Iraqi Journal of Science, 2020, Vol. 61, No. 9, pp: 2277-2292
DOI: 10.24996/ijs.2020.61.9.15

ISSN: 0067-2904

Hydrochemical Assessment of Groundwater and Some Springs in Qazaniyah Area, Diyala province, East of Iraq

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Received: 9/10/2019 Accepted: 17/12/2019

Abstract

The Qazaniyah study included the analysis of 18 wells and 2 springs for the dry period in October 2018 and the wet period in April 2019, including the analysis of physical and chemical properties and the study of heavy elements (Fe, Zn, Cd, Pb, Ni and Cu).The results showed that the water wells and springs for the two periods are highly mineralized and characterized by low alkalinity and very high hardness. Water was fresh in some wells and salty in the others, whereas it was fresh in the springs. Most of the wells had sodium sulphates type, except the wells 12, 7, 6, and 5 which were of Calcium sulphate type. The springs for both seasons had calcium sulphate type. Based on the World Health Organization criteria , all the wells for both periods are not suitable for human drinking, whereas the springs are suitable only for drinking of livestock and poultry. Sodium adsorption rate (SAR) was excellent for groundwater and springs for both seasons. The percentage of sodium (Na%) in both seasons showed that the wells 18,17,15,11,4,3 as well as the springs are within the permissible limits for irrigation purposes, while the remaining of the wells was not.

Keywords: Hydrochemical, Groundwater, Springs, Trace, Qazaniyah.

تقييم هيدروكيميائي للمياه الجوفية في منطقة قزانية، محافظة ديالى، شرق العراق

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قسم علم الارض، كلية العلوم، جامعة بغداد، بغداد، العراق.

الخلاصة

تضمنت الدراسة في منطقة قزانية على تحليل 18 بئرا و 2 من العيون وللموسمين الجاف في شهر اكتوبر 2018 والرطب في شهر ابريل 2019 حيث شملت على تحليل الخواص الفيزيائية والكيميائية وكذلك دراسة العناصر الثقيلة(الحديد، الزنك، الكادميوم، الرصاص، النيكل، النحاس والكروم). حيث اظهرت النتائج ان مياه الابار والعيون للموسمين شديدة التمعدن و تتميز ب قلوية خفيفة وذات عسرة عالية جدا وعذبة في بعض الابار ومالحة في بقية الابار لكنها عذبة في العيون وان اغلبها ذات نوع كبريتات الصوديوم باستثناء الابار (12,7,6,5) هي نوع كبريتات الكالسيوم وان العيون للموسمين هي نوع كبريتات الكالسيوم. وان العناصر الثقيلة المذكورة كلها ضمن حدود منظمة الصحة العالمية، وان جميع الابار وللموسمين هي غير صالحة لشرب الانسان باستثناء العيون فإنها صالحة للشرب ولكنها صالحة لشرب المواشي والدواجن ونسبة امتزاز الصوديوم (SAR) تعتبر ممتازة للمياه الجوفية والعيون للموسمين، وان نسبة الصوديوم المئوية (Na%) لأغراض الري للآبار (18,17,15,11,4,3) وكذلك العيون وللموسمين تعتبر ضمن الحد المسموح به بينما بقية الابار نسبتها غير مسموح بها.

Introduction

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Groundwater geochemistry research is one of the major studies concerned with the sub-surface environment's water chemistry. Groundwater's chemical composition is the double product of water reaching the groundwater reservoir and its interactions with the different minerals -containing rocks[1]. The value of groundwater depends on the dissolved substances in the water and certain chemicals that are transferred to water by these substances.

Study Area

The study area is situated at the Iraqi-Iranian border in the eastern part of Diyala Governorate, between 33° 43' 00" and 33 ° 15' 00" to the north and between 46 00'00 "and 4515'00" to the east. It is far from the center of Qazaniyah, about 150 km north-east of Baghdad city, occupying an area of about 1038 km^2, as shown in fig 1. Geologically, the study area covers the quaternary and tertiary sediments appearing along the rim of the Hamrin mountain range [2]. The quaternary and tertiary periods are identified by the uncountable structures of the geological layers. It is particularly located at the Iraqi-Iranian border, which is represented by the Miocene and the Pliocene sediments and includes the formations of Euphrates and Fatha. Quaternary sediments cover the study area in general, including those of the modern and the ancient quaternary, each represented by several units that differ according to their geomorphological and lithological characteristics; Pleistocene sediment, Alluvial Fans and Terraces Deposits (Figure-1).

This study aimed at studying the hydrochemical characteristics of groundwater and springs in Qazaniyah area and determining groundwater origin. We also aimed at the evaluation of water quality and comparing it with the international and Iraqi standards in order to determine suitability for different usage purposes. We also investigate the possibility of contamination of water by major and minor ions and heavy elements.

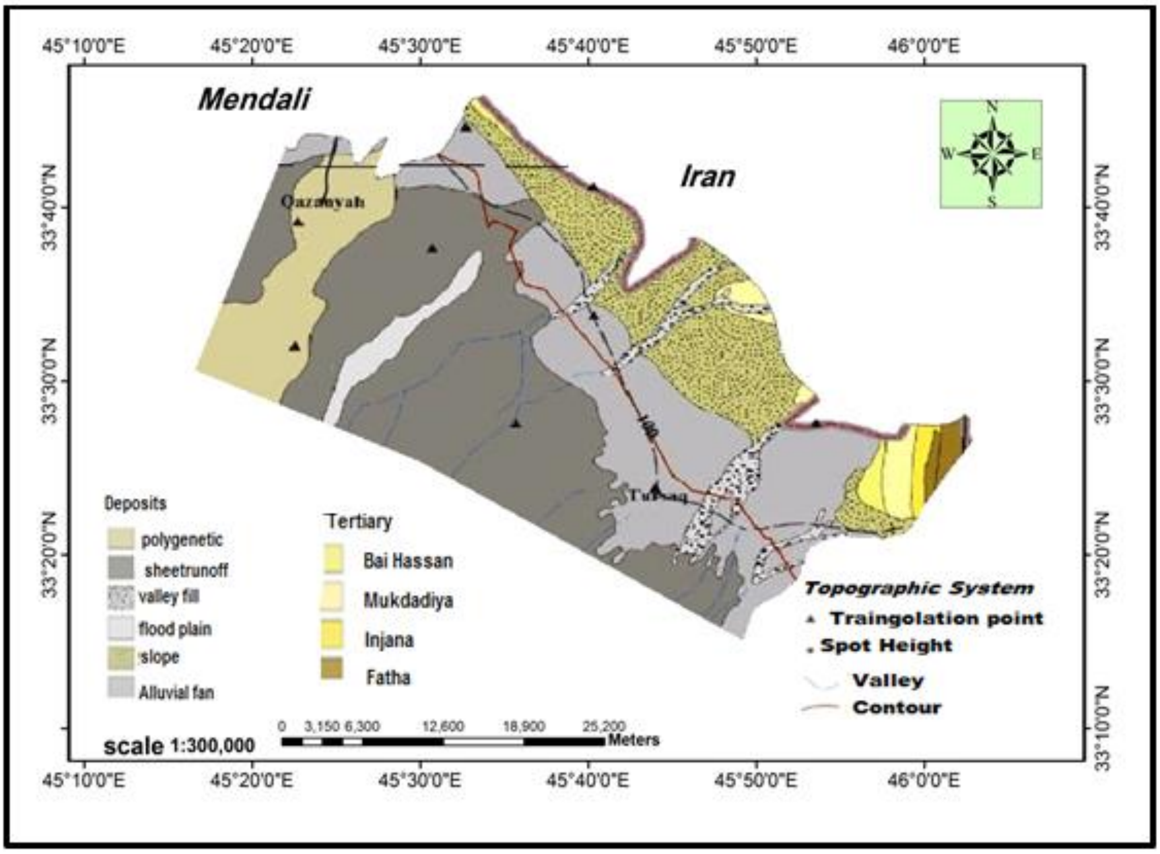

Figure 1-Geological map of the study area; 1:300,000 (GEOSURV,2018)

