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Water Quality of Groundwater in Selected Wells in Zubair Area, Basra City

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ABSTRACT

Zubair area is located at the extreme part of the south of Iraq and represents the southern part of the western desert, bounded by the north latitudes 30o05'-30o25' and east longitudes 47o30'- 47◦55'. Groundwater is a major natural resource in the study area because no perennial river exists. Groundwater from twenty wells in the study area were analyzed in order to determine some of chemical variables such as major cations (Ca^{+2}, Mg^{+2} ,Na^{+} ,K^{+}) and major anions (CL^{-} ,SO_4^{-2} ,HCO_3^{-} ,CO_3^{-2} ,NO_3^{-}) along with several physical variables such as hydrogen ion concentration (pH) , total dissolved solids (TDS), and electrical conductivity (EC). Hydro-chemical analysis showed that the groundwater of the study area is excessively mineralized, depending on the relation between EC and mineralization. Depending on total hardness (TH), all samples were with very hard water. High chloride concentration in the groundwater of the study area may be an indicator of pollution by sewage and agriculture fertilizers. The increase in flow length of the groundwater in the study area would change the water quality from bicarbonate to sulfate and chloride. The predominant cations recorded are calcium and magnesium along with chloride from the anions, so that the water type is Ca-Mg-CL for most samples. The water wells studied are not suitable for drinking purposes of humans. Depending on TDS and EC values, the water samples are not suitable for irrigation according to FAO 1997 classification. However, the results also revealed an excellent water class depending on Na percentage (Na%) and EC according to Todd 1980 classification for irrigation water. Also, an excellent water class (S1) for agriculture was recorded depending on SAR classification of Subramain, 2005.

Keywords: Water quality, groundwater, irrigation water, Alkalinity.

نوعية المياه الجوفية لآبار مختارة في منطقة الزبير، مدينة البصرة

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الخلاصه

تقع منطقة الزبير عند أقصى جنوب العراق بين دائرتي عرض (30o05'-30o-25') شمالاً وخطي طول(47o30'- 47o 55')شرقاً ، وتمثل الجزء الجنوبي من الصحراء الغربية ،وتعتبر المياه الجوفية مصدر المياه الرئيس في هذه المنطقة لخلوها من المياه السطحية وشحة الامطار فيها. تمت في هذه الدراسة فحص المياه لعشرين بئراً لكشف تراكيز ايونات عناصر الكالسيوم، المغنيسيوم، الصوديوم، البوتاسيوم، الكلوريد،

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الكبريتات، البيكاربونيت، الكاربونيتوالنترات (Ca+2,Mg+2,Na+,K+ ,CL−,SO4−2,HCO3−,CO3−2& NO3−) وشمل الفحص كذلك معرفة بعض المتغيرات الفيزيائية مثل الدالة الحامضية (pH) والاملاح الذائبة الكلية(TDS) والتوصيلية الكهربائية(EC) ،ومن هذه المتغيرات تم معرفة بعض المؤشرات والخصائص المعتمدة لأغراض التقييم ومعرفة ملائمة المياه لمختلف الاستخدامات البشرية ،اذ أظهرت النتائج أن المياه في الآبار المختارة كانت شديدة التمعدن استناداً للعلاقة بين التوصيلية الكهربائية ودرجة تمعدن المياه ،وأن جميع الآبار ذات مياه عسرة جداً .كما بينت الدراسة ارتفاع نسبة تركيز آيون الكلوريد والذي قد يشير الى التلوث بمياه المجاري او نتيجة استخدام الأسمدة الكيميائية في الزراعة. وأن النتائج بينت سيادة ايونات الكالسيوم، المغنيسيوم والكلوريد وبالتالي يكون نوع المياه هو كالسيوم- مغنيسيوم كلوريد لمعظم مياه الآبار التي شملتها الدراسة. وان طول مجرى المياه الجوفية أدى الى تغيير نوعية المياه من البيكاربونات الى الكبريتات ثم الى الكلوريد. كذلك بينت هذه الدراسة عدم صلاحية مياه جميع الآبار لشرب الانسان حسب المواصفات العراقية والعالمية، وأنها غير مناسبة للري حسب تصنيف منظمة الغذاء العالمية(FAO,1997) استناداً لقيم الاملاح الذائبة الكلية والتوصيلية الكهربائية ،بينما تكون ممتازة للري حسب تصنيف (Tood,1980) استناداً لقيم النسبة المئوية للصوديوم (Na%) والتوصيلية الكهربائية. أما تصنيف(Subramain ,2005) واستناداً الى نسبة امتزاز الصوديوم (SAR) فقد بين ان المياه من المستوى الممتاز للزراعة (S1).

