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Hydrochemical Assessment of water resources at Baquba City, Diyala Governorate, Eastern Iraq

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Abstract
For hydrochemical assessment of water resources at Baquba City, Diyala Governorate, four surface water samples were collected from the Diyala River and eight groundwater samples inside the city of Baquba. The samples were collected in the two periods, the dry period in October 2018 and the wet period in February 2019. The pH, EC, TH, turbidity, the major ions and trace elements (Fe, Cu, Co, Cd, Pb, Zn and Ni) were investigated. The results showed that the surface and groundwater are turbid, very hard and slightly brackish to moderately saltine in the groundwater, while it is hard to very hard and fresh in surface water. Heavy element analyzes revealed contamination of surface water samples and groundwater with the elements Cadmium, Nickel, Lead, Cobalt and Iron. The water type The water surface and groundwater samples are Na-Ca-Mg-So4- Chloride. The results showed that the water of Baquba is not suitable for human drinking, suitable for irrigation and livestock drinking purposes. According to the sodium adsorption ratio (SAR) and magnesium hazard (MH), all surface and groundwater samples are suitable for irrigation purposes.

Keywords: Surface water, Groundwater, Baquba city, water suitability.

تقيم هيدروكيميائي لمصادر المياه في مدينة بعقوبة – محافظة ديالى شرق العراق

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الخلاصه
لأغراض التقييم الهيدروكيميائي لموارد المياه في مدينة بعقوبة بمحافظة ديالى ، تم جمع أربع عينات من المياه السطحية من نهر ديالى، وثماني عينات من المياه الجوفية داخل مدينة بعقوبة. تم جمع العينات في فترتي الجفاف في أكتوبر 2018 والفترة الرطبة في فبراير 2019. وتضمنت التحليلات التي أجريت للعينات تحليل المعلمات الأتية: الأس الهيدروجيني ، والتوصيل الكهربائي ، و TH ، والعكورة ، والأيونات الرئيسية والعناصر النزرة (Fe، Cu، Co، Cd، Pb، Zn and Ni). أظهرت النتائج أن المياه السطحية والجوفية عكرة ، وقليلة الملوحة إلى معتدلة الملوحة في المياه الجوفية ، بينما تكون شديدة الملوحة الى عذبة في المياه السطحية. كشفت تحليلات العناصر الثقيلة عن تلوث عينات المياه السطحية والمياه الجوفية بعناصر الكادميوم والنيكل والرصاص والكوبالت والحديد. عينات المياه السطحية والجوفية هي $Na-Ca-Mg-SO_4$– كلوريد. وأظهرت النتائج أن مياه بعقوبة غير صالحة لشرب الانسان وصالحة للري ولأغراض شرب المواشي. وفقًا

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لنسبة امتصاص الصوديوم (SAR) ومخاطر المغنيسيوم (MH) ، فإن جميع عينات المياه السطحية والجوفية مناسبة لأغراض الري.

Introduction:

The population growth, arid climate, and agricultural and industrial development have increased the stresses on the water resources. Water is polluted when contains materials that makes it unsuitable for different usesresulting naturally, or from human activities. Water quality comprises the physical, chemical and biological criteria of water [1] .Iraqi Rivers are exposed to numerous pollution processes. The Diyala River is one of five tributaries that flow into the Tigris River [2]. The Diyala River represents the main vital surface water resource for the city of Baquba in addition to the groundwater. The city of Baquba is the capital of Diyala Governorate, eastern Iraq. It is about 50 km northeast of Baghdad ,located between: latitudes (33º 30′ 08″- 33º 70′ 04″N) and longitudes(44º 10′ 36″- 44º 85′ 83″ E) Figure 1.The The aim of the current research is to study the hydrochemical characteristics of surface and ground water, and evaluation water suitability for different uses.

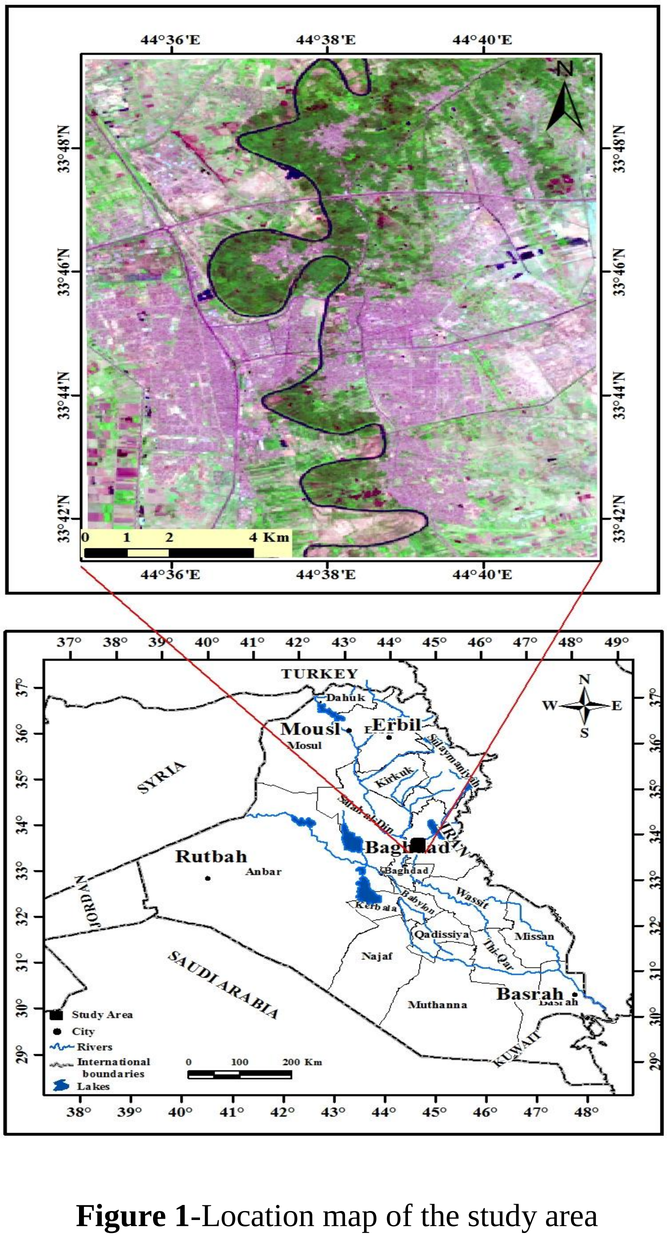

Figure 1-Location map of the study area

Materials and methods

Four surface water and eight groundwater samples were collected within the city of Baquba, (Figure 2). Sampling was carried out in two seasons, the dry season during October 2018 and the wet season during February 2019. Samples were kept in a refrigerator at 4 ° C until they are sent to the Ministry of Science and Technology laboratories for the required analysis. Laboratory analyzes included physiochemical analyzes such as pH, EC, TH, and turbidity, and biological analyzes for the oxygen demand (DO) and chemical oxygen demand (COD) as well as measuring the concentrations of major ions and trace elements such as Fe, Pb, Co, Cd, Zn, Cu and Ni. The water samples were collected following the ideal and international procedures [3,4 ,5and 6].