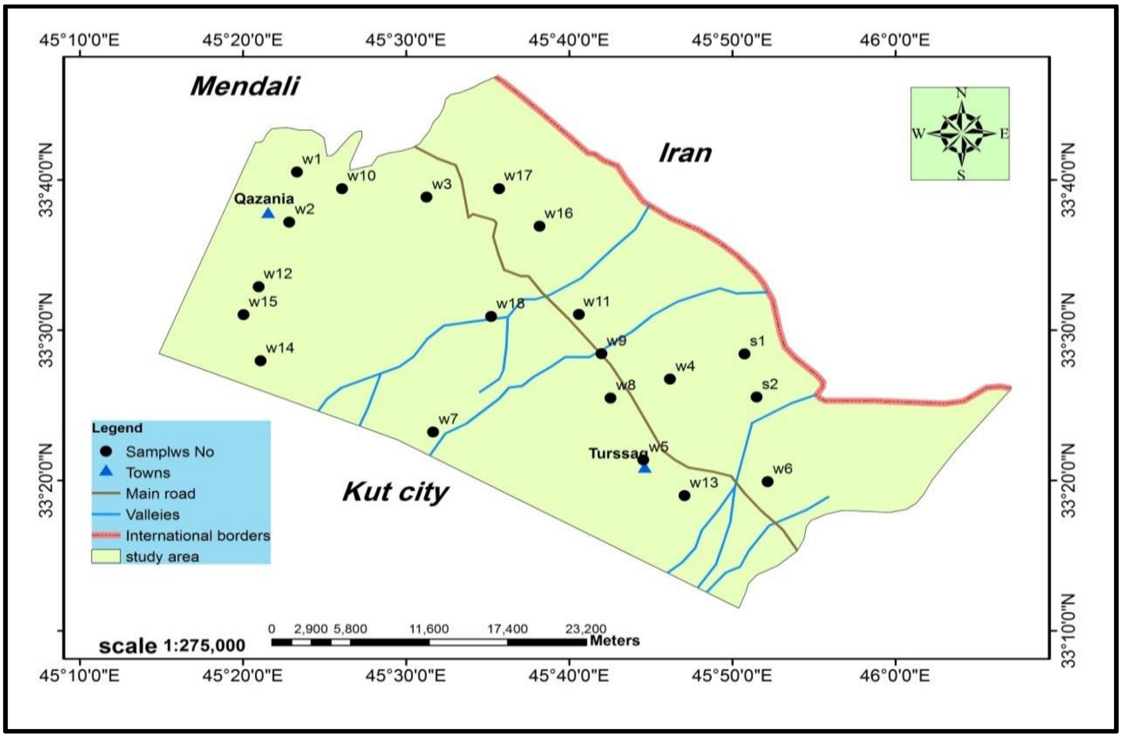

Figure 2- The location of the wells and some springs in the study area.

Table 1-The field collected data of the selected groundwater and spring water samples.

Samples No.	Latitude	Longitude	Well depth	Elevation (m)	S.W.L (m)
W.1	33.658	45.551	65.2	59.7	13
W.2	33.622	45.546	90	76	10
W.3	33.64	45.637	71.43	86	7
W.4	33.508	45.798	75	117	23
W.5	33.450	45.780	72	80.8	17
W.6	33.434	45.863	60	106.5	11
W.7	33.470	45.641	66	98	5
W.8	33.495	45.759	62	79.5	11
W.9	33.527	45.753	66	97	7
W.10	33.646	45.581	84	90	16
W.11	33.555	45.738	66	100	15
W.12	33.575	45.525	103	60	17
W.13	33.425	45.808	77	112	7
W.14	33.522	45.527	67	102	13
W.15	33.555	45.515	82	62	8
W.16	33.618	45.712	60	105	16
W.17	33.646	45.685	60	93.3	11
W.18	33.554	45.68	67	89.2	19
S.1	33.527	45.848	---	102	---
S.2	33.496	45.856	---	107	---

MATERIALS AND METHODS

The laboratory work involved physical and chemical analyses of water samples, which included the determination of the concentrations of cations (Ca^{2}+, Mg^{2}+, Na^{+}, K^{+}), anions (HCO_{3}-, SO_{4}^{2}-, Cl^{-}), minor ions (NO_{3}--, PO_{4}^{3-}), and trace elements (Fe, Ni, Cu, Zn, Cd, Cr and Pb), in addition to the parameters of pH, TDS and EC. Levels of major and minor ions and trace elements were studied in the Ministry of Science and Technology's laboratories. Table -2 demonstrates the analytical methods for the various parameters. AqQa version 1.1 of Rock Ware was used to assess water quality and water classification. The coordinates for each sample were determined using GPS, including longitude, latitude and altitude.

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

$$A = 100 - U \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where U is uncertainty or reaction error, A is accuracy or certainty, and r is concentration of ions in epm units.

Using the above equation, the tests of U% and A for all samples over two periods showed values within acceptable limits (less than 5%) which indicates that the test can be used for hydrochemical analysis.

Table 2-Accuracy of chemical analysis of the water samples for two periods.

