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Hydrochemical Assessment of Groundwater of Dibdibba Aquifer in Al-Zubair Area, Basra, South of Iraq and its Suitability for IrrigationPurposes

Firas Mudhafar Abdulhussein
Department of Geology, College of Science, University of Baghdad, Baghdad, Iraq.

Abstract

This study focuses on cation and anion concentrations and their distribution in the Dibdibba aquifer in the Zubair area at Basra city, southern Iraq to assess the groundwater quality for the agricultural purpose. The physicochemical properties (TSS, Ec, pH, cation and anion concentrations) of the groundwater samples through 18 wells was measured. Results showed that the dominant groundwater type is Na, Mg, Ca-Chloride type. The Magnesium Hazard, Sodium Adsorption Ratio, Na%, total dissolved solid, Electrical conductivity and pH were used to assess the suitability of groundwater for irrigation purposes.. The assessment results indicate that the groundwater is characterized by no Mg-harmful, excellent with SAR and Na%, permissible with pH values, but unsuitable in terms of TDS and EC due to high salinity represented by Ca and Cl.

Keywords: Hydrochemistry; Groundwater; Dibdibba Aquifer; Irrigation; SAR.

تقييم هيدروكيميائي للمياه الجوفية في خزان دبدبة في منطقة الزبير، البصرة ،جنوب العراق وبيان صلاحيتها لأغراض الري

فراس مظفر عبد الحسين
قسم علم الارض، كلية العلوم، جامعة بغداد، بغداد، العراق.

الخلاصة

تركز هذه الدراسة على تركيز الايونات الموجبة والسالبة وتوزيعها في الخزان الجوفي لتكوين دبدبة في منطقة الزبير في مدينة البصرة جنوب العراق، وذلك لتقييم نوعية المياه الجوفية للأغراض الزراعية. تم قياس الخصائص الفيزيائية–الكيميائية (المواد العالقة الكلية، التوصيل الكهربائي، الايونات الموجبة والايونات السالبة) لعينات المياه الجوفية من خلال 18 بئرا. وأظهرت النتائج أن نوع المياه الجوفية السائدة هي صوديوم، مغنيسيوم، كالسيوم– كلوريدية. تم استخدام نسبة خطورة المغنيسيوم، نسبة امتزاز الصوديوم، النسبة المئوية للصوديوم، المواد الصلبة الذائبة الكلية، التوصيلية الكهربائية، ودرجة الحموضة لتقييم مدى ملائمة المياه الجوفية لأغراض الري. تشير نتائج التقييم إلى أن المياه الجوفية تتميز بعدم وجود ضرر مغنيسي، ونسبة امتزاز الصوديوم كانت ممتازة، والنسبة المئوية للصوديوم وقيم الرقم الهيدروجيني ضمن الحدود المسموحة، ولكنها غير مناسبة من حيث الاملاح الصلبة الذائبة الكلية والتوصيلية الكهربائية بسبب الملوحة العالية المتمثلة بايونات الكالسيوم والكلور.

Introduction

The study area deals with the Dibdibba Aquifer located in Basra Figure-1. Groundwater occurs within the permeable pebbly sandstones which sometimes contains beds of mudstone, siltstone.

Email: hadigeq@yahoo.com

The study area characterized by temperature of about (12-38ºC) as minimum - maximum average of monthly in January- July respectively with mean of 26 ºC. Many studies had been achieved on the groundwater in area between Safwan and Al-Zubair. The population community needs urgently water for live purposes; one of these necessary purposes is irrigation. At the study area, there is no any further source of water except the groundwater, Thus the suitability of groundwater for irrigation is recommended. The hydraulic properties in Safwan- Zubair area using the analytical and numerical methods has been evaluated [1]. The area is of confined to unconfined aquifer; the clayey sediments effect on salinity of the groundwater in the unconfined aquifer [2] A detailed hydrogeological study including water balance, chemical and physical characterization of Safwan-Zubair groundwater had been carried out by [3] where he divided the Dibdibba aquifer into an unconfined and semi-confined aquifers based on the variation in hydraulic properties and hydrogeological parameters [3]. A mixing state between the the Dibdibba aquifers was recorded by [4]. The quality is not suitable for human drinking with a reduction in the water table of about 1m was mentioned by [5] The supplying of water quality depends upon which purpose will be used for. In such area of study, groundwater is very required. The area is agriculturally important, so the evaluation of the groundwater is required. This study aims to describe the geochemical properties and assess the water quality for irrigation purposes.