The total hardness of the water samples was calculated according to the following formula [7 and 8]:

TH=2.497Ca+4.115Mg

The accuracy was calculated according to the following equation:

$$R.D\% = \left|\frac{rC - rA}{rC + rA}\right| * 100$$

A% =100 – R.D %

Where:

R.D %: Relative difference percentage,

rC=sum of cations in epm units,

rA= sum of anions in epm units,

A% : Accuracy .

The results are reflected that the accuracy values are less than (%5) in all samples, and can be used in geochemical interpretations (Table 1).

Table 1-Accuracy and relative differences of water analysis results

Dry period(October 2018)				Wet period(February 2019)			
Sample No.	**R.D (%)**	**A %**	**Notes**	**Sample No.**	**R.D (%)**	**A %**	**Notes**
RW1	1.807	98.19	Accepted	RW1	0.199	99.8	Accepted
RW2	2.780	97.22	Accepted	RW2	0.356	99.64	Accepted
RW3	1.904	98.09	Accepted	RW3	0.849	99.15	Accepted
RW4	4.832	95.16	Accepted	RW4	0.539	99.46	Accepted
W1	2.231	97.76	Accepted	W1	4.272	95.72	Accepted
W2	1.877	98.12	Accepted	W2	3.837	96.16	Accepted
W3	1.898	98.1	Accepted	W3	4.242	95.75	Accepted
W4	1.722	98.27	Accepted	W4	1.224	98.77	Accepted
W5	4.210	95.79	Accepted	W5	4.460	95.54	Accepted
W6	4.596	95.40	Accepted	W6	3.518	96.48	Accepted
W7	4.856	95.14	Accepted	W7	4.652	95.35	Accepted
W8	1.839	98.16	Accepted	W8	4.789	95.22	Accepted

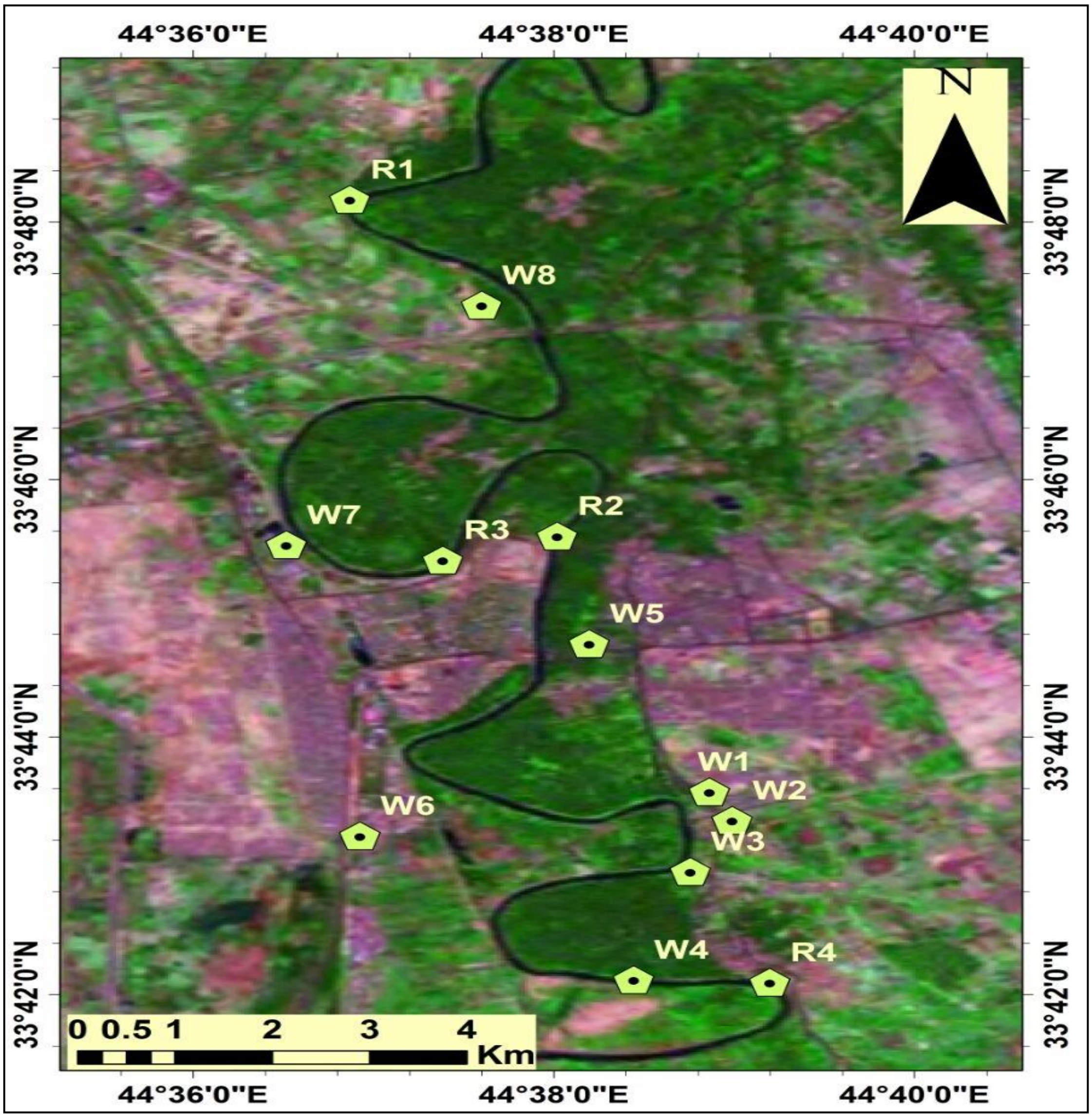

Figure 2- Location map of water samples

Results and discussion

Surface Water Physical Properties

All the results of physical and chemical measurements of surface water and groundwater for the dry and wet periods are tabulated in Table 2.