Sample No.	**Dry Period**			**Wet period**		
	U	**A%**	**Decision**	**U**	**A%**	**Decision**
W1	2.9	97.1	Certain	2.8	97.2	Certain
W2	2.2	97.8	Certain	3.1	96.9	Certain
W3	1	99	Certain	4.35	95.65	Certain
W4	0.19	99.81	Certain	1.97	98.03	Certain
W5	3.8	96.2	Certain	5.59	94.41	Certain
W6	2.3	97.7	Certain	1.8	98.2	Certain
W7	3.2	96.8	Certain	4.2	95.8	Certain
W8	1.8	98.2	Certain	2.7	97.3	Certain
W9	1.16	98.84	Certain	4.7	95.3	Certain
W10	0.31	99.69	Certain	3.4	96.6	Certain
W11	3.8	96.2	Certain	5	95	Certain
W12	2.6	97.4	Certain	1.45	98.55	Certain
W13	1.73	98.27	Certain	6.15	93.85	Certain
W14	1.3	98.7	Certain	3.7	96.3	Certain
W15	1.17	98.83	Certain	3.71	96.29	Certain
W16	0.6	99.4	Certain	3.94	96.06	Certain
W17	0.8	99.2	Certain	3.85	96.15	Certain
W18	0.6	99.4	Certain	3	97	Certain
S1	0.18	99.82	Certain	2	98	Certain
S2	0.1	99.9	Certain	1.42	98.58	Certain

Result and discussion

Physical Properties

Table 3-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	23	7.3	1183	3580	25	7.2	1171	3560
W.2	20	7,2	2059	3110	27	7.2	1986	3095
W.3	21	7.21	1252	2040	29	7.1	1189	2025
W.4	23	7.4	1713	2530	25	7.3	1691	2515
W.5	22	7.4	2506	3700	27.5	7.3	2380	3610
W.6	19	7.4	2382	3700	24.5	7.31	2237	3590
W.7	23	7.4	2325	3700	26.7	7.32	2290	3580
W.8	22	7.4	2474	3700	22.5	7.2	2292	3585
W.9	21	7,2	2117	3110	26	7.1	2097	3085
W.10	19	7,2	2803	3110	28	7.2	2021	3096
W.11	23	7,2	1968	3110	27.5	7.2	1898	3070

W.12	24	7.4	3841	7100	28.4	7.3	3620	7000
W.13	21	7.4	3685	7100	26.3	7.25	3520	6098
W.14	23	7.34	3724	5400	27.8	7.23	3557	5350
w.15	22	7.34	3820	5400	28	7.22	3640	5405
w.16	24	7.21	1144	2040	27	7.11	1102	1998
w.17	22	7.21	1224	2040	29.3	7.1	1125	2015
w.18	21	7.21	1043	2040	26.6	7.2	1001	2010
S.1	19	7.4	599	1030	27	7.27	572	1020
S.2	21	7.4	619	1030	29	7.38	598	1020

Hydrogen Number (pH) The pH of groundwater samples in the dry period ranged around 7.2-7.4 with an average of 7.34, whereas that for the wet period ranged between 7.1-7.32 with an average of 7.21 . The values in two spring (S1 and S2) for the dry period were 7.4 and 7.4 and for the wet period 7.27 and 7.38, respectively.

Electrical conductivity (EC)

EC values in the groundwater samples ranged between 2040 and 7100 µS/cm with an average of 3695 µS/cm in the dry period, while it ranged between 2010 and 7000 µS/cm with an average of 3593.72 µS/cm in the wet period. The values in S1 and S2 were 1030 and 1030 µS/cm, in the dry period and 1020 and 1020 µS/cm for the wet period, respectively. According to a previously described relationship between EC and mineralization degree of water [3], we found that the type of all water samples in the present study area is excessively mineralized water for the two periods (Table-4).

Table 4-The relationship between electrical conductivity and water mineralization according to [3]

EC µS/cm	Mineralization	Sample No for both periods
<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 samples of the Groundwater and the springs

Total Hardness (TH)

T.H quality in groundwater samples range from (445-1943.83) ppm with an average of (1088.048) ppm in dry period, whereas in springs (S1,S2) they range from (263.34 to 272.35) ppm with an average of (1028.2) ppm in wet period, whereas in springs (S1,S2) they range from (415.46-1963.9) ppm to (240.63 and 242.22) respectively[4].and[5]. Due to the high concentrations of calcium and magnesium in the water samples, groundwater and springs in the study area are graded as having very hard water for the two periods.

Total dissolved solid (TDS)

TDS values in the groundwater samples ranges between (1043-3841) ppm with an average of (2292.4) ppm in the dry period, while it ranges between (1001-3640) ppm with an average of (2156.5) ppm in the wet period. For S1and S2, the values were (599 and 619) ppm, respectively in dry period ,while in wet period are (572 and 598) respectively. It is clear that the salinity in the dry period was higher than that in the wet period, which is due to the dilution occurring in the wet period as a result of rainfall (Figure-(3A,B).

Chemical Properties

Cations and Anions

Calcium ion concentration in groundwater samples varied from 118 to 423 ppm and 112 to 402 ppm in dry and wet periods, respectively. The values in the springs (S1, S2) were (75 and 77) ppm and (70 and 69) ppm in dry and wet periods, respectively. Calcium concentration decreases in wet periods due to the precipitation dilution effect. Magnesium ion concentration in the groundwater samples varied from 37 to 216 ppm and from 33 to 268 ppm in dry and wet periods, respectively. The values in the springs (S1, S2) were (18 and 19) ppm and (16 and 17) ppm in dry and wet periods, respectively. Sodium ion concentrations in the groundwater samples ranged between 148-499 ppm in dry period and 143-483 ppm in wet period, whereas in the springs (S1, S2) they were (66 and 69) ppm and (51 and 54) ppm in dry and wet periods, respectively. Potassium ion concentrations in the groundwater samples varied from 9 to 20 ppm and 8 to 18 ppm in dry and wet periods, respectively, whereas in the springs (S1, S2) they were (2 and 3) ppm and (2 and 1) in the dry and wet periods, respectively.

Chloride concentrations in the groundwater samples ranged between 199-756 ppm in dry period and 154-679 ppm in wet period, whereas in springs (S1 , S2) they were (91 and 101) ppm and (84 and 87) ppm in dry and wet periods respectively. The groundwater samples of the study area are classified as being of normal chloride except (w12,w15 and w16) in dry period may be classified as Oligochloride water, so the springs are classified as normal chloride, for two periods, whereas the springs are classified as being of normal chloride for the two periods (Table- 5). Sulfate ion concentrations in the groundwater samples ranged between 358.6-1488 ppm in dry period and 350-1406 ppm in wet period, whereas in springs (S1,S2) they were (164 and 167) ppm and (121 and 125) ppm in dry and wet periods, respectively. The groundwater samples of study area are classified as having normal sulfate to oligosulfate water for the two periods, while (S1 and S2) may be classified as having normal sulfate (Table- 5). Bicarbonate ion concentrations in the groundwater samples varied from 145 to 463 ppm in the dry period and 134 to 434 ppm in the wet period, whereas in springs (S1 and S2) they were (135 and 137) ppm and (131 and 131) ppm in dry and wet periods, respectively, (Tables-5, 6 and 7).

Table 5-Classification of water samples from the current study according to Schoeller's (1956) [6] classification of water.