Site and nature of the study area

The study area is a flat plain of very gentle slop towards northeast. It is located in Al-Zubair district within Basra, southern Iraq Figure-1. The detailed location for each groundwater well in addition to the elevation and well depth are given in Table-1. The studied aquifer is within the Dibdibba Formation (Pleistocene- Pliocene) and has a large extension over large areas in the southern and central part of Iraq, and its type locality is in the Burjisiya area in Basra. It is composed of sand and sandy gravels with subordinate layers and lenses of silty and sandy clay. According to Jassim and Al-Jiburi [6]. The contact of the formation with the underlying Fatha Formation is conformable in SE Iraq [7]. The main body of the aquifer include lenses of mudstones which have different thickness and of high variation in physical and chemical characteristics [8]. A seasonal wadies and sand dunes are occurred in the study area.

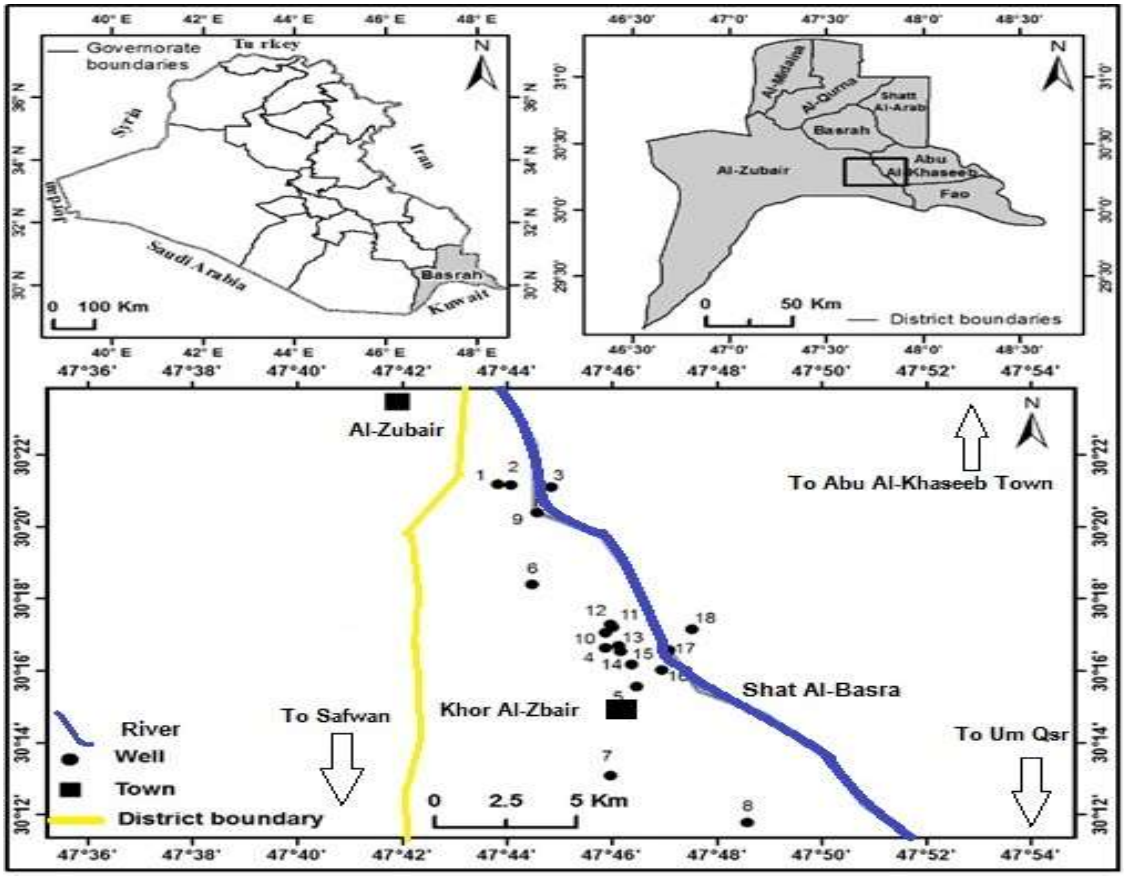

Figure1-Location map shows the study area.

