Hussein and Abdulhussein *Iraqi Journal of Science, 2020, Vol. 61, No. 8, pp: 1978-1993*
DOI: 10.24996/ijs.2020.61.8,15

ISSN: 0067-2904

Hydrochemical Evaluation of Surface and Groundwater in Khan Al-Baghdadi Area, Al- Anbar Province / West of Iraq

Sarmad Jamal Hussein*, Firas Mudhafar Abdulhussein
Department of Geology, College of Science, University of Baghdad, Al-Jaderia, Baghdad, Iraq

Received: 29/9/2019 Accepted: 19/4/2019

Abstract

The hydrochemical study of the surface and groundwater in Khan AL-Baghdadi area included interpretation of physical, chemical and biological properties of 14 wells and 6 surface water samples collected from Euphrates River.. The study covered two periods representing dry and wet periods in October 2018 and April 2019, respectively. The surface water samples were characterized as slightly alkaline, fresh water, excessively mineralized, calcium-chloride type, and hard to very hard class. While the groundwater samples were characterized as slightly alkaline, brackish water, excessively mineralized, calcium-chloride and sodium-chloride type, and hard to very hard class. The assessment of water for irrigation purposes for both water sources in the dry period showed a Sodium Adsorption Ratio (SAR) of no harmful effects, while the Soluble Sodium Percentage (Na%) demonstrated a good irrigation Water Class, except for one well with a permissible irrigation Water Class. While in the wet period, all surface and groundwater samples were of a good irrigation Water Class, except for two wells with permissible irrigation Water Class. In terms of total dissolved solids (TDS) and electrical conductivity (EC), all surface water samples for the two periods were within the permissible limits of irrigation water quality, whereas groundwater samples for the two periods showed unsuitable limits, except for three wells within the permissible limits of irrigation water quality. The microbiological tests showed that all samples of surface and groundwater are classified as clean.

Keywords: Hydrogeochemical, Surface and Groundwater, Khan Al-Baghdadi.

التقييم الهيدروكيميائي للمياه السطحية والجوفية في منطقة خان البغدادي محافظة الانبار، غرب العراق

سرمد جمال حسين ، فراس مظفر عبدالحسين
قسم علم الارض، كلية العلوم، جامعة بغداد، بغداد، العراق

الخلاصة

تتضمن الدراسة الهيدروكيميائية للمياه السطحية والجوفية في منطقة خان البغدادي تفسير الخصائص الفيزيائية والكيميائية والبيولوجية عن طريق ١٤ بئراً و٦ نماذج من المياه السطحية لنهر الفرات بمنطقة خان البغدادي ولفترتين ،الفترة جافة في أكتوبر ٢٠١٨ والفترة الرطبة في أبريل ٢٠١٩. تتميز عينات المياه السطحية بالقلوية الخفيفة ، مياه عذبة ، شديدة التمعدن ، ونوع كلوريد الكالسيوم وذات عسرة عالية جدا. في حين تتميز عينات المياه الجوفية بالقلوية الخفيفة ، والمياه المالحة ،شديدة التمعدن ،ونوع كلوريد الكالسيوم و كلوريد الصوديوم وذات عسرة عالية جدا. أظهرت المياه (الآبار ومياه النهر) التي تم تقييمها لأغراض الري أن

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*Email: sarmadgamal6656@gmail.com

نسبة امتصاص الصوديوم (SAR) ليس لها أي آثار ضارة من الصوديوم ، نسبة الصوديوم الذائبة((Na%) في الفترة الجافة ، جميع عينات المياه السطحية والجوفية هي مياه ري جيدة ، باستثناء بئر واحد كان من المياه الصالحة للري ، في حين أن جميع عينات المياه السطحية والجوفية في الفترة الرطبة هي مياه الري الجيدة ، باستثناء بئرين مسموح بهما لمياه الري ، ومن حيث (TDS) و (EC) ، تكون جميع عينات المياه السطحية لفترتين داخل الحدود المسموح بها لجودة مياه الري ، لكن جميع عينات المياه الجوفية لفترتين تقع ضمن الحدود غير المناسبة لجودة مياه الري ، باستثناء ثلاثة ابار داخل الحدود المسموح بها لجودة مياه الري.أظهرت الاختبارات البيولوجية أن جميع عينات المياه السطحية والجوفية تصنف على أنها نظيفة.

Introduction

Surface water and groundwater contain different kinds of salts with different concentrations, depending on their sources and the amount of soluble constituents present in the geological formations through which these waters pass [1]. The quality of groundwater depends on its purpose, while the needs for drinking water, industrial water, and irrigation water vary widely [2]. The study area is located in the northwestern part of Al-Anbar governorate, between the latitudes 33 º 47 ' - 34 º 0 ' N and longitudes 42º 28'- 42 º 45' E. The area of Khan Al-Baghdadi, represents the main focus of the present research (Figure-1). The region is characterized by a location that is parallel to the Euphrates River.