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, as in the cases of increased salinity, forces farmers to leave their farms and search for new farms with better water resources. Groundwater is a vulnerable resource because it may deplete or degrade due to many reasons, including overexploitation, reduction of groundwater, recharge, and contamination. Such conditions occur in Zubair area, which represents one of the largest and most important agricultural regions in southern Iraq. A comprehensive understanding of the groundwater quality in Zubair area is needed due to the lack of alternative water sources. The objective of the present research is of three fold: 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 them with the Iraqi and global specifications.

The Study Area

Zubair area is located at the southernmost part of Iraq and represents the southern part of the western desert, bounded by north latitudes (30◦ 05□--30◦ 25-) and east longitudes (47◦ 30--47◦ 55-). Morphologically , the area is a flat plain that generally slopes towards northeast. The important geomorphologic features within this area include the shallow wades which may carry occasional runoff after rainstorm, the tidal flat, and the sand dunes that are disposed throughout the area in the southern and southwestern parts. A single significant alleviation within the area is Jabal Sanam, a rounded hill which rises about 150 meter above sea level [1]. Hydrologically, the upper part of Dibdibba formation, in which the most productive units are sands and gravels, is the main aquifer in Zubair area. The rock types show that the formation is of fluvial origin. It is characterized by unconfined to semi-confined conditions [2].

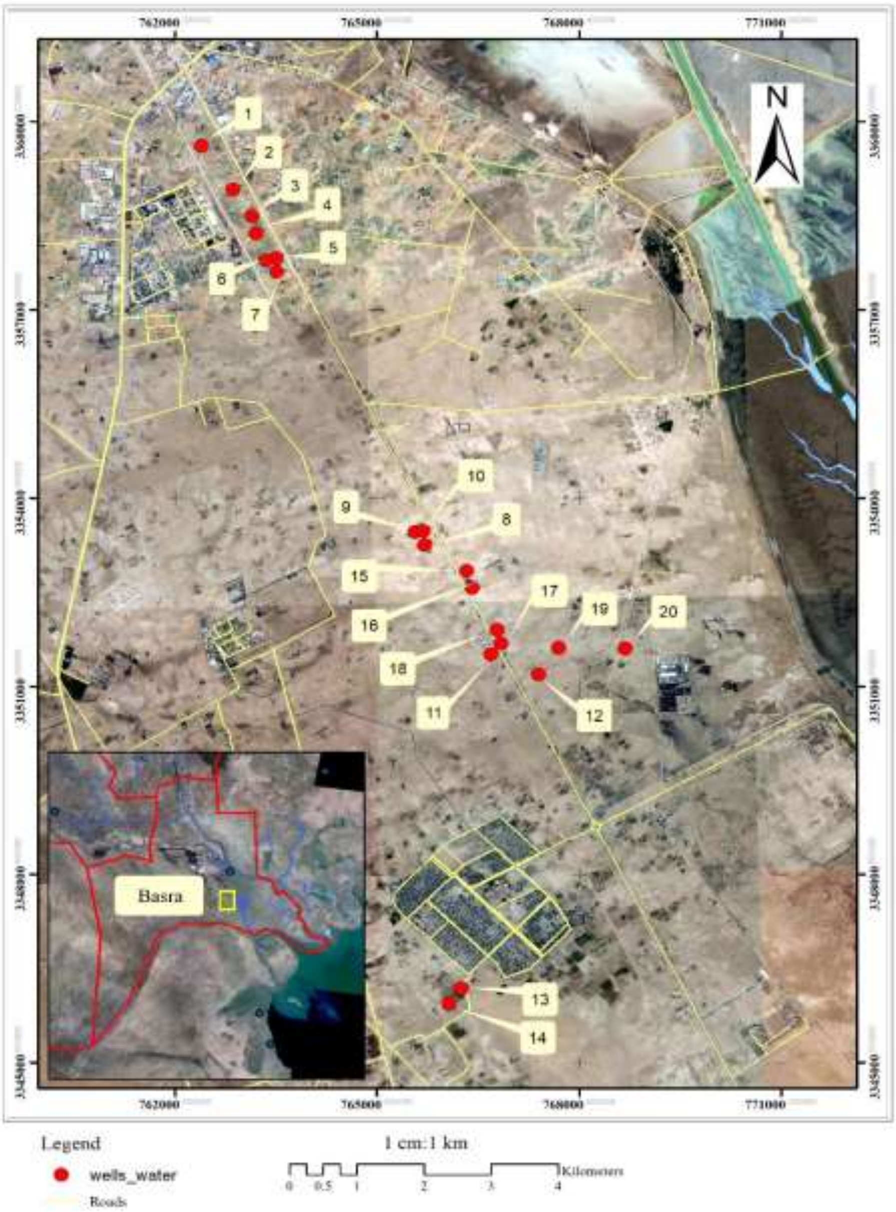

Figure 1-Location map of the study area.