The pH values of surface water samples range between 7.46 and 7.73 with an average value of 7.58 in the dry period, and they range between 7.41 and 7.66 with an average value of 7.52 in the wet period.

The total dissolved solids (TDS) of the Diyala River water range between 891 to 955 ppm in the dry period with an average value of 927.75ppm, while in the wet period are ranging between 463 to 507 ppm with an average value of 481.25 ppm.

The electrical conductivity is directly proportional to the concentration of the total dissolved materials, and the concentration of the dissolved salts is inversely proportional to the discharge and water levels [7].

The Electrical conductivity (EC)of the Diyala River water range between 1400 to 1510 µS/cm in the dry period with an average value of 1457.5 µS/cm, while in the wet period are ranging between 732 to 800 µS/cm with an average value of 758 µS/cm.

The Turbidity values of the Diyala River water range between 2.5 to 11.51 NTU in the dry period with an average value of 6.32 NTU, while, in the wet period are ranging between 11.5 to 19.3 NTU with an average value of 15.75 NTU.
The Total Hardness (TH) of the Diyala River water range between 320.57 to 365.1 mg/L in the dry period with an average value of 340.7 mg/L, while, in the wet period are ranging between 167.3 to 183.1 mg/L with an average value of 173.95 mg/L.

Groundwater Physical Properties

The pH values of groundwater samples range between 7.58 and 8.05 with an average value of 7.74 in the dry period, and they vary between 7.37 and 7.99 with an average value of 7.68 in the wet period**.**
The total dissolved solids (TDS) of the groundwater range between 605 to 3890 ppm in the dry period with an average value of 1818.375 ppm, while, in the wet period, vary between 737 to 2530 ppm with an average value of 1526 ppm.
The Electrical conductivity (EC) of the groundwater ranges between 950 to 6170 µS/cm in the dry period with an average value of 2868.75 µS/cm, while, in the wet period are ranging between 1160 to 3930 µS/cm with an average value of 2397 µS/cm.
The Turbidity values of the groundwater are ranging between 4.8 to 16.5 mg/L in the dry period with an average value of 11.9 mg/L, while, in wet period are ranging between 6.9 to 13.1 mg/L with an average value of 10.56 mg/L.
The Total Hardness (TH)of the groundwater are ranging between 212.74 to 1536.6 mg/L in the dry period with an average value of 676.7 mg/L , while, in the wet period are ranging between 272.53 to 915 mg/L with an average value of 577.16 mg/L .

Table 2-Physical and chemical measurements from lab analysis of surface water and groundwater for the dry and wet period compared with standards [3][4]

Symbols	Dry period(October 2018)					Wet period(February 2019)				
	pH	TDS(ppm)	EC µS/cm	Turbidity NTU	TH mg/L	pH	TDS(ppm)	EC µS/cm	Turbidity NTU	TH mg/L
SW1	7.4	891	1400	2.5	320.573	7.4	485	765	15.2	171.453
SW2	7.5	925	1450	8.3	341.887	7.5	507	800	17.0	183.059
SW3	7.5	955	1510	11.51	335.415	7.4	463	732	19.3	167.338
SW4	7.7	940	1470	3.0	365.099	7.6	470	735	11.5	173.95
Mean	5755	927.75	1457.5	6.3275	340.7435	7.52	481.25	758	15.75	173.95
W1	7.5	3425	5430	6.5	1167.15	7.5	1120	1760	8.5	435.015
W2	7.4	605	950	4.8	212.743	7.3	1115	1739	6.9	415.918
W3	7.6	827	1300	14.8	311.464	7.6	1006	1580	11.6	382.718
W4	7.8	803	1260	10.2	283.258	7.7	737	1160	9.2	272.531
W5	7.7	1730	2710	16.5	656.867	7.6	1550	2440	12.8	596.48
W6	8.0	2409	3780	13.90	929.398	7.9	2530	3930	12.0	915.015
W7	7.9	3890	6170	15.0	1536.605	7.8	2330	3660	13.1	902.95
W8	7.9	858	1350	13.6	316.178	7.5	1820	2860	10.4	696.679
Mean	7.737	1818.375	2868.75	11.9125	676.7079	7.68	1526	2397.37	10.562	577.1633
ISQ,2009 [4]	6.5-8.5	1000			500	6.5-8.5	1000	-------	--------	500
WHO,2008 [3]	6.5-8.5	1000	250	5.0		6.5-8.5	1000	250	5.0	500

Hydrochemical Properties for surface water

All the results of the concentration and averages of major ions of surface and groundwater samples for the wet and dry periods are tabulated in Tables 3 and 4.

Calcium concentrations in surface water range from 71.0 ppm to 77.0 ppm with a mean of 74.25 ppm in the dry period and range from 39.0 ppm to 42.0 ppm with a mean of 40.0 ppm in the wet period.

Magnesium concentrations in surface water range between 33.0 ppm to 42.0 ppm with a mean of 37.75 ppm and 17.0 ppm to 19.0 ppm with a mean of 18.0 ppm for dry and wet periods respectively.

Sodium concentrations in surface water range between 89.0 ppm to 100.0 ppm with a mean of 92.50 ppm, and 44.0 ppm to 48.0 ppm with a mean of 46.0 ppm for dry and wet periods respectively.

Potassium concentrations in surface water range between 3.7 ppm to 4.2 ppm with a mean of 3.93 ppm, and 2.8 ppm to 3.1 ppm with a mean of 2.98 ppm for dry and wet periods respectively.

The chloride concentrations in surface water range between 200.0 ppm to 219.0 ppm with a mean of 210.0 ppm, and 100.0 ppm to 114.0 ppm with a mean of 107.75 ppm for dry and wet periods, respectively.

Sulphate in surface water concentrations range from 156.0 ppm to 168.0 ppm with a mean of 161.75 ppm, and from 76.0 ppm to 88.0 ppm with a mean of 83.75 ppm in the dry and wet periods respectively.

Bicarbonate concentrations of surface water samples range from 60.0 ppm to 68.0 ppm with a mean of 63.5 ppm in the dry period ,and from 40.0 ppm to 45.0 ppm with a mean of 42.0 ppm in the wet period.

The mean concentration of phosphates of surface water samples range from 0.36 ppm to 0.41 ppm with a mean of 0.39 ppm in the dry period ,and from 0.35 ppm to 0.39 ppm with a mean of 0.37 ppm in the wet period.