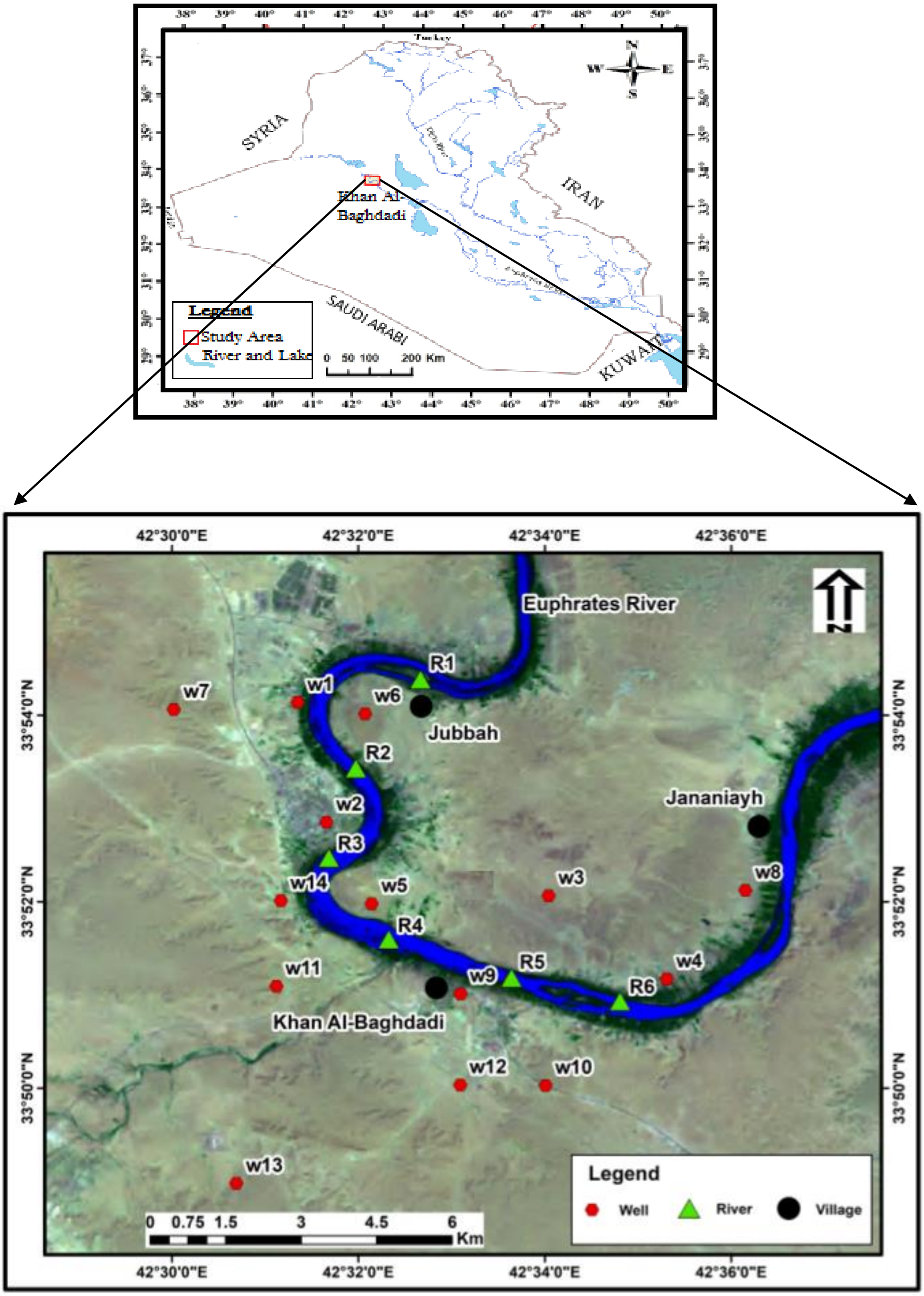


Figure1-Location map showing the study area and water sampling sites.

Table 1-Coordinates of the studied samples

Samples No.	Latitude	Longitude	Well depth(m)
W.1	33.9022	42.5225	58
W.2	33.8808	42.5275	80
W.3	33.8681	42.5675	42
W.4	33.8525	42.5850	32
W.5	33.8669	42.5356	31
W.6	33.9006	42.5342	40
W.7	33.9014	42.5000	70
W.8	33.8686	42.6022	50
W.9	33.8508	42.5517	35
W.10	33.8344	42.5667	30
W.11	33.8519	42.5186	50
W.12	33.8333	42.5519	70
W.13	33.8169	42.5114	50
W.14	33.8672	42.5189	55
R.1	33.9059	42.5446	_
R.2	33.8899	42.5326	_
R.3	33.8744	42.5272	_
R.4	33.8588	42.5388	_
R.5	33.8527	42.5604	_
R.6	33.8485	42.5798	_

W:Groundwater, R:Surface water

Materials and Methods

The laboratory works included the physical and chemical analysis of water samples in the laboratory of the Ministry of Science and Technology. It represents a total of 14 well samples and 6 samples from Euphrates River collected in October 2018 and April 2019. The measurements were conducted according to the standard methods [3] and included hydrogen number (pH), EC, TDS, and temperature (T) using TDS-EC-pH-T meter. Calcium, magnesium, chloride and bicarbonate, sodium and potassium were analyzed using flame photometer. Sulfate was determined by spectrophotometer. Trace elements were determined by atomic absorption spectrometer. Rock Ware AqQa version 1.1 was used for classification of water and determination of water type. The coordinates for each sample, including longitude, latitude and elevation were measured using GPS. The accuracy of the results was determined using the equation below [4]:

$$U\% = \left| \frac{r\sum \text{cations} - r\sum \text{anions}}{r\sum \text{cations} + r\sum \text{anions}} \right| \times 100 \quad \text{.......(1)}$$

$$A = 100 - U \quad \text{.......... (2)}$$

where:

U%: Uncertainty (reaction error).

A: Certainty or Accuracy.

When uncertainty or reaction error was U%≤5, the results could be certain or accepted for interpretation, but if $5 < U\% \leq 10$, the results are probably certain, while if U% >10% the results are uncertain [5]. For assessing irrigation water quality, parameters such as the percentage of sodium (Na%) and sodium adsorption ratio (SAR) were calculated depend on the chemical variables of water samples [6] .The total hardness (TH) was measured by the equation below[7]:

$$TH = 2.497\ Ca^{2+} + 4.115\ Mg^{2+} \quad \text{........... (3).}$$

Furthermore, TDS (mg/L) and pH values were calculated as in the following equation [7]:

$$TDS(mg/l)\,\frac{(SO_4^{2-}.Cl^{-}.HCO_3^{-}.CO_3^{2-})}{(Na^{+}.Ca^{2+}.Mg^{2+}.K^{+})}\,pH \quad \text{...............(4).}$$

Geological Setting

The exposed formations within the study area ranged in age from Oligocene to Pliocene, with different types of Quaternary deposits. The western shoreline receded towards the area of the present day Euphrates River, which crosses many geological formations within the stable shelf of the Nubian-Arabian craton in Iraq. In Iraq, Oligocene sediments are absent over most of Rutba subzone, Salman zone, and Zubair and Euphrates subzones of Mesopotamia [8]. The exposures of the formations of the study area (Figure-2) can be described as follows.

Anah Formation (Lower Oligocene)

The formation consists of massive, coralline, creamy, very hard limestone and dolomite limestone, which are locally strongly karstified leading to cavities and caverns of different sizes [9].

Euphrates Formation (Lower Miocene)

The Euphrates formation is depositional in atypical shallow marine facies of tropical to subtropical conditions. The two members of this formation are described below[10]:

- Lower Member: The pebbles are composed of limestone and dolomite, and they are fine crystalline, hard, and angular subangular to rounded splintary. They are cemented by calcareous and clayey matrix, overlain by limestone, dolomitized, recrystallized thickly bedded, fossiliferrous grey, and very hard.
- Upper Member: It consists of marl, bracciated limestone, dolostone, marly limestone and dolomite limestone.

Fatha Formation (Lower Fars) (Middle Miocene)

The formation, located east of Euphrates, is developed in its normal lithological constituents of the nature cycle (marl, limestone, gypsum and claystone). It is divided into four members, each exposed on one side of the Euphrates river [10].

Quaternary Deposits (Pleistocene to Holocene)

These deposits are divided into the following units [10]:

- River Terraces (Pleistocene)

The terraces are preserved in the study area along the Euphrates river. They are composed of medium grained, well rounded pebbles which consist of chert, flint and limestone with admixture of igneous and metamorphic rocks.

- Gypcrete (Pleistocene-Holocene)

The formation of gypcrete is restricted mainly to the eastern part of the study area. It is composed of secondary gypsum or highly gypiferous soil.

- Slope deposits (Pleistocene -Holocene)

The lithology of these deposits is sand, silt and clay with rock fragments. They are occasionally rich in secondary gypsum mixed with loamy soil.

- Residual Soil (Pleistocene-Holocene)

This is considered as gypcrete due to the very high content of secondary gypsum. In areas where gypsum is absent, the residual soil consists of sandy, silty, clayey, brown soil with limestone fragments. Gypsum is spread as a result of the erosions from Fatha formation.

- Valley fill deposits (Holocene)

The floor of deep valleys in the study area is covered by gravels mixed with sand and high admixture of rock fragments.

-Flood plain deposits (Holocene)

The Euphrates river has sandy, salty and clayey materials on both sides of its valley. The width and thickness are also variable. They are occupied as agriculture fields.

Sabkha deposits(Holocene)

These are composed of salt accumulation on mainly muddy soil. Locally, the salt is coarse crystalline with continuous growth of crystals.