Water type	**Cl^- concentration (epm)**	**Dry period**	**Wet period**
Super chloride water	**More than 700**		
Marine chloride water	**420-700**		
Strong chloride water	**140-420**		
Medium chloride water	**40-140**		
Oligochloride water	**15-40**	**w12,w15 and w16**	**w12,w15 and w16**
Normal chloride water	**Less than 15**	**All others sample**	**All others sample**
Water type	**SO_4^{2-} concentration (epm)**	**Dry period**	**Wet period**
Super sulfate water	**More than 58**		
Sulfate water	**24-58**	**w5,w6,w7,w8,w12,w13,,w14,w15 and w16**	**w5,w6,w7,w8,w12, w13,,w14,w15 and w16**
Oligosulfate water	**24-6**	**w1,w2,w3,w4,w9,w10,w11,w17 and w18**	**w1,w2,w3,w4,w9,w10,w11,w17 and w18**
Normal sulfate water	**Less than 6**	**s1 and s2.**	**s1 and s2.**
Water type	**HCO_3^-concentration (epm)**	**Dry period**	**Wet period**
Super carbonate water	**More than 7**	**W13 and W14**	
Normal carbonate water	**7-2**	**W1,W2,W3,W4,W5,W6,W7,W8, W9,W10,W11,W12,w15,W16,W17,W18,S1 and S2**	
Under carbonate water	**Less than 2**		

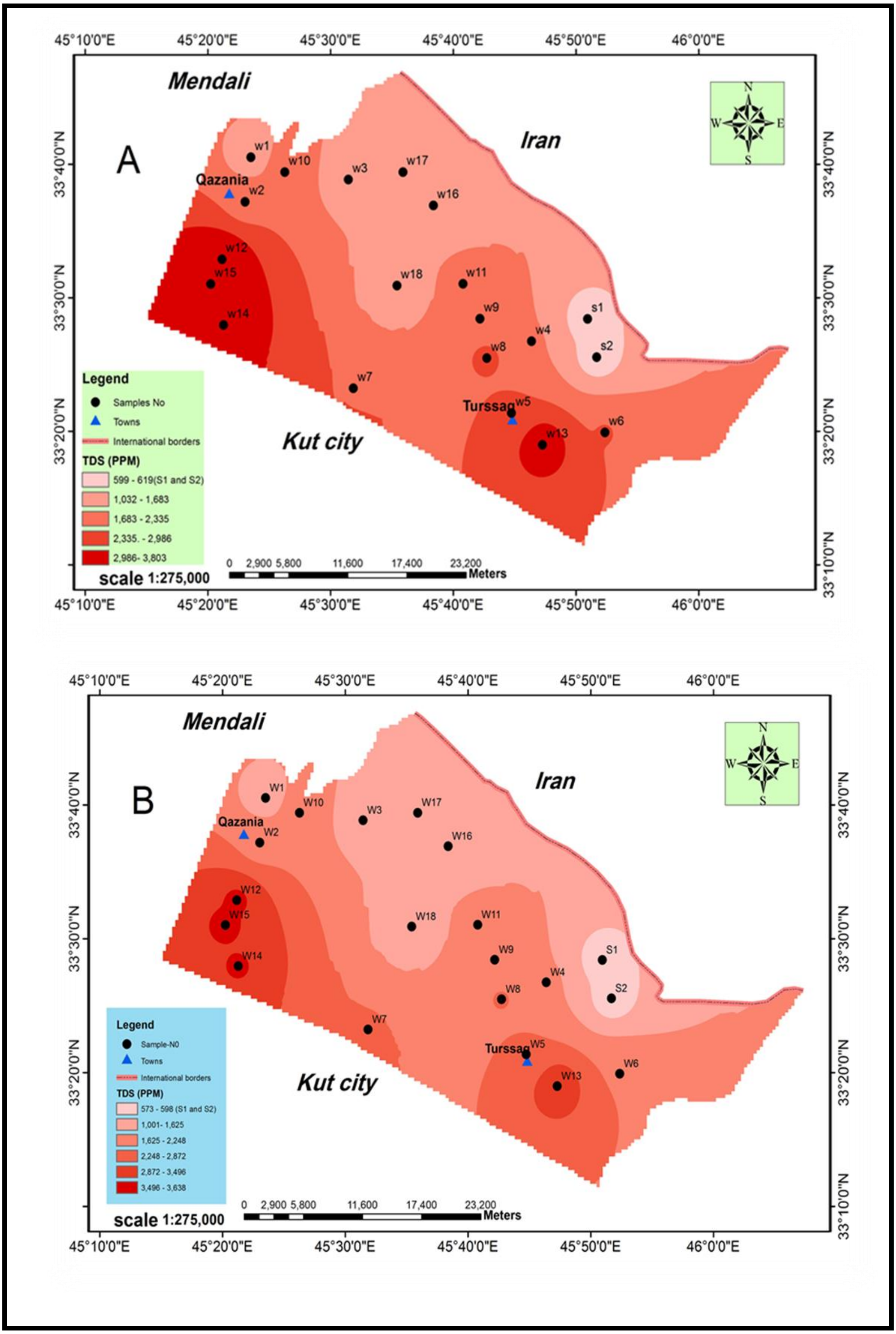

Figure 3-The spatial distribution of TDS (mg/ l) in the study area where (A) represents water dry period while (B) represents wet period.

Table 6-The concentrations of different ions in water models in the dry period (October, 2018).

Samples No.	Unit	Na+	K+	Ca^{2+}	Mg^{2+}	SO$_4^{2-}$	HCO$_3^-$	Cl
W1	ppm	194	15	128	41	415	175	211
	epm	8.4	0.40	6.4	3.4	8.64	2.9	6
	epm%	45.16	2.15	34.41	18.28	50.3	16.5	34.2
W2	ppm	311	19	205	91	763	294	346
	epm	13.5	0.50	10.3	7.6	15.9	4.8	9.8
	epm%	42.32	1.57	32.29	23.82	52.1	15.7	32.1
W3	ppm	183	15	138	43	432	194	217
	epm	7.9	0.40	6.9	3.6	9	3.2	6.2
	epm%	42.02	2.13	36.7	19.15	48.9	17.4	33.7
W4	ppm	236	9	183	79	576	265	343
	epm	10.2	0.20	9.2	6.6	12	4.3	9.8
	epm%	38.93	0.76	35.11	25.19	45.9	16.48	37.5
W5	ppm	290	12	290	157	989	292	423.5
	epm	12.6	0.30	14.5	13.1	20.6	4.8	21.1
	epm%	31.11	0.74	35.8	32.35	54.9	12.8	32.3
W6	ppm	284	11	285	132	926.4	281	431
	epm	12.3	0.30	14.3	11	19.3	4.6	12.3
	epm%	32.45	0.79	37.73	29.02	53.3	12.7	33.9
W7	ppm	258	11	283	129	902	275	379.7
	epm	11.2	0.30	14.2	10.7	18.8	4.5	10.9
	epm%	30.77	0.82	39.01	29.4	55	13.1	31.8
W8	ppm	301	13	246	157	960	295	441
	epm	13.1	0.30	12.3	13.1	20	4.8	12.6
	epm%	33.76	0.77	31.7	33.76	53.5	12.8	33.7
W9	ppm	322.7	18.47	206	94.3	801.6	303.5	359
	epm	14	0.50	10.3	7.9	16.7	5	10.3
	epm%	42.81	1.53	31.5	24.16	52.3	15.64	32
W10	ppm	276	16	222	103	796.8	295	368
	epm	12	0.40	11.1	8.6	16.6	4.8	10.5
	epm%	37.38	1.25	34.58	26.79	52	15	32.9
W11	ppm	281	16	220	100	797	202	341
	epm	12.2	0.40	11	8.4	16.6	3.3	9.74
	epm%	38.13	1.25	34.38	26.25	56	11.13	32.8
W12	ppm	468	18	423	216	1474	406	683.9
	epm	20.3	0.50	21.2	18	30.7	6.7	19.5
	epm%	33.83	0.83	35.33	30	53.9	11.8	34.3
W13	ppm	489	20	400	203	1416	458	690
	epm	21.3	0.50	20	16.9	29.5	7.5	19.7
	epm%	36.29	0.85	34.07	28.79	52	13.3	34.7
W14	491	18	390	213	693	1450	1449	693
	epm	21.4	0.50	19.5	17.7	30.2	7.6	19.8
	epm%	36.21	0.85	32.99	29.95	52.4	13.2	34.4
W15	ppm	499	19	413	208	1474	395	756
	epm	21.7	0.50	20.7	17.3	30.7	6.5	21.6