The mean concentration of nitrate of surface water samples range from 2.6 ppm to 3.2 ppm with a mean of 2.9 ppm in the dry period ,and from 1.7 ppm to 2.3 ppm with a mean of 1.97 ppm in the wet period.

Hydrochemical Properties for groundwater

Calcium concentrations in groundwater samples range from 44.0 ppm to 355.0 ppm with a mean of 150.5 ppm in dry period ,and range from 63.0 ppm to 210.0 ppm with a mean of 133.5 ppm in the wet period.

Magnesium concentrations in ground water range between 25.0 ppm to 158.0 ppm with a mean of 73.13 ppm and 28.0ppm to 101.0 ppm with a mean of 59.25 ppm for dry and wet periods respectively.

Sodium concentrations in groundwater range between 62.0 ppm to 420.0 ppm with a mean of 192.25 ppm, and 77.0 ppm to 265.0 ppm with a mean of 160.88 ppm for dry and wet periods respectively.

Potassium concentrations in ground water range between 2.5 ppm to 15.6 ppm with a mean of 6.96 ppm, and 3.7ppm to 6.6 ppm with a mean of 4.86 ppmfor dry and wet periods respectively.

Chloride concentrations in the groundwater range between 139.0 ppm to 856.0 ppm with a mean of 399.13ppm and 174.0 ppm to 506.0 ppm with a mean of 330.13 ppm for dry and wet periods respectively.

Sulphate concentrations of groundwater range from 101.0 ppm to 773.0 ppm with a mean of 345.0 ppm, and range from 141.0 ppm to 480.0 ppm, with a mean of 285.88 ppm in dry and wet periods respectively.

Bicarbonate concentration values in groundwater ranged from 46.0 ppm to 279.0 ppm, with a mean value of 130.13 ppm in the dry period, and from 51.0 ppm to 221.0 ppm, with mean of 118.25 ppm in the wet period(Tables 5, and 6).
The mean concentration of phosphates in groundwater are ranging from 0.35 ppm to 0.63 ppm with a mean of 0.465 ppm in the dry period and from 0.36 pm o 0.51 ppm with a mean of 0.42 ppm in the wet period.
The mean concentration of nitrate in groundwater are ranging from 2.0 ppm to 19.2 ppm with a mean of 8.1 ppm in the dry period, and from 2.5 ppm to 13.4 ppm with a mean of 7.0 ppm in the wet period.

Table 3- Concentration and averages of major ions of surface water and groundwater samples for the dry period.

Sample	Unit	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl-	HCO_3^-	$SO_4^=$	PO_4^{3-}	NO_3^-
SW1	ppm	74	33	89	4.2	186	60	163	0.41	3.2
	epm	3.69	2.71	3.87	1.07	5.24	0.98	3.39		
	epm%	32.52	23.91	34.10	9.45	56.31	9.81	33.87		
SW2	ppm	71	40	92	3.8	198	68	156	0.38	2.6
	epm	3.45	3.29	4	0.97	5.58	1.11	3.24		
	epm%	30	27.86	33.89	8.22	57.82	31.40	10.77		
SW3	ppm	75	36	100	4	205	65	168	0.36	3
	epm	3.74	2.96	4.35	1.02	5.78	1.06	3.49		
	epm%	30.98	24.52	36.01	8.46	57.51	9.91	32.56		
SW4	ppm	77	42	89	3.7	195	61	160	0.4	2.8
	epm	3.84	3.45	3.87	0.94	5.5	0.99	3.33		
	epm%	31.71	28.51	31.95	7.8	57.65	9.77	32.57		
Mean		74.25	37.75	92.5	3.925	210	63.5	161.75	0.3875	2.9
W1	ppm	240	138	355	14.2	714	200	673	0.58	15.4
	epm	11.97	11.35	15.44	3.63	20.14	3.27	14.01		
	epm%	27.86	26.77	36.41	8.56	53.8	8.75	37.43		
W2	ppm	44	25	62	3.4	139	46	101	0.35	2
	epm	2.19	2.03	2.69	0.86	3.92	0.75	2.10		
	epm%	28.08	26.30	34.49	11.11	55	10.57	29.49		
W3	ppm	72	32	86	2.5	190	59	152	0.35	2.4
	epm	3.59	2.63	3.74	0.63	5.35	0.96	3.16		
	epm%	33.87	24.82	35.27	2.41	55.49	10.01	34.49		
W4	ppm	64	30	82	2.6	180	54	135	0.37	2.2
	epm	3.19	2.46	3.56	0.66	5.07	0.88	2.81		
	epm%	32.28	24.94	36.05	6.71	56.53	9.85	33.61		
W5	ppm	151	68	181	6.1	385	138	294	0.46	8.5
	epm	7.53	5.59	7.87	1.55	10.86	2.26	6.12		
	epm%	33.39	24.79	34.89	6.91	55.83	11.62	32.53		
W6	ppm	214	96	259	8.5	512	205	438	0.56	11.8
	epm	10.67	7.89	11.26	2.17	14.44	3.35	9.11		
	epm%	34.84	24.61	33.76	6.77	52.67	12.25	35.07		
W7	ppm	355	158	420	15.6	856	279	759	0.63	19.2
	epm	17.71	12.99	18.27	3.98	24.14	4.57	15.8		
	epm%	33.44	24.52	34.49	7.53	53.88	10.20	35.91		
W8	ppm	64	38	93	2.8	217	60	128	0.42	3.1
	epm	3.19	3.12	4.04	0.71	6.12	0.98	2.66		
	epm%	28.82	28.20	36.50	6.46	60.84	9.77	29.38		
Mean		150.5	73.125	192.25	6.96	399.125	130.125	345	0.465	8.075
ISQ,2009[4]		150	100	200		350		400		50
WHO,[3] 2008		100	125	200	12	250		250	10	50

Table 4- Concentration and averages of major ions of Surface water and groundwater samples for the wet period.