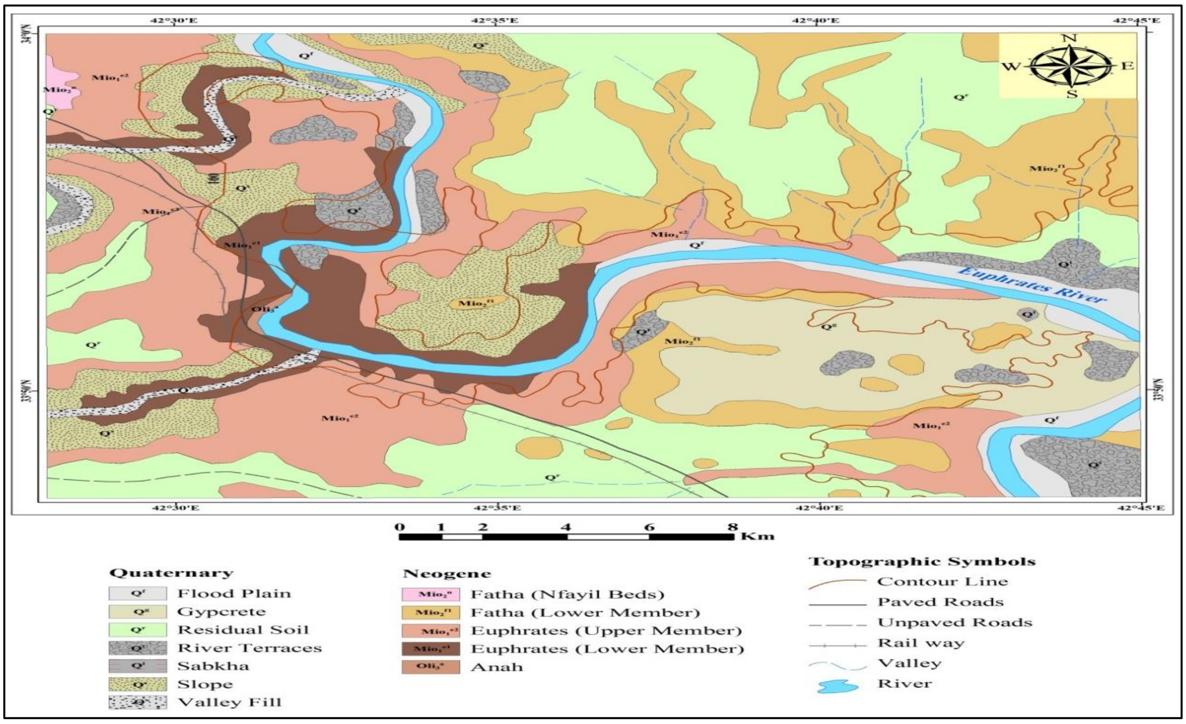


Figure 2-Geological map of Khan Al-Baghdadi area (GEOSURV).

Results and discussion

Physical Properties

The main goals of studying the physicochemical characteristics of water are to determine the origin of water and the degree of pollution [11]. The results of physical analysis of the surface and groundwater samples are shown in Table-2.

Table 2-The physical values of water samples in the study area

Samples No.	Dry period				Wet period			
	T(C°)	pH	TDS(ppm)	EC(μs/m)	T(C°)	pH	TDS(ppm)	EC(μs/cm)
W.1	22.3	7.9	3672	5682	20.1	7.0	3270	5162
W.2	22.5	7.9	1557	2547	19.1	7.2	1528	2431
W.3	23.1	8.0	1922	2871	21.1	7.0	1861	2625
W.4	23.2	7.8	3860	5768	21.9	7.4	3283	5286
W.5	24.8	7.7	2550	3885	23.6	7.3	2136	3345
W.6	25.2	7.9	1127	1597	20.1	7.1	1097	1357
W.7	25.9	7.7	4888	7294	21.7	7.0	4342	6832
W.8	25.2	7.8	3521	5438	24.4	7.1	2910	4854
W.9	22.5	7.9	2719	4031	20.2	7.3	2097	3142
W.10	26.7	7.5	3719	5586	19.9	7.1	3531	5264
W.11	25.9	7.9	4062	7301	24.8	7.3	3801	6231
W.12	28.9	7.1	4725	7543	25.4	7.2	4380	7247
W.13	27.1	8.0	2988	4278	25.1	7.1	2882	4089
W.14	24.2	7.7	2675	3883	24.7	7.1	2504	3880
R.1	27.2	7.5	651	1465	25.7	7.8	630	1327
R.2	28.1	7.5	643	1437	28.8	7.0	637	1336
R.3	27.4	7.4	647	1453	24.1	7.1	619	1316
R.4	29.3	7.6	642	1402	26.3	7.3	614	1313
R.5	28.2	7.4	644	1446	25.2	7.4	618	1309
R.6	27.5	7.4	652	1471	27.4	7.3	627	1321

Temperature (T)

Water temperature is related to solar radiation and air temperature, where water temperature of streams and springs closely follows air temperature [12]. The temperature of the surface water samples for the dry period ranged between 27.2° and 29.3° with an average of 27.95°; whereas that for the wet period ranged between 24.1° and 28.8° with an average of 26.17°. The temperature of groundwater samples for the dry period ranged 22.3°-28.9° with an average of 24.82°, whereas that for wet the period ranged 19.1°-25.4° with an average of 22.29°.

Hydrogen Ion Concentration (pH)

The pH of surface water samples in the study area for the dry period ranges between (7.4-7.6) with an average (7.4), and for wet period ranges (7.0-7.8), with average (7.3). The pH of groundwater samples for the dry period ranges between (7.1- 8.0) with average (7.77), and for the wet period ranges between (7.0- 7.4) with average (7.66). According to a previous study [13], the water samples are slightly alkaline.

Total Dissolved Solids (TDS)

The TDS of surface water samples for dry period ranges between (635-652) with average (645.3), and for wet period ranges between (614 -637) with average (624.1). TDS of groundwater samples for dry period ranges between (1127 -4589) with average (3132), and for wet period ranges between (1097 -4380) with average (2822). It is clear that the salinity in the dry period is higher than that for the wet period, which is due to the dilution occurring in the wet period as a result of rainfall. According to a previous report [7], all surface water samples for the two periods are classified as fresh water, while the groundwater samples are classified as brackish water.

Table 3-Classification of water salinity of the present study according to (Todd, 2007).

Water Class	Todd, (2007)	Dry Period	Wet period
Fresh Water	10-1000	All surface water samples	All surface water samples
Brackish Water	1000-10000	All groundwater samples	All groundwater samples
Salty Water	10000-100000		
Brine Water	<100000		

Electrical Conductivity(EC)

The EC of water samples for dry period ranges between (1402 -1471) with average (1445.6) , and for wet period ranges between (1313 -1336) with average (1320.3), while the EC of groundwater samples for dry period ranges between (1597 -7543) with average (4836) , and for wet period ranges between (1357 -7247) with average (4410). It is clear that the electrical conductivity in the dry period is was higher than that in the wet period, which is due to the dilution resulted from rainfall recharge to the ground water, leading to a decrease in ion concentration in water during the wet period. According to a previous report [11], the type of all surface and groundwater samples in the study area for the two periods is excessively mineralized water.

Table 4-Relationship between Electrical Conductivity and Mineralization according to (Detay, 1997)

EC µS/cm	Mineralization	Dry Period	Wet period
<100	Very Weakly Mineralized water	-----	-----
100-200	Weakly Mineralized water	-----	-----
200-400	Slightly Mineralized water	-----	-----
400-600	Moderately Mineralized water	-----	-----
600-1000	Highly Mineralized water	-----	-----
>1000	Excessively Mineralized water	All surface and groundwater samples	All surface and groundwater samples

Chemical Properties

The chemistry of water is detected mainly by ion concentrations. More than 90% of the dissolved solids in groundwater can be attributed to seven ions: Ca^{2+},Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-} and HCO_3^{-} [14]. The results of the chemical examination of the samples from the present study are shown in Tables -(5 and 6).