Materials and Methods

The physical and chemical data for twenty wells in Zubair area (Figure-1) were obtained from the General Commission for Groundwater, Basrah Province, Iraq. The parameters included the positive ions (K+ ,Na+ ,Mg+2 ,Ca+2), negative ions (Cl-,SO4-2,HCO3-,CO3-2 ,NO3-), pH, EC, and TDS (Table-1).

Water samples were collected in September 2014 (water deficit period). The samples were placed in plastic bottles with a volume of 1.5 liter which were previously washed with distilled water and then rinsed in sample water for each well to ensure the elimination of pollutants. Values of pH and EC were measured immediately in the field using calibrated EC-pH meter with standard solutions, while the levels of TDS were measured by evaporation. Water samples were analyzed to determine ions concentration in the laboratories of the General Commission for Groundwater.

Results and Discussion

Physical Parameters

Table 1-Physical and chemical values for ground water from the study area

Well No	pH	EC µs\cm	TDS ppm	K+ ppm	Na+ ppm	Mg+2 ppm	Ca+2 ppm	Cl- ppm	SO4-2 ppm	HCO3 -ppm	CO3-2 ppm	NO3- ppm
1	7.3	7370	5220	0.3	109.5	267.8	761.5	1849	300	295	1.5	
2	7.4	10400	7540	5.8	153.8	243.2	801.6	2249	180	46.5	5.5	
3	7.4	10700	7660	6.8	154.1	218.6	761.5	2599	310	52.5	15	
4	7.4	10370	7260	7.9	150.8	413.2	861.7	2399	300	45	3.5	
5	7.6	5210	3690	14.7	97.5	231.1	581.1	1299	198	58	4.5	
6	7.3	8420	5980	3.3	127.6	474.7	841.6	1699	250	33.5	5	
7	7.3	8330	5950	1.2	129.6	755.4	701.4	1749	200	33.5	6.5	
8	7.3	10650	7610	14.9	179.4	462.2	881.7	2849	340	36	3.5	
9	7.3	11100	7920	11.5	174	328.3	881.7	8299	490	34	3	
10	7.3	12750	9070	68.1	178.8	389.0	1102	3498	410	46.5	7.5	
11	7.4	6610	4730	51.3	106.8	304.0	801.6	1249	420	57.5	7.5	2.1
12	7.4	7250	5210	36.6	114.9	365	821.6	1649	360	44	4	1.7
13	7.3	12570	9000	51.4	224.5	632.7	1402	3798	280	16	4.5	2.6
14	7.6	7690	5510	37.8	172.9	485.9	1703	2899	350	20	8.5	3.6
15	7.6	15490	10970	281.1	74.4	327.9	1182	3248	260	20.5	5	
16	7.4	11200	7980	218.5	31.8	169.5	1002	2499	60	33.5	2	
17	7.6	8550	6030	181.1	43.5	169.7	901.8	3748	50	7.5	8.5	
18	7.5	8710	6160	186.4	41.2	157.4	941.8	1949	50	7.5	11.5	
19	7.9	10300	7350	215.5	48.1	120.5	1182	2499	70	55.5	8	
20	7.2	5240	3720	127.7	25.3	96.56	841.6	1099	150	83.5	6.5	
range	7.2-7.9	5210-15490	3690-10970	0.3-281.1	25.3-224.5	96.56-755.5	581.1-1703	1249-8299	50-490	7.5-295	1.5-15	
mean	7.4	9445	6729	74.32	116.9	330.6	947.7	2656	251.4	51.3	7.65	

*Hydrogen ion concentration (PH): It is the reciprocal of the logarithm (base 10) of the hydrogen ion concentration in moles per liter [3]. pH is one of the most important operational quality parameters of water [4]. Neutral water has a PH value of 7.0 , alkaline water is higher than 7.0, and acidic water is lower 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 [5]. pH value in the water of the study area ranged between 7.2and 7.9, with a mean value of 7.4. All wells were weakly alkaline (7.2-7.6) except well number 19 (pH=7.9).

*Electrical conductivity (EC): It is the ability of 1cm3 water to conduct an electric current at a standard temperature of 25C◦. It is measured in micro Siemens per centimeter (µ.s\ cm) and is depending on the total amount of soluble salts [6]. 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 [7]. The EC values in the groundwater of the study area had a range of 5210-15490 µ.s\cm with a mean of 9445 µ.s\cm. Accordingly, water samples are classified as having excessively mineralized water (Table-2).