	epm%	36.05	0.83	34.39	28.74	52.2	11	36.5
W16	ppm	7.1	0.40	6.1	3.6	1488	395	752.5
	epm	21.66	0.49	20.6	17.08	31	10.98	21.5
	epm%	41.28	2.33	35.47	20.93	52.6	11	36.5
W17	ppm	181	15.00	139	39	427.2	189	217
	epm	7.9	0.40	7	3.2	8.9	3.1	6.2
	epm%	42.70	2.16	37.84	17.3	48.9	17	34
W18	ppm	148	14	118	37	359	145	199
	epm	6.5	0.40	5.9	3	7.47	2.4	5.68
	epm%	41.14	2.53	37.34	18.99	48	15	36.5
S1	ppm	66	2	75	18	164	135	91
	epm	2.40	0.049	3.65	1.5	3.4	2.7	2.6
	epm%	34.94	1.2	45.78	18.07	41.4	26.8	31.7
S2	ppm	69	3	77	19	167	137	101
	epm	2.52	0.047	3.75	1.58	3.47	2.78	2.8
	epm%	34.88	1.16	45.35	18.6	40.7	26.4	32.8

Table 7-The concentrations of different ions in water models in the wet period (April, 2019)

Samples No.	Unit	Na+	K+	Ca^{2+}	Mg^{2+}	SO_4^{2-}	HCO_3^-	Cl
W1	ppm	164	13	114	36	382	155	164
	epm	7	0.34	5.7	3	7.96	2.5	4.68
	epm%	44.2	2.1	35.3	18.4	52.6	16.5	30.9
W2	ppm	295	17	194	81	715	284	294
	epm	13	0.44	9.7	6.7	14.9	4.6	8.4
	epm%	43.3	1.5	32.7	22.5	53.4	16.5	30.1
W3	ppm	171	14	129	39	418	173	156
	epm	7	0.35	6.4	3.2	8.7	2.8	4.45
	epm%	42.7	2	36.9	18.4	54.5	17.5	27.9
W4	ppm	205	8	169	70	504	238	280
	epm	9	0.21	8.4	5.8	10.5	3.9	8
	epm%	38.2	0.9	36.2	24.7	46.8	17.4	35.7
W5	ppm	276	11	271	146	912	274	361
	epm	12	0.29	13.5	12	19	4.5	10.3
	epm%	31.7	0.8	35.8	31.8	56.2	13.3	30.5
W6	ppm	251	10	261	122	888	251	357
	epm	11	0.26	13	10	18.5	4.1	10.2
	epm%	31.9	0.8	38	29.3	56.4	12.5	31
W7	ppm	248	10	275	120	864	230	350
	epm	11	0.26	13.7	9.9	18	3.8	10
	epm%	31.1	0.8	39.6	28.5	56.6	11.9	31.4
W8	ppm	251	12	235	143	854	252	385
	epm	11	0.31	11.7	11.8	17.8	4.1	11

	epm%	31.4	0.9	33.8	33.9	54.1	12.5	33
W9	ppm	312	17	196	87	734	278	292
	epm	14	0.43	9.8	7.1	15.3	4.5	8.34
	epm%	43.9	1.4	31.6	23.1	54.4	16	29.6
W10	ppm	264	14	210	99	754	273	287
	epm	11	0.36	10.5	8.1	15.7	4.5	8.2
	epm%	37.7	1.2	34.4	26.7	55.3	15.8	28.9
W11	ppm	271	14	204	84	758	172	273
	epm	12	0.35	10.2	6.9	15.8	2.8	7.8
	epm%	40.3	1.2	34.8	23.6	59.8	10.6	29.5
W12	ppm	448	15	402	189	1373	366	679
	epm	19	0.38	20.1	15.6	28.6	6	19.4
	epm%	35.1	0.7	36.2	28	53	11.1	35.9
W13	ppm	438	17	345	268	1406	434	539
	epm	19	0.43	17.2	22	29.3	7.1	15.4
	epm%	32.4	0.7	29.3	37.5	56.6	13.7	29.7
W14	ppm	481	17	386	201	1382	430	574
	epm	21	0.44	19.3	16.5	28.8	7	16.4
	epm%	36.6	0.8	33.7	28.9	55.2	13.4	31.4
W15	ppm	483	18	398	194	1373	360	658
	epm	21	0.46	19.9	16	28.6	5.9	18.8
	epm%	36.7	0.8	34.7	27.9	53.7	11	35.3
W16	ppm	149	14	117	39	365	158	154
	epm	6	0.35	5.8	3.2	7.6	2.6	4.4
	epm%	40.8	2.2	36.8	20.2	52	17.8	30
W17	ppm	161	13	119	36	379	162	158
	epm	7	0.33	5.9	3	7.89	2.6	4.51
	epm%	43.1	2	36.6	18.3	52.6	17.3	30
W18	ppm	143	12	112	33	350	134	155
	epm	6	0.32	5.6	2.7	7.3	2.2	4.42
	epm%	41.9	2.1	37.7	18.3	52.4	15.8	31.8
S1	ppm	51	2	70	16	121	131	73.5
	epm	2	0.04	3.5	1.3	2.52	2.1	2.1
	epm%	31.4	0.5	49.4	18.6	37.5	31.3	31.3
S2	ppm	54	1	69	17	125	131	77
	epm	2	0.04	3.4	1.4	2.6	2.1	2.2
	epm%	32.5	0.5	47.6	19.4	37.7	30.4	31.9

Trace Elements

In the present study, seven trace elements, including Fe, Ni, Cu, Cd, Pb, Zn and Cr, were analyzed. It should be noted that concentration of (Cr) could not be tested in all water samples. By comparing the water samples from two periods according to the standards criteria for trace elements in drinking water [7, 8], all water samples were found to be within the limits. Figures 4 and5 explain the variations of trace element concentrations for water samples in the study area in two periods

