5-8.5
Water of study area(mean)	373	181	836	582	1321	4.9	1679	5188	7.3

According to this classification, groundwater in the study area is not suitable for most types of industries.

2-4-5 Suitability of water resources for building purposes:

Altoviski (1962)[38] classification for building purposes depends on the levels of most of the major cations and anions and was used to evaluate the suitability of water samples in the studied area for building purposes (Table-14).

Table 14-Evaluation of water for building purposes [38].

Ions (ppm)	Permissible limit	Water studied area	
		range	Mean
Na^{+}	1160	133-1384	633.5
Ca^{+2}	437	129-802	373
Mg^{+2}	271	87-373	181
CL^{-}	2187	242-2202	836
SO_4^{-2}	1460	439-2285	1321
HCO_3^{-}	350	68-1342	582

It is clear that groundwater in study area are suitable for building purposes.

3-Conclusions

Depending on pH value of water, in study area, the water is suitable for different uses.

According to the high value of electrical conductivity (EC), the groundwater of study area is classified as excessively mineralized according to Detay, 1997[8].The high value of total dissolved solids (TDS) in water is attributed to the long flow path of groundwater. Depending on total hardness (TH) parameter, all samples showed very hard water according to Tood, 2007[13] and Boyd, 2000[14] classification. This may mostly be a result of the presence of Rus Formation.The predominant cations in water of the study area are sodium and calcium, whereas sulfate and chloride are the most common anions, thus the water type is Na^{+}-Sulfate for most samples in the study area.

The groundwater in the studied wells is not suitable for human drinking. Depending on TDS and EC values, the water samples are from moderate saline class .Water type is safe for irrigation according to Eaton 1950[35],depending on RSC. An excellent water class was found depending on Na% and EC, according to Tood, 1980[12] classification for irrigation water. Excellent water class (S1) for agriculture was found depending on SAR, according to Subramain, 2005[36]classification. Groundwater for all studied wells is suitable to use for livestock purposes according to Altoviski, 1962[38] classification. It is clear that groundwater in the study area is suitable for building purposes according to Altoviski, 1962[38] classification.

4-References

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