*Total Dissolved Solids (TDS): It is a measure of the total of minerals dissolved in water and is a very good parameter in the evaluation of water quality [8]). This parameter is also known as salinity [9] and measured by part per million (ppm) or milligram per liter (mg\L) units. The TDS value in the groundwater of the study area was in the range of 3690-109700 ppm, with a mean of 6729 ppm. TDS content of groundwater may increase by movement of water through rocks containing soluble minerals, which can be concentrated by evaporation [10].

Table 2-The relation between EC and mineralization (After Detay, 1997)[7]

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(5210-15490)

2-2: Chemical Analysis (major cations and anions):

*Calcium ion (Ca+2): Subsurface water is in contact with sedimentary rocks which derive most of their calcium from calcite, aragonite, dolomite, anhydrite, and gypsum [11]. Some calcium carbonate is desirable for domestic water because it provides covering in the pipes, which protects them against corrosion [12]. Sewage water contains a large quantity of organic material which, when oxidized, release quantities of CO2, which leads to increase Ca+2 [13]. Calcium concentration in water samples of the study area ranged between 581.16 and 1703.4 ppm with a mean value of 947.81 ppm.

* 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 [13]. Magnesium ion concentration in the groundwater of the study area had a range of 96.5 – 755.5 ppm, with a mean value of 330.68 ppm.

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

$TH=2.497\ Ca^{+2}+4.115Mg^{+2}$ [14].

where Ca+2 and Mg+2 are the concentrations of the ions in ppm. Water is classified into several types according to total hardness as in Table 3.

Total hardness (TH) in the study area ranges between 2402and 6257 ppm with a mean value of 3725 , which indicates that all samples had very hard water.

Table 3-Classification of water according to total hardness

Tood 2007[15]		Boyd 2000[16]	
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

* 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 evaporated deposits, the dissolve of halite is also important. Clay mineral may, under certain conditions, release large quantities of commutable sodium [17]. Sodium is a significant factor in assessing water for irrigation and plant watering, where high levels affect soil structure and the plants ability to take up water [18]. Sodium concentration is important in classifying irrigation water, because sodium reacts with soil to reduce its permeability [15]. Sodium concentration in the water from the study area had a range of 25.3-224.5 ppm with a mean value of 116.92 ppm.

*Potassium (K+) : Clay minerals, feldspar, and mica are the main sources of potassium ion, along with the evaporates containing highly soluble sylvite in some sedimentary rocks. The concentration of potassium ion is less than the concentration of sodium ion in groundwater, with the reason being the less solubility of sodium [19]. Potassium ion increases in groundwater due to the use of chemical fertilizers [20]. Potassium plays an important role in nerve function and a central role in plant growth. In every liter of human blood, there are 180-220 mg /L) of potassium, and the lack of this amount, as well as increasing it, causes disturbance in the body [4]. Potassium concentration in water samples of the study area ranged between 0.3 and 281.1 ppm with a mean value of 74.32 ppm. High concentrations of potassium in some samples of the study area were possibly due to the use of chemical 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. In groundwater, its content varies from few ppms in the snow fed to a high content in desert brines. Chloride ion is available in evaporated rocks and in rock minerals such as apatite and soda [21]. In addition, the treatment of water with chloride can lead to increasing its concentration in the groundwater [4]. Chloride concentration in the water samples of the study area ranged between 1249.61 and 8299.1 ppm with a mean value of 2656.75 ppm. High chloride concentration in the groundwater of the study area may be an indicator to pollution by sewage and agriculture fertilizers.

* Sulfate (SO4-2): Sedimentary rocks such as gypsum and anhydrite represent an important source of sulfate [15]. Other sources for sulfate include agricultural and industrial activities [22]. Sulfate concentration in the water samples of the study area ranged between 50 and 490 ppm with a mean value of 251.4 ppm. Most water wells of the study area are within the standard concentration of IQS 2009[23] (400 ppm) and WHO 2007[24](250 ppm).

* Alkalinity (HCO3- ,CO3-2): It is a consistent measure of carbonate and bicarbonate ions for most natural water. The main source of carbon dioxide that produces alkalinity in groundwater is the CO2 gas fraction of the atmosphere, or the atmospheric gases present in the dirt or in the unsaturated zone, which is located between the surface of the ground and the water level of groundwater [25]. The concentrations of HCO3- and CO3-2 in the study area had the ranges of 7.5- 295 and 1.5-15 ppm, respectively, with a mean value of 51.3, 7.65 ppm.

*Nitrate (NO3-): Organic matters as well as fertilizers represent the most common nitrate sources in natural water; it comes from industrial and agricultural activities [26,27]. Nitrate has a direct effect on plant growth and may cause a hazard for drinking water sources if its levels reach 10 ppm or more [28]. NO3- in the water of the study area was undetectable for most wells, except wells number 11,12.13, and 14 which ranged between 1.7 and 3.6 ppm, with a mean value of 2.5 ppm. Nitrate concentrations in the study area are lower than the standard values of IQS 2009[23] and WHO 2007[24] (50 ppm for both standards).