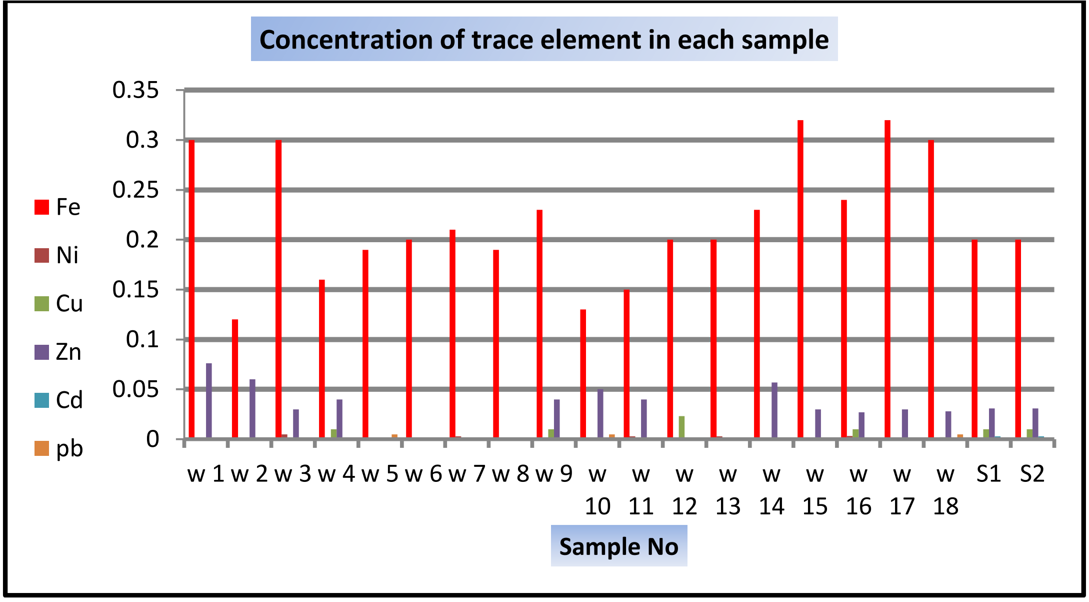

Figure 4-Variation of trace elements concentration for water samples in the study area for the dry period.

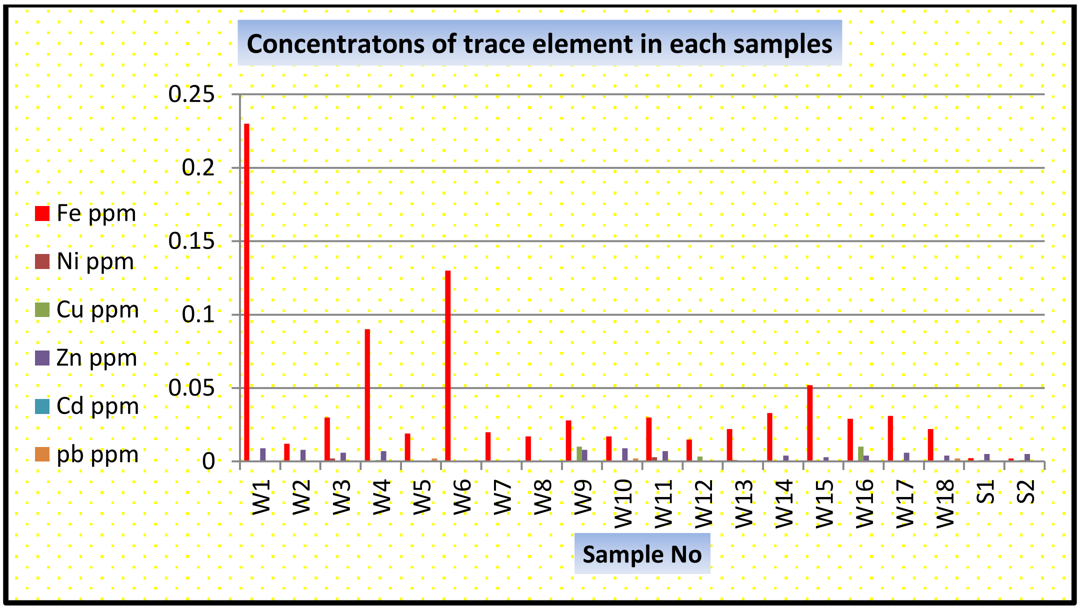

Figure 5-Variation of trace elements concentration for water samples in the study area for the dry period.

Hydrochemical formula and water type

The following formula (Kurlolov formula) was used to determine the water type of the samples [12]:

$$\text{TDS (mg/l)} = \frac{\text{Anions (epm\%) in decreasing order}}{\text{Cations (epm\%) in decreasing order}} \quad \text{pH} \ldots\ldots\ldots(3)$$

The results of water type are shown in Table-4.

Table 4-The percentage ratio of prevailing water type in water samples for both periods

Dry period			Wet period		
Water type	**Frequency**	**Occurs Ratio (%)**	**Water type**	**Frequency**	**Occurs Ratio (%)**
Na_2SO_4	13	65 %	Na_2SO_4	13	65 %
$Ca\ SO_4$	6	30 %	$Ca\ SO_4$	6	30 %
$Mg\ SO_4$	1	5%	$Mg\ SO_4$	1	5%

Groundwater classification

Piper Diagram

According to the application of a previously published diagram [10], all water samples from the two periods were falling into class e, which represents earth alkaline water with increased alkaline portion and predominant sulfate and chloride Figures-(6 and 7).

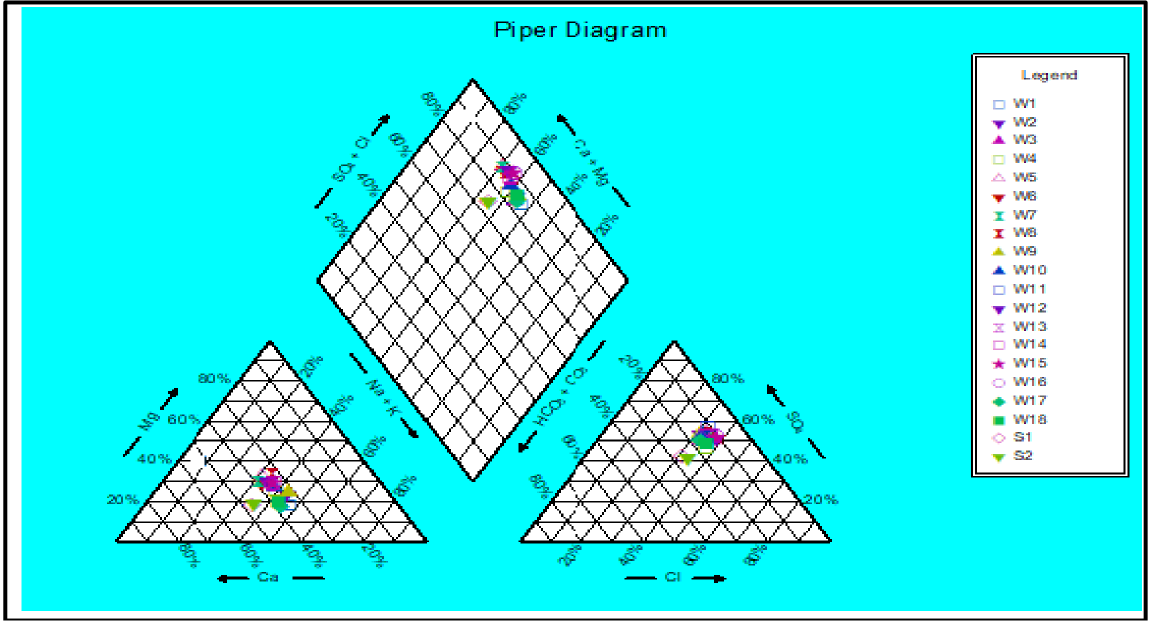

Figure 6-Piper diagram of the water samples in the dry period.