Table 5-Results of chemical analysis and total hardness of the water samples in the dry period

Samples N0.	Unit	Ca	Mg	Na	K	∑ Cations	HCO3	SO4	Cl	∑ Anions	TH (ppm)
W.1	ppm	407	235	440	16	1098	213	1299	1034	2546	1983.35
	epm	20.35	19.58	19.13	0.41	59.47	3.49	27.06	29.54	60.09	
W.2	ppm	170	78	220	2.7	470.7	132	488	452	1072	745.58
	epm	8.50	6.50	9.56	0.069	24.63	2.64	10.17	12.91	25.24	
W.3	ppm	210	98	268	4	580	194	533	574	1268	927.78
	epm	10.50	8.16	11.65	0.103	30.42	2.64	11.10	16.40	30.14	
W.4	ppm	388	254	494	10.5	1146.5	237	1193	1258	2688	2013.94
	epm	19.40	21.16	21.47	0.269	62.31	3.89	24.85	35.94	64.68	
W.5	ppm	254	170	333	12	769	167	812	798	1777	1333.7
	epm	12.70	14.16	14.47	0.308	41.65	2.74	16.92	22.80	42.45	
W.6	ppm	123	47	155	2.7	327.7	142	309	338	789	500.67
	epm	6.15	3.91	6.73	0.069	16.88	2.33	6.44	9.66	18.42	
W.7	ppm	589	302	578	16	1485	367	1400	1622	3389	2713.72
	epm	29.45	25.16	25.13	0.41	80.16	6.02	29.17	46.34	81.52	
W.8	ppm	432	210	478	24.7	1144.7	232	923	1213	2368	1943.1
	epm	21.60	17.50	20.78	0.63	60.52	3.80	19.23	34.66	57.69	
W.9	ppm	301	169	358	12.8	840.8	189	793	890	1872	1447.09
	epm	15.05	14.08	15.56	0.72	45.03	3.10	16.52	25.43	45.04	
W.10	ppm	467	210	430	24.7	1131.7	245	935	1401	2581	2030.6
	epm	23.35	17.50	18.69	0.63	60.18	4.02	19.48	40.03	63.52	
W.11	ppm	413	245	482	19.2	1159.2	234	1432	1231	1666	2039.45
	epm	20.65	20.41	20.95	0.49	62.52	3.84	29.83	35.17	68.84	
W.12	ppm	563	312	546	13	1434	342	1507	1285	3148	2689.82
	epm	28.15	26	23.73	0.33	78.22	5.84	31.40	36.71	73.95	
W.13	ppm	312	188	360	14.7	874.7	230	892	978	2100	1552.68
	epm	15.60	15.66	15.65	0.37	47.30	3.77	18.58	27.94	50.29	
W.14	ppm	288	156	367	12	823	145	813	890	1848	1361.16
	epm	14.40	13	15.95	0.308	43.66	2.38	16.94	25.43	44.74	
R.1	ppm	85	21	80	2.7	188.7	136	178	142	456	298.81
	epm	4.25	1.75	3.47	0.06	9.55	2.23	3.71	4.06	9.99	
R.2	ppm	85	20	80	2.8	187.8	132	172	145	449	294.70
	epm	4.25	1.66	3.47	0.07	9.47	2.16	3.58	4.14	9.90	
R.3	ppm	84	20	79	2.7	185.7	137	175	143	455	292.20
	epm	4.20	1.66	3.43	0.06	9.37	2.25	3.65	4.09	9.99	
R.4	ppm	84	21	78	2.9	185.9	139	171	141	451	296.31
	epm	4.20	1.75	3.39	0.07	9.42	2.28	3.56	4.03	9.87	
R.5	ppm	84	20	79	2.8	185.8	133	173	146	452	292.20
	epm	4.20	1.66	3.43	0.07	9.37	2.18	3.60	4.17	9.97	
R.6	ppm	86	20	80	2.7	188.7	135	175	147	457	297.20
	epm	4.30	1.66	3.47	0.06	9.51	2.21	3.65	4.20	9.97	

Table 6-Results of chemical analysis and total hardness of the water samples in the wet period

Sample N0.	Unit	Ca	Mg	Na	K	∑ Cations	HCO3	SO4	Cl	∑ Anions	TH (ppm)
W.1	ppm	452	124	483	1.3	1060.3	176	1087	931	2194	1639.64
	epm	22.60	10.33	21.00	0.03	53.96	2.88	22.64	26.60	52.13	
W.2	ppm	187	87	213	0.9	487.9	124	464	442	1030	825.07
	epm	9.35	7.25	9.26	0.02	25.88	2.03	9.66	12.62	24.32	
W.3	ppm	227	108	276	0.98	611.9	176	493	568	1237	1011.38
	epm	11.35	9.00	12.00	0.02	32.37	2.88	10.27	16.22	29.38	
W.4	ppm	474	139	452	1.2	1066.2	186	1034	976	2196	1756.29
	epm	23.70	11.58	19.65	0.03	54.96	3.04	21.54	27.88	52.47	
W.5	ppm	306	97	283	1.07	687.07	138	685	613	1436	1163.67
	epm	15.30	8.08	12.30	0.02	35.71	2.26	14.27	17.51	34.04	
W.6	ppm	145	48	174	1.2	368.2	93	298	329	720	559.78
	epm	7.25	4.00	7.56	0.03	18.84	1.52	6.20	9.40	17.13	
W.7	ppm	641	182	607	1.4	1431.4	336	1321	1236	2893	2350.52
	epm	32.05	15.16	26.39	0.03	73.64	5.50	27.52	35.31	68.34	
W.8	ppm	384	142	327	0.99	853.99	178	763	1092	2033	1543.62
	epm	19.20	11.83	14.21	0.02	45.27	2.91	15.89	31.20	50.01	
W.9	ppm	300	83	304	1.01	688.01	124	586	683	1393	1091.13
	epm	15.00	6.91	13.21	0.02	35.61	2.03	12.20	19.51	33.75	
W.10	ppm	513	184	475	1.43	1173.43	217	894	1231	2342	2038.74
	epm	25.65	15.33	20.65	0.03	61.67	3.55	18.62	35.17	57.35	
W.11	ppm	452	201	520	1.8	1174.8	176	1261	1176	1437	1956.11
	epm	22.60	16.75	22.60	0.04	62.00	2.88	26.27	33.60	62.75	
W.12	ppm	594	234	563	1.2	1392.2	274	1397	1173	2863	2446.74
	epm	29.70	19.50	24.47	0.03	73.70	4.49	29.10	33.51	67.42	
W.13	ppm	342	201	384	1.1	928.1	242	821	873	1936	1681.11
	epm	17.10	16.75	16.69	0.02	50.57	3.96	17.10	24.94	46.01	
W.14	ppm	352	85	402	1.02	840.02	127	740	786	1653	1229.35
	epm	17.60	7.08	17.47	0.02	42.18	2.08	15.41	22.45	39.95	
R.1	ppm	97	28	67	0.51	192.5	134	167	131	432	357.58
	epm	4.85	2.33	2.91	0.01	10.10	2.19	3.47	3.74	9.41	
R.2	ppm	91	31	73	0.52	195.5	137	163	136	436	354.91
	epm	4.55	25.03	3.17	0.01	10.32	2.24	3.39	3.88	9.52	
R.3	ppm	95	29	62	0.48	186.4	135	165	127	427	356.69
	epm	4.75	2.41	2.69	0.01	9.87	2.21	3.43	3.62	9.27	
R.4	ppm	93	26	65	0.47	184.4	131	168	126	425	339.36
	Epm	4.65	2.16	2.82	0.01	9.65	2.14	3.50	3.60	9.24	
R.5	ppm	96	25	63	0.48	184.3	136	158	135	429	342.75
	epm	4.80	2.08	2.73	0.01	9.63	2.23	3.29	3.85	9.37	
R.6	ppm	92	27	71	0.49	190.4	137	166	128	431	340.97
	epm	4.60	2.25	3.08	0.01	9.95	2.24	3.45	3.65	9.36	