2-3 Water types and hydro chemical formula: Types of water are connected with the chemical and physical properties, which change relatively with respect to time and place. These changes are slow in groundwater in comparison with surface water [29]. Water type is very important to determine its suitability for the different uses (human, agricultural and industrial purposes). Many classifications depend on the main cations and anions concentrations by unit equivalent weight of ion (epm) or milli equivalent per liter (meq / l). The hydro-chemical formula is defined as an equivalent weight ratio for all ions (which have a ratio of higher than 15%) in groundwater, which is arranged regularly according to the concentration of each ion, in addition to TDS and pH values. The result of this formula indicates the water type. The formula (Kurlolov formula) was adopted from Ivanov *et al.* [30] and is as follows:

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

Table-3 shows the type of groundwater in the studied area resulted from the hydro chemical formula, which is important in geochemical operations during the flow of groundwater, where the increase in flow length will change the water quality from bicarbonate to sulfate and chloride, which could be an indicator to the length of groundwater flow [31]. This applies to the results of this study, since we note that most models had water where chloride predominates.

Table 4-Hydro chemical formula and water type for samples of the study area

well No.	Hydro chemical formula	Water type
W.1	5230 CL- 82.39 SO4-2 9.88(HCO3- +CO3-2)7.7 7.3 Ca+2 58.4 Mg+234.2 Na+7.3 K+ 0.01	Ca+2 Mg+2 CL- Chloride
W.2	7540 CL- 93.1 SO4-2 5.5(HCO3-+CO3-2) 1.37 7.4 Ca+259.6 Mg+230.1 Na+ 9.9 K+ 0.2	Ca+2Mg+2 CL- Chloride
W.3	7670 CL- 90.3 SO4-2 7.9(HCO3- +CO3-2) 1.6 7.4 Ca+2 60.2 Mg+228.8 Na+ 10.6 K+0.2	Ca+2 Mg+2 CL- Chloride
W.4	7260 CL- 90.5 SO4-2 8.3 (HCO3- +CO3-2)1.1 7.4 Ca+2 51.9 Mg+2 40.8 Na+7.7 K+ 0.2	Ca+2 Mg+2 CL- Chloride
W.5	3690 CL-88.6SO4-29.98(HCO3-+CO3-2)2.6 7.6 Ca+2 54.9 Mg+2 36.37 Na+ 8 K+ 0.7	Ca+2 Mg+2 CL- Chloride
W.6	5980 CL-88.98 SO4-29.68(HCO3- +CO3-2) 1.5 7.3 Ca+2 48.2 Mg+2 45.3 Na+ 6.3 K+ 0.09	Ca+2 Mg+2 CL- Chloride
W.7	5950 CL- 90.9 SO4-2 7.68 (HCO3- +CO3-2)1.4 7.3 Mg+2 60.7 Ca +2 33.8 Na+ 5.3 K+ 0.02	Mg+2 Ca+2 CL- Chloride
W.8	7610 CL- 91.1 SO4-28.04(HCO3-+CO3-2) 0.8 7.3 Ca+248.5 Mg+2 42.4 Na+8.5K+0.4	Ca+2 Mg+2 CL- Chloride
W.9	7920 CL-95.5 SO4-2 4.1(HCO3- + CO3-2)0.2 7.3 Ca+2 55.5 Mg+2 34.4 Na+7.5 K+0.3	Ca+2 Mg+2 CL- Chloride
W.10	9070 CL- 91.19 SO4-2 7.8 (HCO3-+CO3-2) 0.9 7.3 Ca+256.7 Mg+233.4 Na+8 K+1.7	Ca+2 Mg+2 CL- Chloride
W.11	4730 CL-77.8 SO4-2 19.3(HCO3-+CO3-2) 2.63 NO3- 0.07 7.4 Ca+2 56.1 Mg+2 35.4 Na+6.5 K+ 1.8	Ca+2Mg+2CL-SO4-2 Chloride
W.12	5210 CL- 84.7 SO4-2 13.6(HCO3-+CO3-2)1.5 NO3- 0.04 7.4 Ca+2 53.05 Mg+2 39.2 Na+ 6.4 K+1.2	Ca+2 Mg+2 CL- Chloride
W.13	9000 CL-94.4 SO4-2 5.1(HCO3-+CO3-2) 0.3 NO3- 0.03 7.3 Ca+252.01 Mg+239.1 Na+7.8 K+0.9	Ca+2 Mg+2 CL- Chloride
W.14	5510 CL-91.1 SO4-2 8.1 (HCO3-+CO3-2)0.6 NO3- 7.6 Ca+2 63.4 Mg+230.1 Na+5.6 K+0.7	Ca+2 Mg+2 CL- Chloride
W.15	10770 CL-93.9 SO4-2 5.5 (HCO3-+CO3-2)0.5 7.6 Ca+2 61.02 Mg+2 28.2 K+ 7.4 Na+ 3.3	Ca+2 Mg+2 CL- Chloride
W.16	7980 CL- 97.4 SO4- 1.7 (HCO3-+CO3-2) 0.85 7.4 Ca+270.3 Mg+2 19.8 K+ 7.8 Na+ 1.9	Ca+2 Mg+2 CL- Chloride
W.17	6030 CL-98.6 SO4-2 0.97 (HCO3-+CO3-)0.37 7.6 Ca+2 68.5 Mg+2 21.5 K+ 7.06 Na+ 2.8	Ca+2 Mg+2 CL- Chloride
W.18	6160 CL-70.8 SO4-2 1.8(HCO3-+CO3-)1.6 7.5 Ca+2 70.5 Mg+2 19.6 K+ 7.1 Na+ 2.6	Ca+2 Mg+2 CL- Chloride
W.19	7350 CL- 96.3 SO4-2 1.9 (HCO3-+CO3-)1.6 7.9	Ca+2 CL- Chloride