Table 1- Coordinates and well depth of the studied wells

Well No.	Latitude	Longitude	Elevation (m)	Well depth (m)
1	30 21 10	47 43 49	6	9
2	30 21 09	47 44 40	3	7
3	30 21 6.3	47 44 37	2	5
4	30 16 38	47 45 52	1	10
5	30 15 34	47 46 28	5	11
6	30 18 23	47 44 29	4	10
7	30 13 50	47 45 58	4	12
8	30 11 46	47 48 35	1	12
9	30 20 23	47 44 34	-2	7
10	30 17 16	47 45 58	2	13
11	30 17 12	47 46 10	5	9
12	30 17 30	47 45 53	4	11
13	30 16 41	47 46 07	0	11
14	30 16 32	47 46 10	-1	12
15	30 16 10	47 46 23	1	11
16	30 16 10	47 46 23	2	7.5
17	30 16 34	47 47 50	3	7
18	30 17 08	47 47 31	0	7

Materials and Methods

A total of 18 well were studied via collecting one water samples from each well during 2014 that have been done by the Iraqi Geological Survey. These samples were analyzed for the major cations (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}), major anions (Cl^{-}, HCO_3^{-}, $SO_4^{=}$, and $CO3^{=}$), were analyzed. Rock Ware AqQa version 1.1 was used for the water classification, and determing water type. The coordinates for each sample including longitude, latitude and elevation were measured using GPS instrument type- 2. The pH, temperature, electrical conductivity (EC) and total dissolved solids (TDS) are measured in-situ after sampling using a portable meter WTW (LF330). The chemical analysis of major ions are carried out in the laboratory of General Commission for Groundwater using a standard procedure of [9]. The accuracy of the results was checked by using the equation below:

$$U\% = \frac{\text{rSum of cations} - \text{rSum of anions}}{\text{rSum of cations} + \text{rSum of anions}} * 100$$

R.D is the uncertainty (reaction error)
rCatios is a summation of positive ions concentrations in (epm) unit.
rAnions is a summation of negative ions concentrations in (epm) unit.
r is the equivalent per million (epm).
C is the certainty or accuracy is applied as:
R.D= 1- U
The result is accepted when R.D $\leq$ 5, but not accepted with risk in case 5< U $\leq$ 10 [10]. The assessment of groundwater for agricultural purpose was done by using Sodium Adsorption Ratio (SAR), Na% or Soluble Sodium Percent (SSP), Magnesium Hazard (MH), total dissolved solid (TDS) and electrical conductivity (EC).

Results and discussion

Physical and chemical characterizations

Results of chemical analysis of the groundwater samples are reported in Table 2. The groundwater chemistry affected by lithology and its interaction with rock [11]. Geochemistry was discussed by the main dissolved solids as components and then presented on Schoeller and Stiff diagrams expressing by hydrochemical formula. The dissolution process leads to increase the concentration of ions in the groundwater, while the linkage of ions together in one compound cause decrease the ion concentrations in the groundwater. The changing in water quality in each well is due to relative change in lithology and water-rock interaction. The detailed phisco-chemical properties of the groundwater samples are presented in the Durov diagram (Figure-2) which clearly shows the range of TDS and pH

values as well as the ion concentrations in each groundwater sample. The high variation in TDS could be attributed to the main body of the aquifer hich includes lenses of mudstones which have different physical and chemical characteristics [8]. A seasonal wadies and sand dunes are occurred in the study area.

It is evident from the Stiff and Schoeller diagrams that groundwater are relatively poor in carbonates and bicarbonates and comparatively rich in chloride. Calcium has higher concentration among cations due to gypsum and calcite precipitation. It is clearly that the average type of the groundwater is Na-Mg-Ca-Chloride as it shown in the Stiff diagram Figure-3. Schoeller Diagram proposed by [12] displays the water is homogeneous in Ca, Na and K, and Cl but of heterogeneity in Mg, HCO_3 and CO_3, and SO_4 Figure-4. This is attributed to the inhomogeneous gypsum distribution in the studied aquifer and its solubility. Piper diagram enhances the results of both the Stiff and Schoeller diagrams and evidently indicate a normal Earth Alkaline water with prevailing of chloride Figure-5.