Calcium ion (Ca^{2+})

The Calcium concentration of surface water samples during dry period ranges between (84-86)ppm with average (84.67)ppm, but during wet period it ranges between (91-97) ppm with average(94) ppm. The higher value of Calcium ion in Euphrates River water is due to the agriculture area and its waste water by irrigation canals. In addition, most Calcium in surface water comes from streams flowing over gypsum, limestone and other calcium-containing rocks and minerals [15]. Calcium concentration of groundwater samples in dry period ranges between (123 -589) ppm with an average (351.22) ppm, while in wet period ranges between (145 -641) ppm with an average (383.5) ppm (Figure-2). The high concentration of calcium in groundwater samples results from the dissolution of limestone of Euphrates Formation in the study area [15].

Magnesium (Mg^{2+})

Magnesium concentration of surface water samples during dry period ranges between (20- 21) ppm with average (20.33) ppm, but during wet period it ranges between (25-31) ppm with average (27.67)ppm. Magnesium concentration of groundwater samples in dry period ranges between (47-312) ppm with average (191) ppm, while in wet period ranges between (48- 234) ppm with average (136.79) ppm, Fig.2. The main source of magnesium in the studied area is the geological units and dissolution of dolomite limestone of Euphrates Formation [15].

Sodium (Na^{+})

Sodium concentration of surface water samples during dry period ranges between (78-80) ppm with average (78.33) ppm, but during wet period it ranges between (62-73) ppm with average (66.83) ppm. Sodium concentration in groundwater samples in dry period ranges between (155- 578) ppm with average (393.50) ppm, while in wet period ranges between (174- 607) ppm with average (390.22) ppm (Fig.2). The source of sodium in the studied area is clay, mineral soil, and evaporation deposits from Fatha Formation[15].

Potassium (K^{+})

Potassium concentration of surface water samples during dry period, ranges between (2.7-2.9) ppm with average(2.7) ppm, but during wet period it ranges between (0.47-0.52) ppm with average (0.49) ppm. Potassium concentration of groundwater samples in dry period ranges between (2.7- 24.7) ppm with average (13.22) ppm, while in wet period ranges between (0.9- 1.8) ppm with average (1.19) ppm (Figure-2). Potassium is commonly present in clays within structures such as illite or adsorbed on other clay minerals [15].

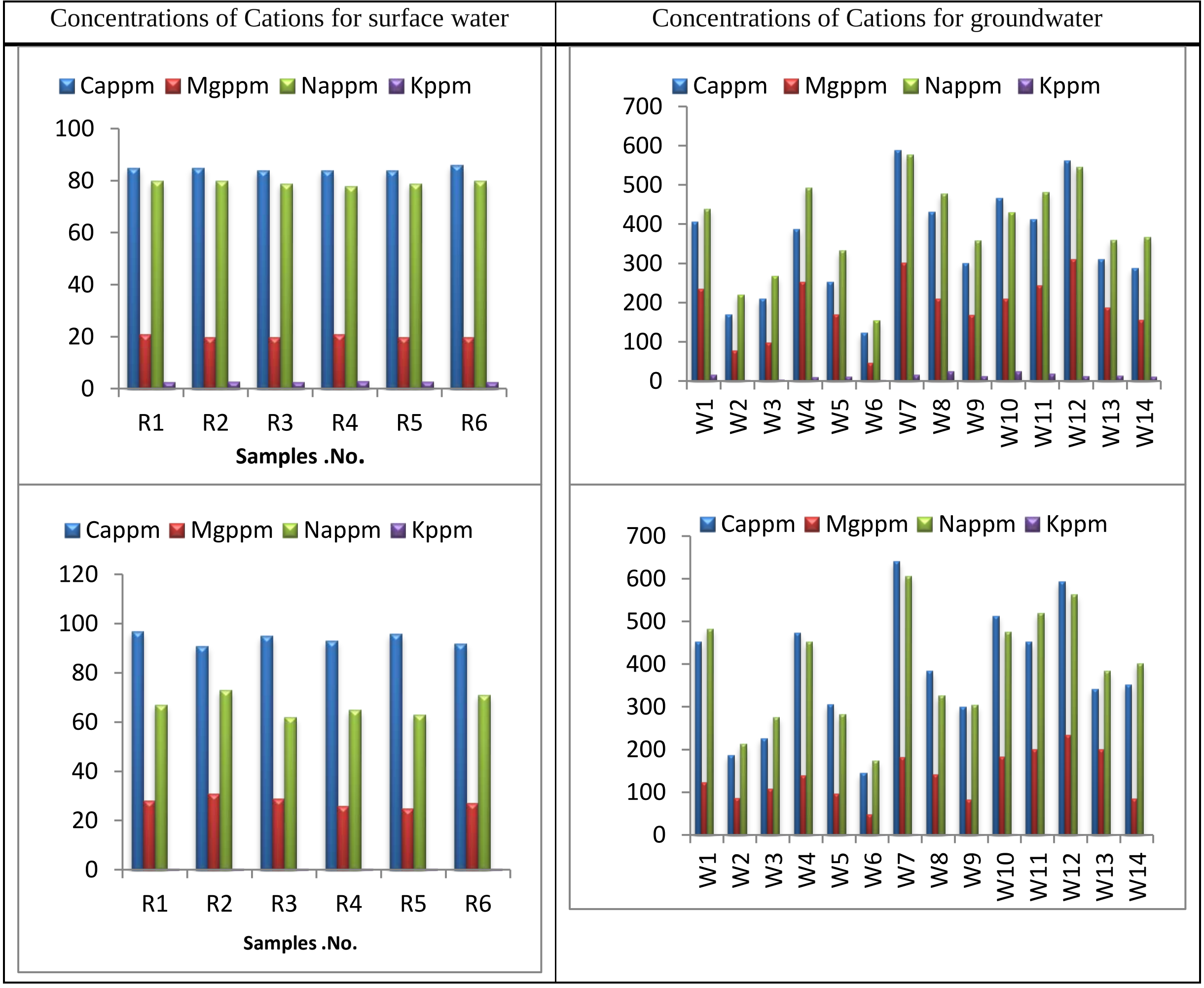


Figure 2-Concentration of cations in water samples for dry and wet periods.

Sulfate (SO_4^{2-})

Sulfate concentration of surface water samples during dry period ranges between (171-178)ppm with average (174) ppm in, but during wet period it ranges between (158-168) ppm with average(164.5) ppm. Concentration of sulfate of groundwater samples in dry period ranges between (309-1507) ppm with average (952.07) ppm, while in wet period ranges between (298- 1697) ppm with average (846) ppm (Fig.3). The main source of sulfate ion in the study area is solutions of sulfate minerals that exist in evaporate rocks such as gypsum of Fatha Formation as well as the anhydrites [15].