	Ca+276.9 Mg+213.08 K+ 7.9 Na+ 2.7		
W.20	3720 CL- 86.8 SO4-28.7 (HCO3-+CO3-)4.4 / Ca+277.3 Mg+214.7 K+ 6 Na+1.8	7.2	Ca+2 CL- Chloride

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 is different 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 ,agriculture and industry [14].

2-4-1 Usage of water for drinking: Groundwater forms an important source of water for drinking and other domestic purposes, especially in some dry and semi-dry regions where surface water is scarce. Iraqi drinking standards (IQS,2009)[23] and those of the world health organization (WHO,2007)[24]are used to determine the suitability of groundwater from the studied area for human drinking purposes, depending on the ionic concentrations of water, TDS, and other components (Table- 5).

Table 5-Comparing the parameters for water samples with the standards of drinking water (WHO, 2007[24] and IQS, 2009)[23].

Parameters	IQS 2009	WHO 2007	studied wells (range)	Suitability
pH	6.5-8.5	6.5-8.5	7.2-9.7	Suitable
EC (µS/cm)	1500	1530	5210-15490	All samples is not suitable
TDS(ppm)	1000	1000	3690-10970	All samples is not suitable
Ca+2 (ppm)	150	75	581-1703	All samples is not suitable
Mg+2(ppm)	100	125	96-755	Most samples is not suitable
Na+(ppm)	200	200	25-224	Suitable except sample no.12
K+(ppm)	-	12	0.3-281	Samples(1,2,3,4,6,7,9) is suitable and other is not suitable
CL- (ppm)	350	250	1249-8299	All samples is not suitable
SO4-2 (ppm)	400	250	50-490	Suitable except samples (9,10,11)
NO3- (ppm)	50	50	0-3.6	All samples is suitable

Overall, it appears that the water for all wells studied is not suitable for drinking by humans, because most of the elements are out of the recommended guide levels.

2-4-2 Water suitability for irrigation and agricultural purposes: This usage depends upon many principles such as sodium adsorption ratio (SAR), residual sodium carbonate (RSC), electrical conductivity (EC), total dissolved solid (TDS), and sodium concentration percentage (Na %).

The Food and Agriculture organization (FAO, 1997)[32] has published one of the classifications depending on EC and TDS value (Table-6).

Table 6-Water type accepted for irrigation according to FAO (1997)[32]

EC µS/cm	TDS ppm	Characterizes
100-200	Less than 200	Water little salinity and suitable irrigate
250-750	200-500	Moderately salinity and need filtration
750-2250	500-1500	High salinity and can't use near
2250-5000	1500-3000	Very high and not suitable irrigate and need to desalination soil
More than 5000	More than 3000	Not actionable irrigate

Compared with the samples of the study area, water is not suitable for irrigation, since the lower TDS value in the study area was 3690 ppm and that of EC was 5210 µS/cm.

*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, thus the sodium hazard will increase [33]. The bicarbonate hazard is expressed by residual sodium carbonate (RSC) which was introduced by Eaton in 1950[34], as follows:

RSC = (CO3-2 + HCO3-)-(Ca+2+Mg+2)

where all ions are measured by the equivalent weight (epm). RSC values in the water from the study area ranges ranged between -125 and -47.2 epm, with a mean value of -73.8. According to the classification of Eaton [34] (Table 7), water from all the samples of groundwater in the study area is safe for irrigation.