Sample No.	Unit	Ca	Mg	Na	K	Cl	HCO_3	SO_4	PO_4	NO_3
	ppm	39	18	47	2.8	111	42	76		
SW1	epm	1.94	1.48	2.04	0.71	3.13	0.68	1.58	0.36	2
	epm%	29.22	24.70	34.11	11.94	57.96	12.74	29.29		
	ppm	42	19	48	3.1	114	45	88		
SW2	epm	2.09	1.56	2.08	0.79	3.21	0.73	1.83	0.39	2.3
	epm%	29.79	24.69	32.98	12.52	55.58	12.74	31.66		
	ppm	39	17	44	3	100	40	85		
SW3	epm	1.94	1.39	1.93	0.76	2.82	0.65	1.76	0.35	1.9
	epm%	30.03	23.98	32.82	13.15	53.77	12.49	33.73		
	ppm	40	18	45	3	106	41	86		
SW4	epm	1.79	1.48	1.95	0.76	2.99	0.67	1.79	0.38	1.7
	epm%	29.92	24.67	32.61	12.78	54.83	12.32	32.83		
Mean		40	18	46	2.97	107.75	42	83.75	0.37	1.97
	ppm	105	42	117	4.3	257	68	211		
W1	epm	4.71	3.45	5.08	1.09	7.24	1.11	4.39	0.41	3.5
	epm%	32.88	24.06	35.44	7.65	56.82	8.73	34.43		
	ppm	99	41	116	4.1	249	63	212		
W2	epm	4.44	3.37	5.04	1.04	7.02	1.03	4.41	0.38	3.1
	epm%	31.95	24.24	36.27	7.53	56.32	8.27	35.39		
	ppm	89	39	104	3.7	228	59	186		
W3	epm	3.99	3.2	4.52	0.94	6.43	0.96	3.87	0.37	2.6
	epm%	31.52	25.31	35.69	7.46	57.06	8.57	34.35		
	ppm	63	28	77	3.8	174	51	141		
W4	epm	2.82	2.3	3.34	0.97	4.9	0.83	2.93	0.36	2.5
	epm%	29.92	24.36	35.43	10.27	56.54	9.63	33.55		
	ppm	140	60	166	4.8	339	131	284		
W5	epm	6.28	4.93	7.22	1.22	9.56	2.14	5.91	0.4	6.9
	epm%	31.95	25.09	36.71	6.23	54.26	12.18	33.55		
	ppm	200	101	265	6.4	508	221	480		
W6	epm	8.98	8.3	11.52	1.63	14.33	3.62	9.99	0.51	13.4
	epm%	29.48	27.28	37.85	5.37	51.27	12.96	35.75		
	ppm	210	92	252	6.6	503	195	442		
W7	epm	9.42	7.56	10.96	1.68	14.18	3.19	9.2	0.48	12.5
	epm%	31.80	25.52	36.97	5.69	53.36	12.02	34.61		
	ppm	162	71	190	5.2	383	158	331		
W8	epm	7.27	5.84	8.26	1.32	10.8	2.58	6.89	0.43	11.8
	epm%	32.03	25.71	36.39	5.85	52.47	12.57	33.47		
Mean		133.5	59.25	160.875	4.862	330.125	118.25	285.875	0.417	7.035
ISQ,2009[3]		150	100	200		350		400		50
WHO,2008[4]		100	125	200	12	250		250	10	50

Heavy metals

Heavy metals (Fe, Ni, Co, Cd, Pb, Cu and Zn) were analyzed for all surface water and groundwater samples. The results show a relative increase in their mean values in the groundwater. When comparing the trace elements between international and Iraqi standards [3 and 4] the results reflect that the concentrations of the trace elements Fe, Ni, Co, Cd, and Pb are above the acceptable limits, whereas Cu and Zn are within the acceptable limits (Tables 5 and 6).

Table 5-Heavy metal concentrations in surface water and groundwater (ppm) for the dry period (October 2018)

Symbols	Heavy metal (ppm)						
	Fe	Zn	Ni	Cu	Cd	Pb	Co
SW1	0.562	0.316	0.083	0.139	0.089	0.096	0.083
SW2	0.1392	0.912	0.136	0.267	0.118	0.137	0.109
SW3	2.110	1.861	0.219	0.329	0.121	0.165	0.120
SW4	0.713	0.509	0.113	0.175	0.109	0.108	0.098
Mean	1.19425	0.8995	0.13775	0.2275	0.10925	0.1265	0.1025
W1	0.832	0.639	0.207	0.335	0.096	0.301	0.098
W2	0.691	0.412	0.231	0.411	0.123	0.228	0.119
W3	5.109	3.430	0.583	0.860	0.196	0.692	0.175
W4	1.316	0.854	0.265	0.662	0.154	0.328	0.129
W5	4.316	2.218	0.503	0.914	0.185	0.613	0.168
W6	3.631	0.635	0.381	0.752	0.190	0.594	0.162
W7	2.114	1.267	0.346	0.513	0.178	0.392	0.148
W8	2.82	1.78	0.29	0.667	0.183	0.467	0.151
Mean	2.603	1.404	0.350	0.639	0.163	0.451	0.143
ISQ,2009 [4]	0.3	3.0	0.02	1.0	0.003	0.01	-------
WHO,2008[3]	<3	3.0	0.02	2.0	0.003	0.01	0.05

Table 6-Heavy metal concentrations in surface water and groundwater (ppm) for wet period**(February 2019)**.

Symbols	Heavy metal (ppm)						
	Fe	Zn	Ni	Cu	Cd	Pb	Co
SW1	0.193	0.169	0.068	0.081	0.056	0.062	0.055
SW2	0.532	0.508	0.092	0.138	0.085	0.103	0.073
SW3	0.809	0.913	0.155	0.161	0.079	0.109	0.081
SW4	0.215	0.276	0.101	0.096	0.081	0.096	0.062
Mean	0.43725	0.4665	0.104	0.119	0.07525	0.092	0.06775
W1	0.246	0.361	0.126	0.170	0.061	0.119	0.068
W2	0.202	0.231	0.139	0.193	0.089	0.136	0.091
W3	1.85	1.281	0.236	0.285	0.121	0.219	0.116
W4	0.4671	0.433	0.141	0.201	0.108	0.158	0.095
W5	1.73	0.968	0.212	0.322	0.125	0.210	0.106
W6	1.49	1.06	0.161	0.269	0.132	0.203	0.102
W7	0.830	0.871	0.152	0.231	0.128	0.175	0.110
W8	0.716	0.820	0.146	0.250	0.130	0.189	0.113
Mean	0.941	0.753	0.164	0.240	0.111	0.176	0.100
ISQ,2009[4]	0.3	3.0	0.02	1.0	0.003	0.01	-------
WHO,2008[3]	<3	3.0	0.02	2.0	0.003	0.01	0.05

It is believed that the source of these heavy metal may be from anthropogenic inputs into soils from different sources, such as agricultural amendments, atmospheric deposition, sewage sludge and may be phosphate fertilizers.