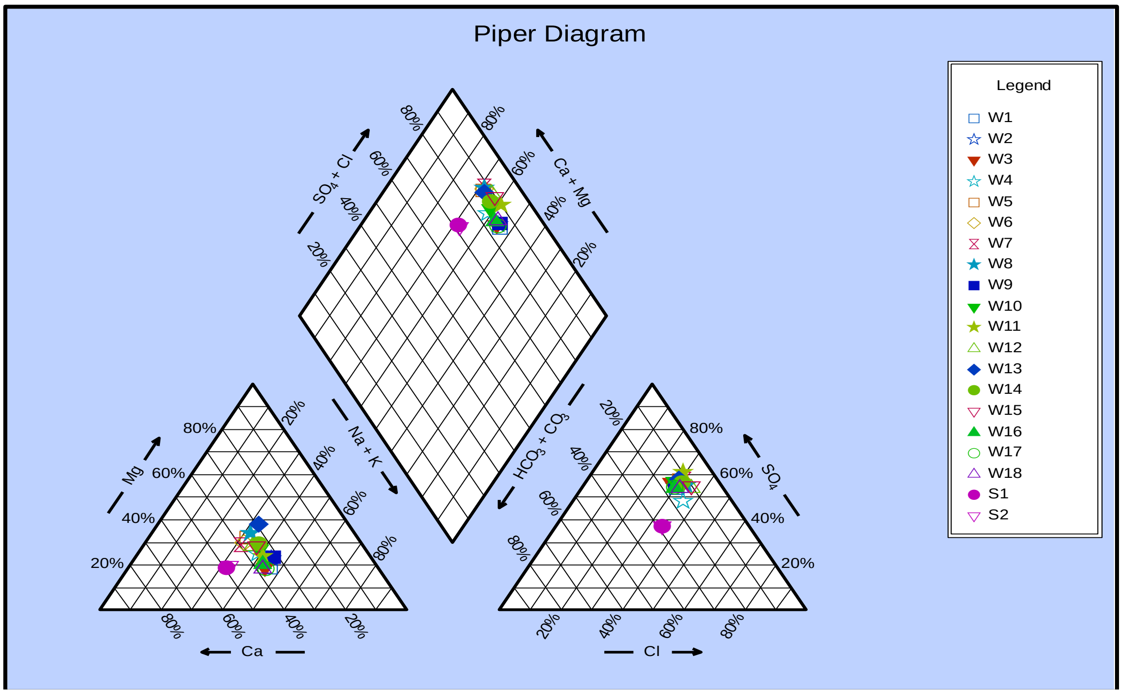

Figure 7-Piper diagram of the water samples in the wet period.

Schoeller Classification

Figures-(8 and 9) illustrate the results of the application of Schoeller classification on water samples for the two periods. The results appear to almost fit those of the hydrochemical formula.

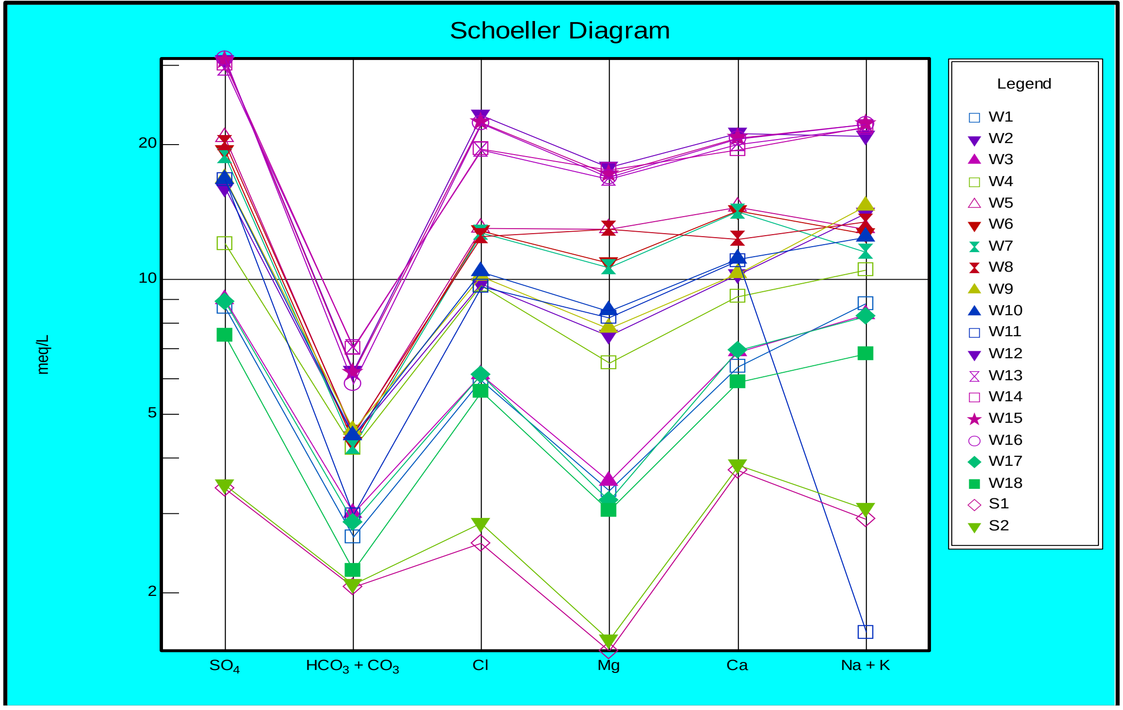

Figure 8-Schoeller diagram of the water samples in the dry period.