Table 7-Classification of irrigation water based on RSC values (Eaton, 1950)[34]

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

$$Na\% = \frac{rNa + rK}{rCa + rMg + rNa + rK} * 100 \quad \text{------------(14)}$$

where all ionic concentrations (*rNa,rK,rCa,rMg*) are expressed in epm. Na% values in the study area ranged between 5.2 and 10.8, with a mean value of 8.6. The classification of Tood ,1980)[14] for irrigation water, which is based on Na% and EC values (Table-7), was adopted in this study and shown in Table-8.

Table 8-Classification of (Todd, 1980)[14] for irrigation water based on (Na %) and (EC).

Water class	Na%	Study area	EC µS/Cm	Study area
Excellent	<20	All samples from this class	<250	
Good	20-40		250-750	
Permissible	40-60		750-2000	
Doubtful	60-80		2000-3000	
Unsuitable	>80		>3000	All samples from this class

*Sodium adsorption ratio (SAR): It is an important parameter for determining the suitability of water for agriculture, because it is a measure of alkali /sodium hazard [35]. Karanth, 2008)[36] defines sodium adsorption ratio SAR of water as:

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

where Na^+, Ca^{+2} and Mg^{+2} are the concentrations of ions in epm units. High values of SAR imply a hazard of sodium which is replacing the absorbed calcium and magnesium, a situation ultimately damaging soil structure (Hem 1985). Four classes of water for agriculture exist depending on SAR values, according to subramain ,2005[35]. All samples in the study area have a SAR value below 10, with a range of 0.2-5.3 epm and a mean of 1.02 epm, which indicate an excellent water class (S1) for agriculture (Table-9).

Table 9-Alkalinity hazard classes of water (Subramain, 2005)[35]

SAR (epm)	Alkalinity hazard	Water class	Representing samples
<10	S1	Excellent	All samples
10-18	S2	Good	
18-26	S3	Doubtful	
>26	S4	Unsuitable	

2-4-3: Groundwater uses for livestock: Samples from the study area were evaluated for livestock and poultry uses based on the classification proposed by Altoviski (1962)(37) (Table-10).

Table 10-Specifications of water samples for livestock consumption according to Altoviski (1962)[37].

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	25 -224
Ca+2	350	700	800	900	1000	581-1703
Mg+2	150	350	500	600	700	96 -755
CL-	900	2000	3000	4000	6000	1249-8299
SO4-2	1000	2500	3000	4000	6000	50 - 490
TDS	3000	5000	7000	10000	15000	3690-10970
TH	1500	3200	4000	4700	54000	2402-6257

Overall, it appears that the water from all wells studied is suitable to use for livestock purposes, but the degree of suitability is different from a well to another, ranging between very good to acceptable for use.

2-4-4 Water suitability for industrial purposes: Water samples from the study area were analyzed for industrial uses by applying Hem(1985)[21] classification (Table-11).

Table 11-Water quality standards for industrial uses, Hem (1985)[21]

Industry type	Ca+2 ppm	Mg+ 2ppm	CL- ppm	HCO3 -ppm	SO4-2 ppm	NO3- 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)	947	330	2656	51	251	Less than 0.36	3725	6729	7.4

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

2-4-5 Suitability of water resources for building purposes: Altoviski (1962)[37]classification for building purposes of water depends on the major cations and anions. It was used to evaluate the suitability of water samples in the studied area for building purposes (Table-12).

Table 12-Evaluation of water for building purposes according to Altoviski (1962)[37].

Ions (ppm)	Permissible limit	Water studied area	
		range	Mean
Na+	1160	25.3-224.5	116.9
Ca+2	437	581.1-1703.4	947.8
Mg+2	271	96.5-755.5	330.6
CL-	2187	1249.6-8299.1	2656.75
SO4-2	1460	50-490	251.4
HCO3-	350	7.5 -295	51.3

From the results, it is clear that the groundwater in study area is suitable for building purposes.