Hydrochemical Formula

The general hydrochemical formula is described as in the following equation [11]:

$$TDS\ (\text{mg}/L) = \frac{\text{Anions (epm\%)in descending order}}{\text{Cations (epm\%)in descending order}}(pH)$$

The hydrochemical formula and water type of the analyzed samples are tabulated in Tables 7 and 8**.** The results reflect that the surface and groundwater samples have the same water type as $Na^{+}\_Ca^{+2}\_Mg^{+2}\_\_So4^{-2}$ Chloride.

HCO_3 , SO_4 , PO_4 , NO_3

Table 7-Hydrochemical Formula for Surface and Groundwater Samples in the dry period

SampleNo.	Hydrochemical Formula	Water type
RW1	TDS(891) $\frac{Na(34.10)Ca(32.52)Mg(23.91)}{Cl(56.31)So4(33.87)}$ PH(7.4)	$Na^{+}\_Ca^{+2}\_Mg^{+2}\_\_So4^{-2}$ Chloride
RW2	TDS(925) $\frac{Na(33.89)Ca(30)Mg(27.86)}{Cl(57.82)So4(31.40)}$ PH(7.5)	$Na^{+}\_Ca^{+2}\_Mg^{+2}\_\_So4^{-2}$ Chloride
RW3	TDS(955) $\frac{Na(36.01)Ca(30.98)Mg(24.52)}{Cl(57.51)So4(32.56)}$ PH(7.5)	$Na^{+}\_Ca^{+2}\_Mg^{+2}\_\_So4^{-2}$ Chloride
RW4	TDS(940) $\frac{Na(31.95)Ca(31.71)Mg(28.51)}{Cl(57.65)So4(32.57)}$ PH(7.7)	$Na^{+}\_Ca^{+2}\_Mg^{+2}\_\_So4^{-2}$ Chloride
W1	TDS(3425) $\frac{Na(36.41)Ca(27.86)Mg(26.77)}{Cl(53.80)So4(37.43)}$ PH(7.5)	$Na^{+}\_Ca^{+2}\_Mg^{+2}\_\_So4^{-2}$ Chloride
W2	TDS(605) $\frac{Na(34.49)Ca(28.08)Mg(26.30)}{Cl(55)So4(29.49)}$ PH(7.4)	$Na^{+}\_Ca^{+2}\_Mg^{+2}\_\_So4^{-2}$ Chloride
W3	TDS(827) $\frac{Na(35.27)Ca(33.87)Mg(24.82)}{Cl(55.49)So4(34.49)}$ PH(7.6)	$Na^{+}\_Ca^{+2}\_Mg^{+2}\_\_So4^{-2}$ Chloride
W4	TDS(803) $\frac{Na(36.05)Ca(32.28)Mg(24.94)}{Cl(56.53)So4(33.61)}$ PH(7.8)	$Na^{+}\_Ca^{+2}\_Mg^{+2}\_\_So4^{-2}$ Chloride
W5	TDS(1730) $\frac{Na(34.89)Ca(33.39)Mg(24.79)}{Cl(55.83)So4(32.53)}$ PH(7.7)	$Na^{+}\_Ca^{+2}\_Mg^{+2}\_\_So4^{-2}$ Chloride
W6	TDS(2409) $\frac{Na(33.76)Ca(34.84)Mg(24.61)}{Cl(52.67)So4(35.07)}$ PH(8)	$Na^{+}\_Ca^{+2}\_Mg^{+2}\_\_So4^{-2}$ Chloride
W7	TDS(3890) $\frac{Na(34.49)Ca(33.44)Mg(24.52)}{Cl(53.88)So4(35.91)}$ PH(7.9)	$Na^{+}\_Ca^{+2}\_Mg^{+2}\_\_So4^{-2}$ Chloride
W8	TDS(858) $\frac{Na(36.50)Ca(28.82)Mg(28.20)}{Cl(60.84)So4(29.38)}$ PH(7.6)	$Na^{+}\_Ca^{+2}\_Mg^{+2}\_\_So4^{-2}$ Chloride

Table 8-Hydrochemical Formula for Surface and Groundwater Samples in the wet period

SampleNo.	Hydrochemical Formula	Water type
RW1	TDS(485) $\frac{Na(34.11)Ca(29.22)Mg(24.70)}{Cl(57.96)So4(29.29)}$ PH(7.4)	$Na^{+}\_Ca^{+2}\_Mg^{+2}\_\_So4^{-2}$ Chloride
RW2	TDS(507) $\frac{Na(32.98)Ca(29.79)Mg(24.69)}{Cl(55.58)So4(31.66)}$ PH(7.5)	$Na^{+}\_Ca^{+2}\_Mg^{+2}\_\_So4^{-2}$ Chloride
RW3	TDS(463) $\frac{Na(32.82)Ca(30.03)Mg(23.98)}{Cl(53.77)So4(33.73)}$ PH(7.4)	$Na^{+}\_Ca^{+2}\_Mg^{+2}\_\_So4^{-2}$ Chloride
RW4	TDS(470) $\frac{Na(32.61)Ca(29.92)Mg(24.67)}{Cl(54.83)So4(32.83)}$ PH(7.6)	$Na^{+}\_Ca^{+2}\_Mg^{+2}\_\_So4^{-2}$ Chloride
W1	TDS(1120) $\frac{Na(35.44)Ca(32.83)Mg(24.06)}{Cl(56.82)So4(34.43)}$ PH(7.5)	$Na^{+}\_Ca^{+2}\_Mg^{+2}\_\_So4^{-2}$ Chloride
W2	TDS(1115) $\frac{Na(36.27)Ca(31.95)Mg(24.24)}{Cl(56.32)So4(35.39)}$ PH(7.3)	$Na^{+}\_Ca^{+2}\_Mg^{+2}\_\_So4^{-2}$ Chloride
W3	TDS(1006) $\frac{Na(35.69)Ca(31.52)Mg(25.31)}{Cl(57.06)So4(34.35)}$ PH(7.6)	$Na^{+}\_Ca^{+2}\_Mg^{+2}\_\_So4^{-2}$ Chloride
W4	TDS(737) $\frac{Na(35.43)Ca(29.92)Mg(24.36)}{Cl(56.54)So4(33.55)}$ PH(7.7)	$Na^{+}\_Ca^{+2}\_Mg^{+2}\_\_So4^{-2}$ Chloride
W5	TDS(1550) $\frac{Na(36.71)Ca(31.95)Mg(25.09)}{Cl(54.26)So4(33.55)}$ PH(7.6)	$Na^{+}\_Ca^{+2}\_Mg^{+2}\_\_So4^{-2}$ Chloride