Table 2- Results of chemical analysis of the groundwater samples

Well No.	Unit	Ca	Mg	Na	K	∑ Cations	HCO3	SO4	Cl	CO3	∑ Anions	R.D
1	ppm	861.72	11.14	128.3	46.1		23	34	1349.6	5.5		
	epm	43	0.92	5.58	1.18	50.68	0.38	0.71	38.07	0.18	44.66	6.31
2	ppm	841.68	23.36	135	55.2		44.6	36	1449.6	5		
	epm	42	1.92	5.87	1.41	51.21	0.73	0.75	40.89	0.17	47.37	3.89
3	ppm	821.64	72.18	178.7	74.2		12.5	48	2149.3	2		
	epm	41	5.94	7.77	1.9	56.61	0.2	1.00	60.63	0.07	63.84	6
4	ppm	801.6	316.2	119.9	4		63.4	56.5	330	1799		
	epm	40	26.01	5.22	1.62	72.85	0.93	6.87	50.76	0.18	64.06	6.42
5	ppm	1082.2	413.5	156.2	53.7		23.5	350	2649.2	5		
	epm	54	34.01	6.79	1.37	96.18	0.39	7.29	74.73	0.17	87.41	4.78
6	ppm	1042.1	608.5	163.1	69.2		22.5	200	3548.9	5		
	epm	52	50.07	7.09	1.77	110.94	0.37	4.16	100.11	0.17	109.6	0.59
7	ppm	1402.8	632.7	224.5	51.4		16	280	3798.8	4.5		
	epm	70	52.05	9.77	1.31	133.13	0.26	5.83	107.16	0.15	117.8	6.13
8	ppm	901.8	84.3	162.7	50.1		59	150	1499.5	6.5		
	epm	45	6.93	7.08	1.28	60.29	0.97	3.12	42.30	0.22	52.89	6.54
9	ppm	821.64	194.2	214.1	49.7		28	110	2099.3	5		
	epm	41	15.97	9.31	1.27	67.56	0.46	2.29	59.22	0.17	66.97	0.44
10	ppm	1002	560	54.8	244.5		28.5	490	3348.9	4		
	epm	50	46.06	2.38	6.25	104.7	0.47	10.2	94.47	0.13	109.1	2.08
11	ppm	781.56	853.0	59.7	249.1		20	360	4298.7	5		
	epm	39	70.17	2.6	6.37	118.14	0.33	7.50	121.27	0.17	134.1	6.32
12	ppm	1162.3	96.18	56.4	189.9		27.5	300	2199.3	5		
	epm	58	7.91	2.45	4.86	73.22	0.45	6.25	62.04	0.17	73.74	0.35
13	ppm	1182.4	328	74.4	281.1		20.5	260	3249	5		
	epm	59	26.98	3.24	7.19	96.4	0.34	5.41	91.65	0.17	102.4	3.02
14	ppm	1002	169.6	31.8	218.5		33.5	60	2499.2	2		
	epm	50	13.95	1.38	5.59	70.92	0.55	1.25	70.50	0.07	74.30	2.33

15	ppm	941.88	157.4	41.2	186.4		7.5	50	1949.4	11.5		
	epm	47	12.95	1.79	4.77	66.51	0.12	1.04	54.99	0.38	67.66	0.85
16	ppm	1182.4	120.6	48.1	215.5		55.5	70	2499.2	8		
	epm	59	9.92	2.09	5.51	76.52	0.91	1.46	70.50	0.27	80.87	2.76
17	ppm	921.44	60.12	4.9	154.4		23.5	290	1499.5	7		
	epm	45.98	4.95	0.21	3.95	55.09	0.39	6.04	42.30	0.23	55.72	0.58
18	ppm	480.96	219	78.2	166.5		16	240	1549.5	5		
	epm	24	18.01	3.4	4.26	49.67	0.26	5.00	43.30	0.17	53.97	4.15