Chloride (Cl^-)

Chloride concentration of surface water samples in dry period ranges between (141- 147) ppm with average 144 ppm, while in wet period ranges between (126- 136) ppm with average 130.50 ppm. Chloride concentration of groundwater samples in dry period ranges between (338- 1622) ppm with average (981.58) ppm, while in wet period ranges between (329- 1236) ppm with average (864.92) ppm (Fig.3). The source of chloride in the studied area is from layers of salts of Halite. The high concentration of chloride in groundwater samples is also due to Halite beds and clay [15]. The decrease of Cl^- concentration in the wet period is due to the dilution process by rainfall.

Bicarbonates (HCO_3^-)

When pH is lower than 8.2, the hydrogen ion is added to the carbonate and become dissolved bicarbonate, but when the pH is higher than 8.2, the process of HCO_3^- depletion to CO_3^{2-} in solution becomes faster [19]. The bicarbonate concentration of surface water samples in dry period ranges between (131- 137) ppm with average (133.67) ppm, while in wet period it ranges between (132- 139) ppm with average (135.3) ppm. Bicarbonate concentration of groundwater samples in dry period ranges between (132- 367) ppm with average (183.36) ppm, while in wet period ranges between (93-336) ppm with average (217.86) ppm (Figure-3). The sources of HCO_3^- in the studied area include clay mineral, soil, and limestone. The high concentration of bicarbonates in groundwater samples is due to the dissolved carbon dioxide in rain water and the solutions of limestone rocks of the Euphrates Formation[15].

Concentration of Anions for surface water	Concentration of Anions for groundwater

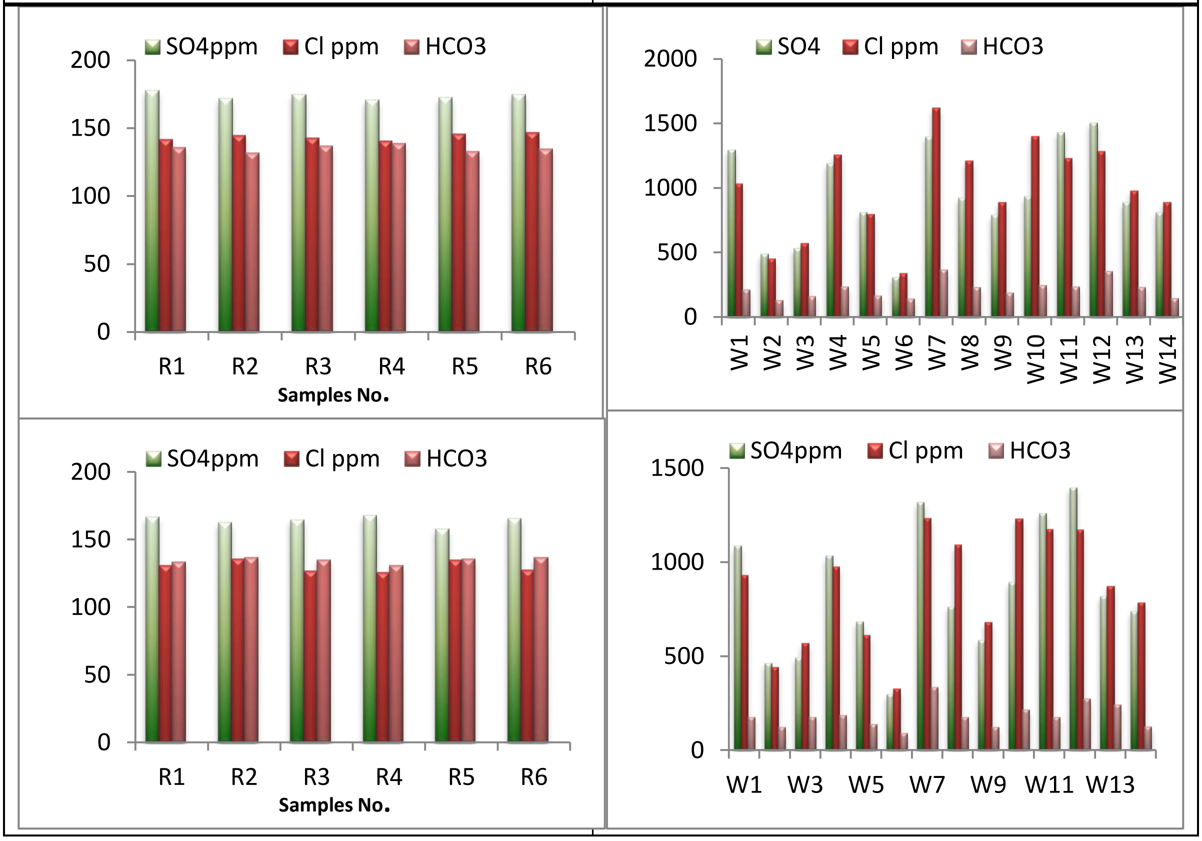


Figure 3-Concentrations of anions in water samples for dry and wet periods.

Total Hardness (TH)

TH can be measured by the following equation [7]:

$$TH = 2.497\ Ca^{2+} + 4.115\ Mg^{2+} \qquad \text{…….. (3)}$$

where TH, Ca, and Mg are measured in ppm.

Total hardness of surface water samples during the dry period ranged between (292.2 -298.8) ppm with average of (295.2) ppm, and the wet period ranged between (339.36 -357.58) ppm with average of (348.71) ppm. TH concentration of groundwater samples in dry period ranges between (500.67 -2713.72) ppm with average (1663.04) ppm, while in wet period ranges between (559.78 -2446.74) ppm with average (1520.93) ppm. TH values for both periods were compared with classifications of water hardness [7], and as a result the groundwater in the studied area is classified as very hard water due to wide exposures to limestone in the study area.

Table 7-Classification of water according to total hardness (Todd,2007).

Type of water	Todd (2007)	Dry Period	Wet Period
Soft	0-60		
Moderate Hard	60-120		
Hard	120-180		
Very Hard	>180	All surface and groundwater samples	All surface and groundwater samples