Conclusions

Depending on pH value of water (ranged 7.2-7.9) in the study area, the water is suitable for different usages. The high value of EC (ranged 5210-15440 µS/cm) resulted in the water from the study area to be classified as excessively mineralized according to Detay, 1997[7]. High value of total dissolved solids (TDS) (ranged 3690-10970 ppm) in water by movement of this water through rocks .Depending on the total hardness (TH) parameter, all samples were with very hard water (ranged 2402-6257 ppm) according to Tood, 2007[15] and Boyd, 2000[16] classification. High chloride concentration (ranged 1249-8299 ppm) in water samples of the study area may be an indicator to pollution by sewage and agriculture fertilizers. The predominant cations in water of the study area are calcium and magnesium, as well as chloride from anions, so that the water type is Ca-Mg-CL for most samples. The water wells studied are not suitable for drinking by humans. Depending on TDS and EC values, the water samples are not actionable for irrigation according to FAO 1997[31]classification. Water type is safe for irrigation according to Eaton 1950[34] depending on RSC. We also recorded an excellent water class depending on Na% and EC according to Tood, 1980[14] classification for irrigation water. Excellent water class (S1) for agriculture depending on SAR according to subramain, 2005[35] classification was also recorded. Water for all wells studied is suitable to use for livestock purposes according to Altoviski, 1962[37] classification. It is clear that groundwater in the study area is suitable for building purposes according to Altoviski, 1962[37] classification for building purposes.

Appendix: Equivalent weight of ions (epm) & equivalent weight ratio (epm %)

w.NO	Deep of well (meter)		K+	Na+	Mg+2	Ca+2	CL-	SO4-2	HCO3- +CO3-2	NO3-
1	8	epm	0.007	4.7	22.2	38.0	52.0	6.25	4.8	-
		epm%	0.01	7.3	34.2	58.4	82.3	9.8	7.7	-
2	10	epm	0.1	6.6	20.2	40.0	63.3	3.7	0.9	-
		epm%	0.2	9.9	30.1	59.6	93.1	5.5	1.3	-
3	9	epm	0.1	6.7	18.22	38.0	73.2	6.4	1.3	-
		epm%	0.2	10.6	28.8	60.2	90.3	7.9	1.6	-
4	12	epm	0.2	6.5	34.4	43.0	67.5	6.2	0.8	-
		epm%	0.2	7.7	40.8	51.0	90.5	8.3	1.1	-
5	8.5	epm	0.3	4.2	19.2	29.0	36.6	4.1	1.1	-
		epm%	0.7	8.0	36.3	54.9	88.6	9.9	2.6	-
6	10	epm	0.08	5.5	39.5	42.0	47.8	5.2	0.7	-
		epm%	0.09	6.3	45.3	48.2	88.9	9.6	1.5	-
7	8	epm	0.03	5.6	62.9	35.0	49.2	4.1	0.76	-
		epm%	0.02	5.4	60.7	33.8	90.9	7.6	1.4	-
8	7.5	epm	0.38	7.8	38.5	44.0	80.2	7.0	0.7	-
		epm%	0.4	8.5	42.4	48.5	91.1	8.0	0.8	-
9	10.5	epm	0.2	7.5	27.3	44.0	233.7	10.2	0.5	-
		epm%	0.3	9.5	34.4	55.5	95.5	4.1	0.2	-
10	11	epm	1.7	7.7	32.4	55.1	98.5	8.5	1.0	-
		epm%	1.7	8.0	33.4	56.7	91.1	7.8	0.9	-
11	10	epm	1.3	4.6	25.3	40.0	35.2	8.7	1.1	0.03
		epm%	1.8	6.5	35.4	56.1	77.8	19.3	2.6	0.07
12	10	epm	0.9	4.9	30.4	41.0	46.4	7.5	0.85	0.02
		epm%	1.2	6.4	39.2	53.0	84.7	13.6	1.5	0.04
13	12	epm	1.3	10.6	52.7	70.1	107.4	5.8	0.4	0.04
		epm%	0.9	7.8	39.1	52.0	94.4	5.1	0.3	0.03
14	10	epm	0.9	7.5	40.4	85.1	81.6	7.2	0.6	0.05
		epm%	0.7	5.6	30.1	63.4	91.1	8.1	0.6	0.04
15	11	epm	7.2	3.2	27.3	59.1	91.5	5.4	0.4	-
		epm%	7.4	3.3	28.2	61.0	93.9	5.5	0.5	-
16	12	epm	5.6	1.3	14.1	50.1	70.4	1.2	0.6	-
		epm%	7.8	1.9	19.8	70.3	97.4	1.7	0.8	-
17	7	epm	4.6	1.8	14.1	45.0	105.6	1.0	0.4	-
		epm%	7.0	2.8	21.5	68.5	98.6	0.9	0.3	-
18	11	epm	4.7	1.7	13.1	47.0	54.9	1.0	0.5	-
		epm%	7.1	2.6	19.6	70.5	70.8	1.8	0.8	-
19	7.5	epm	5.5	2.0	10.0	59.1	70.4	1.4	1.1	-
		epm%	7.1	2.7	13.0	76.9	96.3	1.9	1.6	-
20	8	epm	3.2	1.0	8.0	42.0	30.9	3.1	1.5	-
		epm%	6.0	1.8	14.7	77.3	86.8	8.7	4.4	-

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