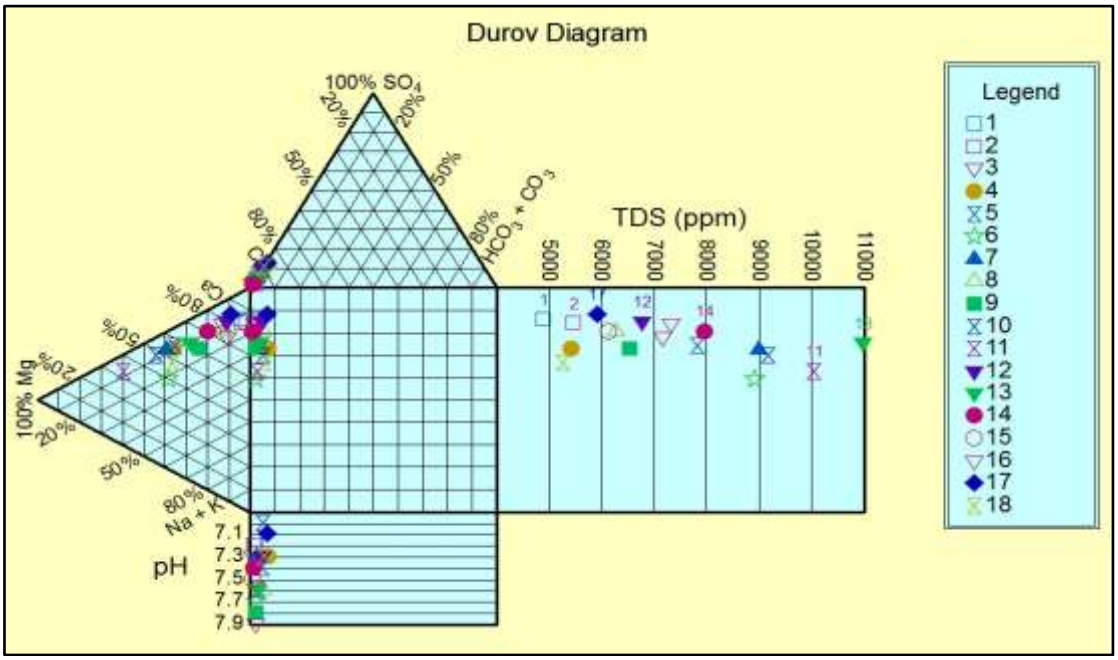

Figure 2-Durov Diagram of the groundwater.

Groundwater assessment for irrigation

Five parameters that are widely sued for assessing the water quality (TDS, EC, MH, SAR, Na% and pH) for irrigation were investigated. The standard categories for each parameter ate listed in Table- 3 and the results are listed in Table-4.

Table 3- The standard categories used for the water assessment for irrigation purpose according to classification of Don (1995)

EC µs\cm	TDS ppm	SAR	Na%	pH	Water Quality
< 250	< 175	<3	< 20	<6.5	Excellent
250−750	175-525	3-5	20-40	6.5-6.8	Good
750−2000	525-1400	5-10	40-60	6.8-7.0	Permissible
2000−3000	1400-2100	10-15	60-80	7- 8	Doubtful
>3000	>2100	>15	>80	>8	Unsuitable

a) Magnesium hazard

The magnesium hazard (MH) parameter was proposed by [13] and widely used to evaluate the water quality for the irrigation, it was given as:

$$MH = Mg/(Ca + Mg) * 100$$

The value of MH >50 means harmful and unsuitable for irrigation, while it indicates suitable and not harmful for irrigation if MH <50 [14].

The MH values in the groundwater sample studied are less than 50 Table-4 indicating no magnesium hazard.