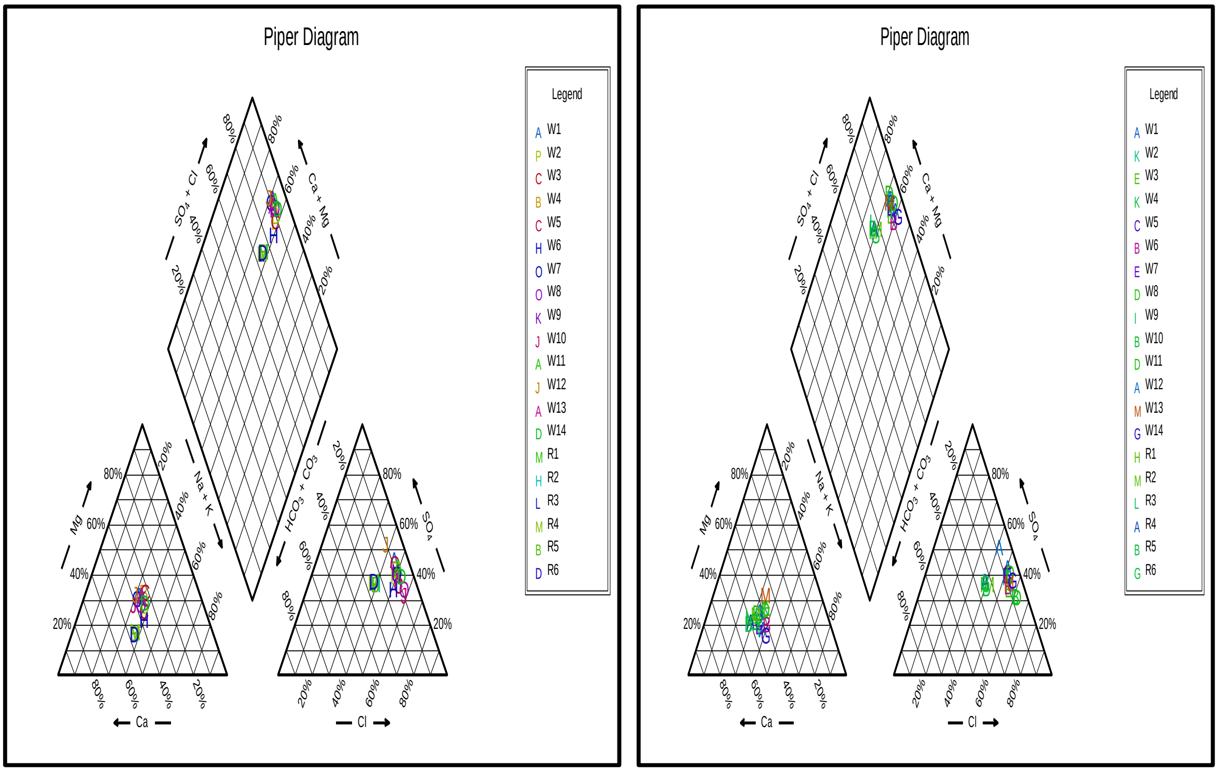
Trace elements

Trace elements are defined as metallic elements of atomic numbers that exceed twenty. Their main sources are weathering rocks or human activities [16]. The Euphrates River and groundwater samples were analysed for trace elements (Pb, Zn , Cd , Cu, Cr, Ni and Fe) for the two periods. In the wet period, the concentrations of trace elements were lower than the detection limit of the device , possibly due to dilution processes by rainfall, while in the dry period the device could only detect Fe, Zn.

Classification of Surface and Groundwater Water

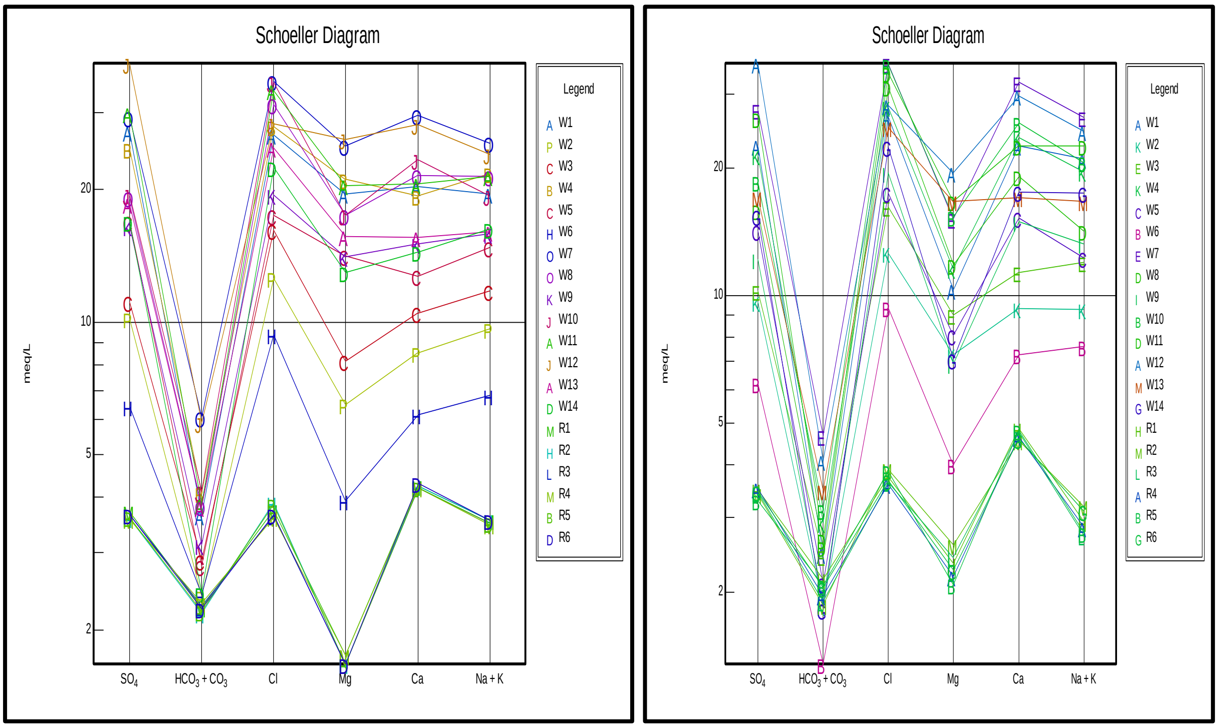
The variation in the existing water types points the interaction between factors such as lithology, recharge, geochemistry of the aquifer and depths of the wells [17].

Several classifications were used to determine water type, such as those described by Piper [18]and Shcoeller [19]. When applying piper classification on the water samples from the study area (Fig 4-a, 4 -b), all the water samples for the two periods fell in class e, which represents earth alkaline water with an increased portion of alkali and prevailing sulfate and chloride. Others samples fell in class g, which represents alkaline water with prevailing sulfate and chloride. The development of salty groundwater which exhibits high salinity (3000<TDS<10000 mg.L-1) can be explained by the dissolution of gypsum (CaSO4.2H2O). According to Scholler classification[19], the surface water samples were with prevailing Ca-Cl family and with a group of chloride, whereas the groundwater samples were with prevailing Ca-Cl and Na-Cl families and with a group of chloride.



(a) (b)

Figure 4-Piper diagram displaying water facies in Khan Al-Baghdadi area,(a):dry period,(b):wet period.



(a) (b)

Figure 5- Schoeller diagram of the surface water and groundwater samples (a): dry period, (b):wet period.

Water assessment for irrigation

Al-Baghdadi is an agricultural area where the population works in agriculture. The suitability of water for irrigation depends on the kind and amount of salts present in the water and their effects on crop growth and development. Four parameters that are widely used for assessing the water quality (TDS, EC, SAR and Na%) for irrigation were investigated [7]. The standard categories for each parameter are listed in Table-7 and the results are listed in Table-8.

Table 8-The standard categories used for the water assessment for irrigation purpose according to the 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

Sodium Adsorption Ratio (SAR)

The sodium hazard is typically expressed as the sodium adsorption ratio (SAR). High values of SAR indicate a hazard of sodium due to replacing the absorbed calcium and magnesium, a situation ultimately damaging the soil structure [15]. SAR values are calculated according to the following equation[7]:

$$SAR=\frac{Na^{+}}{\sqrt{\left(\frac{Ca^{2+}+Mg^{2+}}{2}\right)}} \qquad ......(5)$$

All SAR values in all wells studied indicated a Good category, due to high values (more than 3) as shown in the above classification (Table7), whereas all surface water samples were evaluated as having an excellent category due to their lower values (less than 3) (Table-9).