W6	TDS(2530)$\frac{Na(37.85)Ca(29.48)Mg(27.28)}{Cl(51.27)So4(35.75)}$ PH(7.9)	$Na^{+}\_Ca^{+2}\_Mg^{+2}\_\_So4^{-2}$ Chloride
W7	TDS(2330)$\frac{Na(36.97)Ca(31.80)Mg(25.52)}{Cl(53.36)So4(34.61)}$ PH(7.8)	$Na^{+}\_Ca^{+2}\_Mg^{+2}\_\_So4^{-2}$ Chloride
W8	TDS(1820)$\frac{Na(36.39)Ca(32.03)Mg(25.71)}{Cl(52.47)So4(33.47)}$ PH(7.5)	$Na^{+}\_Ca^{+2}\_Mg^{+2}\_\_So4^{-2}$ Chloride

Piper diagrams

By applying piper diagram [12] for all water samples, it is found that the water types of all samples are classified as (e) which represents the prevailing sulphate and chloride (Figures 3 and 4).

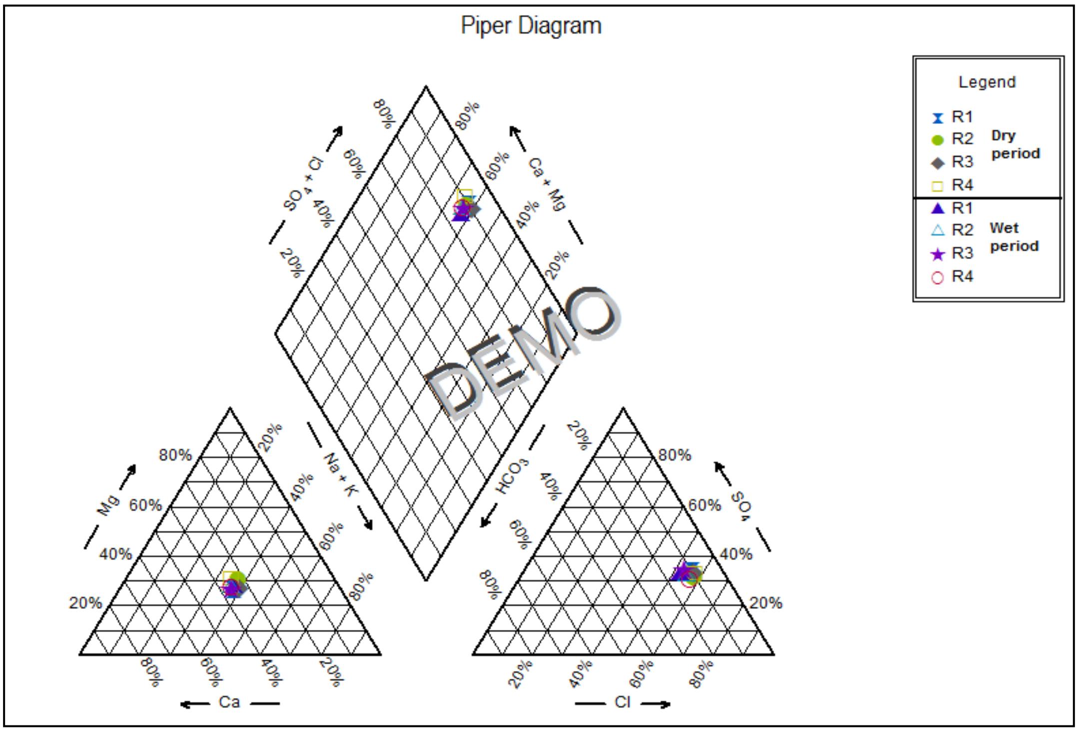

Figure 3-Piper Diagram for Surface Water Samples in dry period and wet period

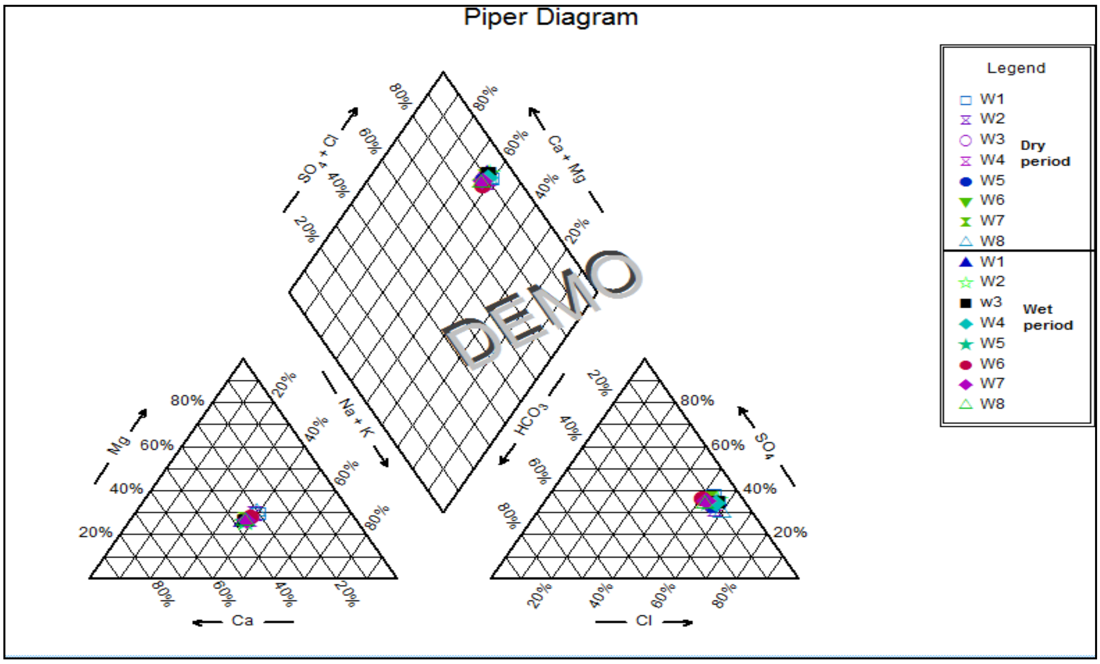

Figure 4-Piper Diagram for Groundwater Samples in dry period and wet period

Water Quality Suitability and Assessment

Water quality assessment for different purposes according to the Iraqi and international standards [3,4,5 and 6] indicated that all surface water is classified fresh water while ground water is classified as slightly to moderately brackish water. All results of turbidity for both periods were out of the allowable limits, excluding SW1, SW4 and W4for dry period were within limits (Table 2).