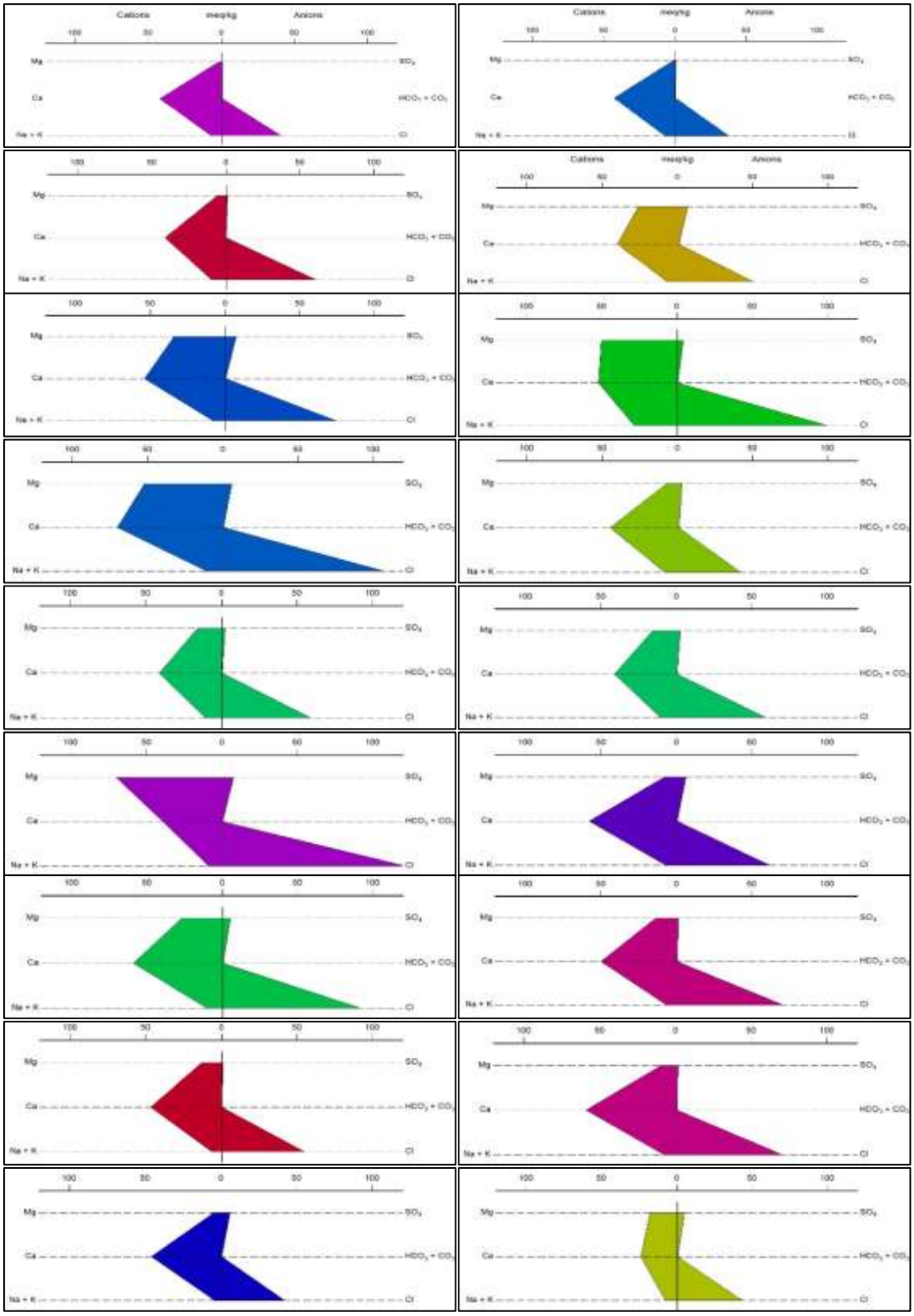

Figure 3- Stiff Diagram of the groundwater

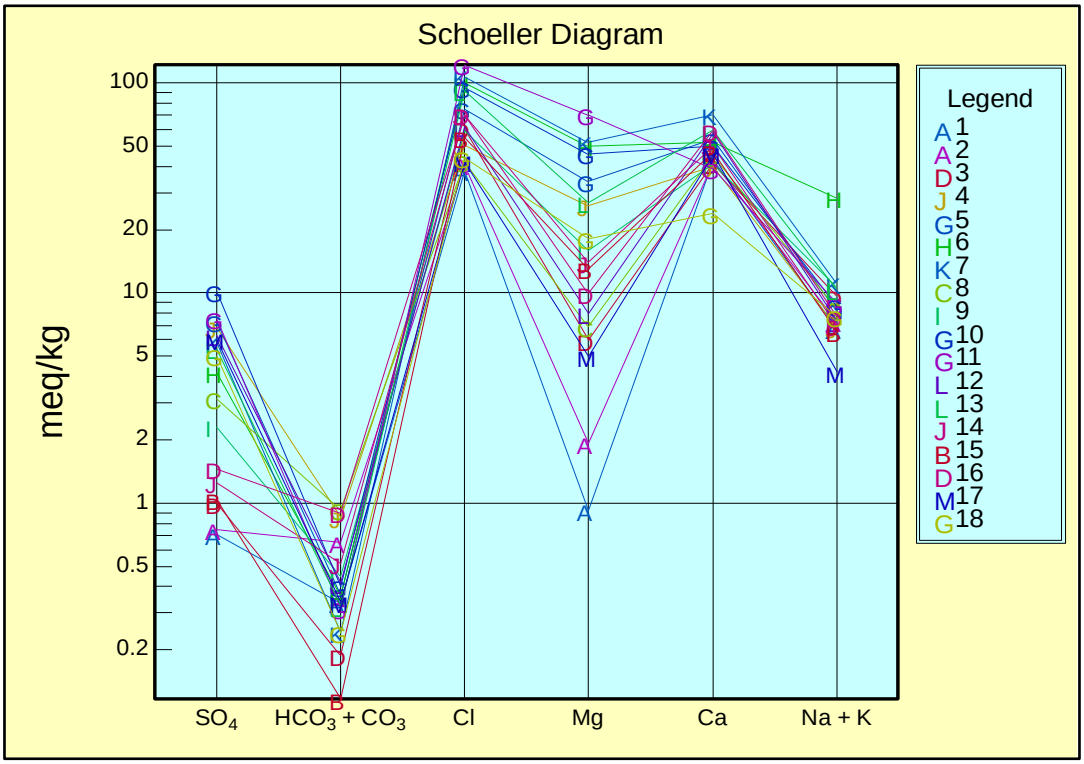