Table 9-SAR, TDS, EC and Na% values of the surface and groundwater for two periods

Sample No.	Dry Period				Wet Period			
	SAR	Na%	EC (μS/cm)	TDS (ppm)	SAR	Na%	EC (μS/cm)	TDS (ppm)
W.1	4.28	32.86	5682	3672	5.18	38.97	5162	3270
W.2	3.49	39.11	2547	1557	3.21	35.87	2431	1528
W.3	3.81	38.64	2871	1922	3.76	37.14	2625	1861
W.4	4.77	34.90	5768	3860	4.68	35.81	5286	3283
W.5	3.95	35.50	3885	2550	3.60	34.53	3345	2136
W.6	3.00	40.35	1597	1127	3.19	40.31	1357	1097
W.7	4.81	31.86	7294	4888	5.43	35.89	6832	4342
W.8	4.70	35.39	5438	3521	3.61	31.46	5047	2910
W.9	4.08	35.30	4031	2719	3.99	37.67	3142	2097
W.10	4.14	32.12	5586	3719	4.56	33.55	5264	3531
W.11	4.62	34.31	7301	4062	5.10	36.54	6231	3801
W.12	4.56	30.77	7543	4589	4.94	33.25	7247	4261
W.13	3.96	33.89	4623	2988	4.06	33.07	4103	2882
W.14	4.31	37.25	3883	2675	4.98	41.49	3880	2504
R.1	2.01	37.16	1465	651	1.54	28.94	1327	630
R.2	2.02	37.50	1437	643	1.68	30.88	1336	637
R.3	2.01	37.39	1453	647	1.42	27.42	1316	619
R.4	1.97	36.81	1402	642	1.53	29.40	1313	614
R.5	2.01	37.41	1446	644	1.48	28.56	1309	618
R.6	2.01	37.29	1471	652	1.67	31.15	1321	627

TDS and EC

The salts, beside affecting the growth of plants directly, also affect the soil structure, permeability and aeration, which indirectly affect the plant growth [7]. According to Don , 1995 classification shown in Table 7, all surface water samples for the two periods were within the permissible limits of irrigation water quality. However, all groundwater water samples for the two periods were within the unsuitable limits of irrigation water quality, except for w2,w3 which were within the doubtful limits of irrigation water quality and w6 which was within the permissible limits of irrigation water quality.

Percentage of sodium (Na %)

Water with an SSP value that is greater than 60% may result in sodium accumulations that will cause a breakdown in the soil's physical properties [20]. The calculation of Na% can be performed using the equation below[21]:

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

All ion concentrations are expressed in meq/l. The Na% values of all surface and groundwater samples for the two periods in the studied area indicated permissible irrigation water (Table-9).

Conclusions

This study provided a detailed description of the physicochemical properties of the surface and groundwater in Khan Al-Baghdadi area at Al- Anbar province, west Iraq. There was no considerable difference in pH values between surface and groundwater, indicating a direct influence on the groundwater by surface water. Concentrations of TDS indicated that the groundwater samples for both periods are considered to be of brackish water, whereas the surface water samples were considered to be of fresh water. Values of EC for groundwater and surface water samples indicated excessively mineralized water for both periods. Total hardness values for groundwater and surface water indicated very hard water and exceeded the permissible limits, due to the wide exposures to limestone and dolomitic limestone in the study area, which are rich in calcium and magnesium. Calcium ion is a predominant cation while Chloride is a predominant anion for surface water samples, whereas Calcium and Sodium ions were the predominant cations and Chloride was the predominant anion for groundwater samples. This might reflect the fact of the presence of limestone rocks and halite mineral, which are the main sources for these ions. As for surface and groundwater suitability for irrigation, all surface water samples for both periods were within the permissible limits of irrigation water quality, but all groundwater water samples for both periods were within the unsuitable limits, except for w2 andw3 which were within the doubtful limits and w6 which was within the permissible limits of irrigation water quality.

References

1. Al-Hamdani, j. A. **2009**. hydrochemical effect of groundwater due to irrigation and drainage projects in tawuq sub-basin., a thesis submitted to the college of science university of Baghdad, in partial fulfillment of the requirements for the degree of master of science in geology.
2. Todd, D. K. **1980**. *Groundwater hydrology second edition*, Jhon Wiley and Sons, Inc. New York. 535p.
3. APHA, **1998**. *Standard Methods of the Examination of Water and Wastewater* .20th ed., Washington D.C., American Public Health Association.
4. Hem, J. D. **1985**. *Study and Interpretation of Chemical Characteristics of Natural Water*. USGS Water Supply, Paper 2254. 263pp.
5. Stoodly, k. D., Lewis, T., and staintion, C. L. **1980**. *Applied Statistical Technique*. John Willey and Sons, London.

6. Singh, A.K., Mondal, G.C., Singh, P.K., Singh, S., Singh, T.B., Tewary, B.K. **2005**. Hydrochemistry of reservoirs of Damodar River basin, India: weathering processes and water quality assessment. *Environmental Geology*, **48**(8): 1014-1028.

7. Todd, D.K. **2007**. *Groundwater Hydrology third edition*, Jhon Wiley & Sons, Third Reprint, Inc. India, p535.

8. Jassim, S.Z. and Goff, J.C. **2006**. Geology of Iraq,Dolin Prague and MoravianMuseum,Brno,341p.

9. Sissakian, V.K. and Hafidh, S. Q.**1994**.The Geology of the Haditha Quadrangle Sheet NI-38-5 (GM 13) Scale 1:250 000. Technical Report No. 2257. Directorate of Geological Survey. State Establishment of Geological Surveyand Mining (GEOSURV). Baghdad. Iraq. 24 p.

10. Sissakian, V.K. and Salih, S.M. **1994**. The Geology of Ramadi Quadrangle, Sheet NJ-38-9 (G.M. – 18), scale 1: 250 000, GEOSURV, Baghdad, Iraq.

11. Detay, M. **1997**. *Water wells implementation, maintenance and restoration*. John Wiley & Sons, London, 379p.

12. Boyd, C. E. **2000**. *Water quality an introduction*, Kluwer Academic publisher, USA.330p.

13. Matthess, G. **1982**. *The Properties of Groundwater*. J. Wiley, New York, 406pp.

14. Fetter, C. W. **1994**. *Applied Hydrogeology*, Upper Saddle River, NJ, fourth edition (Prentice Hall: New Jersey).

15. Al-Paruany, K.B. **2013**. Hydrochemical and a Isotopic study of water resources between Haditha dam and site of Al-Baghdadi Dam college of science. University of Baghdad.171p. unpublished. Ph.D thesis.

16. Drever, J. I. **1997**. *The Geochemistry of natural water, surface and groundwater environments*, 3rd ed., prentice hall, USA, 436P.

17. Appelo, C. A. J. and Postma, D. **2005**. *Geochemistry, ground water and pollution Rotterdam*: A. A. Balkama, 536 P.

18. Piper, A. M. **1944**. A graphic procedure in the geochemical interpretation of water analyses, Transition, *American Geophysical Union*, **25**: 914-928p.

19. Schoeller, M. **1972**. Edute Geochemiique De La Nappe DesP,PStables in fericurs Du Bass in DP,P aquitainse *Journal of Hydrology*, **15**(4): 317-328 (in French).

20. Qannam, Z. **2003**. A hydrogeological, hydrochemical and environmental study in Wadi AL-Arroub drainage basin, south west Bank, Palestine, Vol. 9, DAAD. 211 p.

21. Don C.M. **1995**. A grows guide to water quality. University college station, Texas.