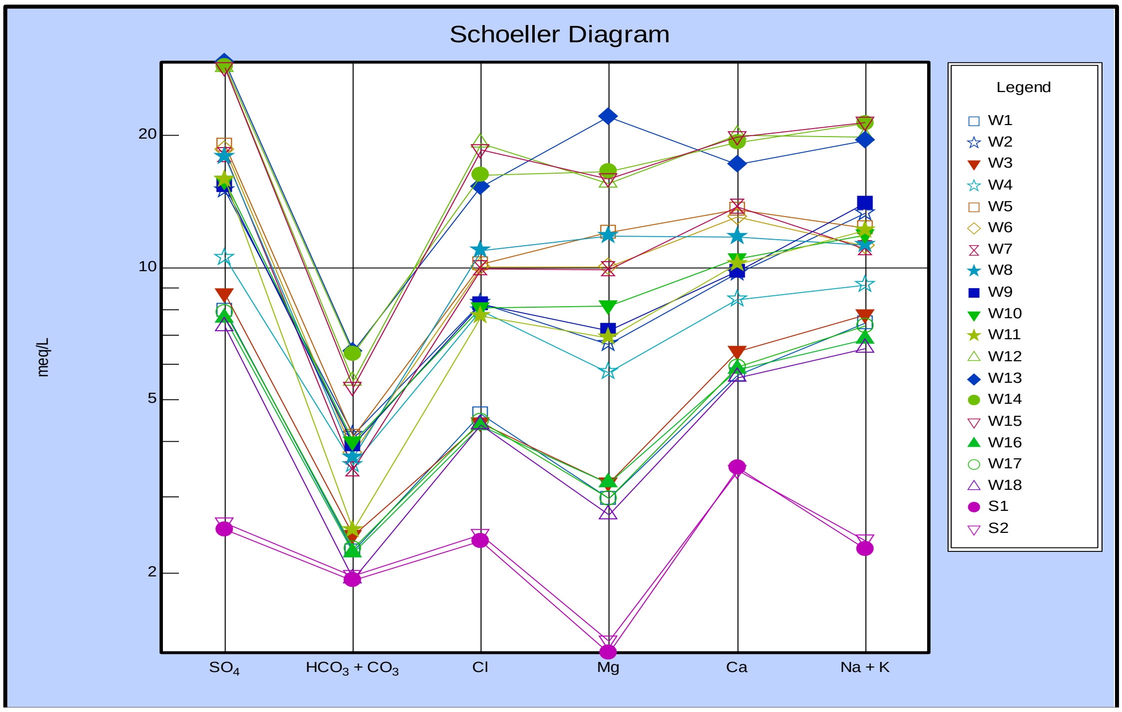

Figure 9-Schoeller diagram of the water samples in the wet period.

Water uses

Water suitability for human drinking

All of groundwater samples, according to from TDS and T.H results, are not suitable for drinking water, but the springs are suitable for drinking water.

All trace elements in water samples, and for both periods, are within the limits specified by earlier reports [7, 8].

Table 8-Concentrations of trace elements according to drinking water standards [6, 7]

Parameters	WHO, 2011	IQS, 2009	Groundwater		Exceeding limits for groundwater	Springs (S1and S2) respectively	Exceeding limits for springs
			Range	Mean			
Ni	0.02	0.02	ND - 0.005	-	Not Exceed	ND	Not Exceed
Cd	0.003	0.003	ND - 0.003	-	Not Exceed	0.003 and 0.003	Not Exceed
Cu	1	1	ND- 0.023	-	Not Exceed	0.01 and 0.01	Not Exceed
Zn	3	3	0.03-0.07	-	Not Exceed	0.03 and 0.03	Not Exceed
Fe	0.3	0.3	0.12-0.32	0.22	Not Exceed	0.2 and 0.2	Not Exceed
Pb	0.01	0.01	ND-0.005	-	Not Exceed	0.01and 0.01	Not Exceed

ND= Not detected

Water suitability for irrigation purposes

Sodium Adsorption Ratio (SAR)

Usually, sodium alkali hazard is expressed as a ratio of sodium adsorption (SAR). The index quantifies the proportion of sodium to calcium and magnesium ions in a sample. High SAR values indicate a sodium risk that replaces absorbed calcium and magnesium, which eventually destroys the soil structure [5]. This index measures the impact of sodium accumulation in the soil as related to relative cations concentration. SAR values are determined on the basis of [13]:

$$SAR = r\,Na / \sqrt{r\,Ca + r\,Mg/2}$$

where:

r: Concentration of ions by (epm) units.

Table 7-Classification of irrigation water based on the SAR values [9].

SAR	Alkalinity hazard	water class
< 10	S1	Excellent
10- 18	S2	Good
18-26	S3	Doubtful
> 26	S4	Unsuitable

According to this classification, all the groundwater samples are lying in class S1.

Soluble Sodium Percentage (Na%)

Increasing sodium ion levels in irrigation water can influence the soil, where it causes its porosity and permeability to decrease, thereby impacting plant growth or causing stunted growth. The percentage of sodium is also an important element, like SAR (Na%) values, for the evaluation of water quality for irrigation purposes and is calculated according to the following equation [5]:

$$Na\% = \frac{rNa + rK}{rCa + rMg + rNa + rK} \times 100\ \%$$

where: The concentrations of ions by (epm) units

Table 8-SAR and Na% values of the water samples for the two periods.

Sample No	Dry period		Wet period	
	SA R	Na%	SAR	Na%
W1	3.82	47.31	3.37	45.76
W2	4.52	43.89	4.55	45.04
W3	3.45	44.15	3.2	43.36
W4	3.64	39.69	3.38	39.34
W5	3.41	31.85	3.36	32.52

W6	3.46	33.25	3.24	32.87
W7	3.18	31.59	3.21	32.3
W8	3.68	34.54	3.22	32.49
W9	4.65	44.34	4.83	46.06
W10	3.83	38.63	3.62	37.92
W11	3.92	39.38	4.11	41.94
W12	4.59	34.67	4.5	35.19
W13	4.97	37.14	4.3	33.14
W14	4.97	37.06	4.96	37.46
W15	4.99	36.88	2.83	41.37
W16	3.23	43.60	4.96	37.41
W17	3.51	44.86	3.33	45.16
W18	3.1	43.67	2.96	43.23
S1	1.79	36.14	1.3	29.82
S2	1.82	36.05	1.3	29.82

According to this classification, groundwater samples in the study area (w1, w 3, w 4, w 11, 15,w17and w18) and both springs (S1 and S2) fall within the permissible limit, while other samples (w2,w5,w6,w7,w8,w9 and w10) fall within the doubtful limit, whereas the remaining (w12,w13,w14 and w16) fall within the unsuitable limit.

Table 9-The standard categories used for the water assessment for irrigation purposes according to classification of [11].

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

Conclusions

This research provided a detailed overview of the reservoir's physicochemical properties in the Qazaniyah region of Diyala Province, East Iraq. There was no significant difference between springs and groundwater in the pH values. Concentrations of TDS indicated that groundwater samples in both periods were considered of brackish or salty water, while fresh water was found in the spring's samples. EC of groundwater and spring samples in both periods showed heavily mineralized water. Total hardness indicated that all water samples (groundwater and springs) are classified as very hard and exceed the permissible limits, due to the wide exposures to limestone and dolomitic limestone in the study area, which are rich in calcium and magnesium. Sodium was a predominant cation and sulphate was a predominant anion in groundwater samples, while calcium was a predominant cation and sulphate was a predominant anion in spring samples, which may indicate the presence of gypsum and anhydrite mineral and limestone rocks as the main sources of these ions. As related to springs and groundwater suitability for irrigation, some wells (w1, w 3, w 4, w 11, 15,w17and w18) and all springs (S1 and S2) were falling within permissible limits of irrigation water quality for the two periods, while other wells (w2,w5,w6,w7,w8,w9 and w10) were within the doubtful limits , and the remaining samples (w12,w13,w14 and w16) were within the unsuitable limit.

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