Figure 4-Piper Diagram of the groundwater.

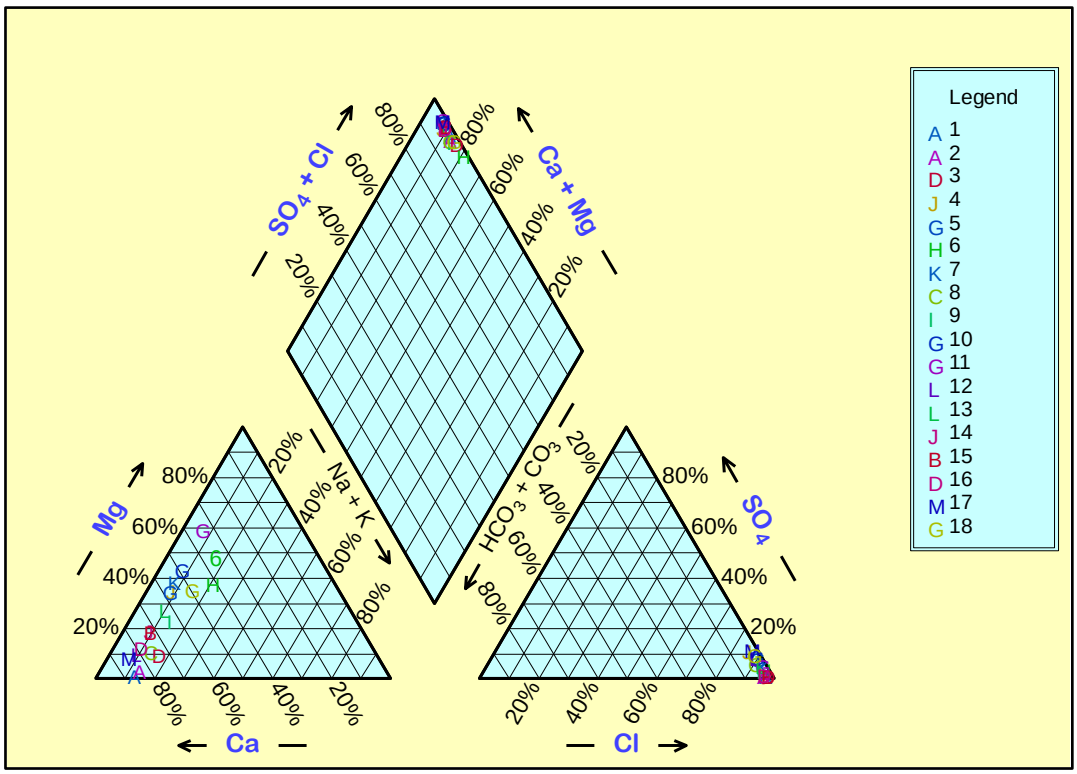

Figure 5- Piper diagram illustrates the groundwater chemistry type.