The mean of total hardness in surface water for the dry and wet period is within the acceptable limits [3][4], while in the groundwater samples for wet period is higher than the acceptable limits according to WHO,2008[3] and IQS,2009[4] (Table 9).

Table 9-Classifications of water hardness (ppm as CaCO3) according to [9] and [10]

Classification	Spellman 2013[10]	Bagley et al. 1997[9]	Sample for both period			
Soft	0-75	0-60				
Moderately hard	75-150	61-120				
Hard	150-300	121-180	All samples of surface water in wet period			
Very hard	>300		All samples of ground water in two period and all samples of surface water in dry period			

Suitability for drinking

The results show that the water samples in the study area are not suitable for human drinking purposes, because of the exceeding of COD, EC, Turbidity, Ni, Pb, Co, and Cd in surface and ground water for the two periods, and TH, Ca, K, Cl, and SO_4 in groundwater for the two periods (Tables 3, 4, 5 and 6).

Water suitability for livestock

According to Altoviski , 1962 classification [13], all surface and groundwater samples in both sampling periods are very good for livestock (Table 10).

Table 10-Water Quality Parameters Guide for The Livestock Uses [13] of surface water and groundwater samples.

Parameter	Surface water Mean	Surface water Mean	Ground water Mean	Ground water Mean	Very Good	Good	Permissible	Can be used	Maximum
	Dry period	Wet period	Dry period	Wet period					
Na^+	92. 5	46	192.25	160.875	800	1500	2000	2500	4000
	V.G	V.G	V.G	V.G					
Ca^{2+}	74.25	40	150.5	133.5					
	V.G	V.G	V.G	V.G					
Mg^{2+}	37.75	18	73.125	59. 25	350	700	800	900	1000
	V.G	V.G	V.G	V.G					
Cl^-	210	107.75	399.125	330.125					
	V.G	V.G	V.G	V.G					
$SO4^{2-}$	161.75	83.75	345	285.875	150	350	500	600	700
	V.G	V.G	V.G	V.G					
TDS	927.75	481.25	1818.375	1526					
	V.G	V.G	V.G	V.G					
TH	343.02	174.31	680.96	594.33	900	2000	3000	4000	6000
	V.G	V.G	V.G	V.G					

Water suitability for Irrigation

Sodium Adsorption Ratio (SAR)

The sodium adsorption ratio is considered as a measure of the suitability of water for use in agricultural irrigation. The higher the SAR, the greater the sodium hazard.SAR calculated from the ratio of sodium to calcium and magnesium by applying the following formula:

$$SAR=\frac{Na}{\sqrt{\frac{Ca+Mg}{2}}}$$

Where:

SAR is sodium adsorption ratio ;Na^{+},Ca^{2+} and $Mg^{2+}$are in meq/l .

Sodium hazard for surface and ground water for both sampling periods are low (Tables 11 and 12) which means the water could be used to irrigate according to Hillel, 2000, classification [6].

Table 11-Sodium Hazard of Water Based on SAR [14]

SAR class	Range of value	Sodium hazard	Comments
S1	<10	Low	Use on sodium sensitive crops
S2	10-18	Medium	Amendments and leaching are needed
S3	18-26	High	Generally unsuitable for continuous use
S4	>26	Very high	Generally unsuitable for use

Table 12-SAR hazards for surface water and ground water samples in dry and wet period

Surface water						Ground water					
Dry period			Wet period			Dry period			Wet period		
Station NO.	SAR meq/l	Hazard	Station NO.	SAR meq/l	Hazard	Station NO.	SAR meq/l	Hazard	Station NO.	SAR meq/l	Hazard
SW1	2.2	Low	SW1	1.60	Low	W1	4.52	Low	W1	2.51	Low
SW2	2.1	Low	SW2	1.59	Low	W2	1.84	Low	W2	2.55	Low
SW3	2.3	Low	SW3	1.5	Low	W3	2.12	Low	W3	2.38	Low
SW4	2.02	Low	SW4	1.52	Low	W4	2.12	Low	W4	2.09	Low
						W5	3.07	Low	W5	3.04	Low
						W6	3.50	Low	W6	3.92	Low
						W7	3.76	Low	W7	3.76	Low
						W8	3.22	Low	W8	3.22	Low

Magnesium hazard

According to Szabolcs and Darab, 1964 classification [15],whom proposed magnesium hazard (MH) equation for irrigation water as follow:

MH = Mg_2+/ $(Ca^{+2}+Mg^{+2})$x100

Where:

MH is magnesium hazard; $Mg^{2+} and Ca^{2+}$are in meq/l

MH values > 50 are considered harmful and unsuitable for irrigation purposes. In the present study, all surface water and groundwater samples (Table13) with respect to MH are suitable for irrigation purposes.

Table 13-Magnesium Hazard for Surface and groundwater samples

Surface water				Ground water				Decision
Summer season		Winter season		Summer season		Winter season		
Station No.	MH	Station No.	MH	Station No.	MH	Station No.	MH	
SW1	30.84	SW1	31.57	W1	36.50	W1	28.57	Suitable for irrigation purposes.
SW2	36.03	SW2	31.14	W2	36.23	W2	29.28	
SW3	32.43	SW3	30.35	W3	30.76	W3	30.46	
SW4	35.29	SW4	31.03	W4	31.91	W4	30.76	
				W5	31.05	W5	30	
				W6	30.96	W6	33.55	
				W7	30.79	W7	30.46	
				W8	37.25	W8	30.47	

Conclusions

1- The results show that the water samples in the study area are not suitable for human drinking purposes.

2- All surface and groundwater samples in both sampling periods are very good for livestock.

3- Sodium hazard for surface and ground water for both sampling periods are low could be used to irrigate.

4- All surface and groundwater samples with respect to Magnesium Hazard are suitable for irrigation purposes.

5- The water type depending on hydrochemical formula of water samples are;$Na^{+1}Ca^{+2}Mg^{+2}So4^{-2}$ Chloride.

6- TDS concentrations indicated that the surface water for both period was fresh ,while in ground water samples was slightly brackish to moderately saltine.

7- Surface water samples are classified as hard in some samples to very hard, while all groundwater samples are very hard.

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