Table 4- Magnesium hazard (MH), SAR, TDS, EC and Na% values in the wells of the groundwater

Well No.	MH	SAR	TDS (ppm)	EC (µs/cm)	pH	Na %
1	0.13	1.19	4901	6980	7.2	13.34
2	0.27	1.25	5470	7740	7.2	14.22
3	0.81	1.60	7194	10220	7.3	17.08
4	2.81	0.91	5430	7600	7.3	9.39
5	2.76	1.02	7840	10880	7.4	8.48
6	3.69	0.99	8930	12400	7.7	7.99
7	3.11	1.25	9000	12570	7.3	8.32
8	0.85	1.39	6290	8930	7.6	13.87
9	1.91	1.74	6550	9220	7.8	15.66
10	3.59	0.34	9190	12930	7.0	8.24
11	5.22	0.35	10060	14250	7.6	7.59
12	0.76	0.43	6790	9670	7.3	9.98
13	2.17	0.49	10970	15490	7.6	10.82
14	1.45	0.24	7980	11200	7.4	9.83
15	1.43	0.33	6160	8710	7.5	9.86
16	0.93	0.36	7350	10300	7.9	9.93
17	0.61	0.04	5920	8380	7.1	7.55
18	3.13	0.74	5270	7420	7.3	15.42
Assessment	Not harmful	Excellent	Unsuitable	Unsuitable	Permissible	Excellent

b) Sodium Adsorption Ratio

Adsorption of sodium by soil can be expressed by the sodium adsorption ratio (SAR). It is the proportion of sodium to calcium and magnesium, which affect the availability of the water to the crop [15]. It is calculated using the following equation, where all ions are in meq/l:

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

All SAR values in all wells studied are evaluated as an excellent category due to their values (less than 3) Table-4.

c) TDS and EC

The TDS and EC are two parameters indicate the ions quantity, so they are widely used for evaluating the water quality. Salts of major cations such as Ca, Mg, Na, and K dissolved in the irrigation water cause harmful to plants. The excessive quantities cause reducing the osmotic activities of the plants and may prevent adequate aeration. The electrical Conductivity (EC) of an electric current is used to estimate physically the amount of dissolved solids. It increases as the amount of ions increases and vice versa. Values of the TDS and EC refer to unsuitable water for irrigation Table-4.

d) Percentage of sodium (Na %)

The percentage of sodium (Na %) which is also named soluble sodium percentage (SSP) was used to assess the water quality for irrigation purpose. The high content of Na in the irrigation water cause direct impact on the plant growth and soil quality as well [16]. Irrigation water with Na% > 60% may result in Na accumulation and possibly a deterioration of soil structure, infiltration, and aeration. The calculation of Na% can be done by using the equation below:

$$\%Na = [Na + k] \times 100 / [Ca + Mg + Na + K]$$

All ion concentrations are expressed in meq/l. The Na% values of the groundwater studied indicate a permissible irrigation water Table-4.

Conclusions

This study gave a detailed description of the physicochemical properties of the groundwater in the Dibdibba aquifer in the Zubair area at Basra city, southern Iraq. The groundwater is of high relative variation in TDS due to the variation in lithology where some mudstone lenses are occurred as proved

by the previous works. The variation in TDS also can be attributed to the seasonal wadies and unhomgenous of dissolution of the cover sediments of the Dibdibba Formation. The groundwater belongs to Na, Mg, Ca-Chloride type. The dominance of Ca is mainly sourced by gypsum dissolution, where the contact of the Dibdibba Formation with the underlying Fatha Formation is conformable in the study area. The groundwater quality type was assessed for the irrigation purpose Magnesium Hazard (MH), Sodium Adsorption Ratio (SAR), Na% along with the total dissolved solid (TDS), Electrical conductivity (EC) and pH. The groundwater is characterized by no Mg-harmful, excellent with SAR and Na%, permissible with pH values, but unsuitable in terms of TDS and EC due to high salinity represented by Ca and Cl.

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