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Hydrochemical Evaluation of Groundwater in Al-Khasfa Area within Haditha, Western Iraq

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Abstract

The main aim of the research is to study the groundwater quality in Al-Khasfa area within Haditha district, western Iraq. To assess the groundwater, eighteen groundwater samples in the study area were collected and analyzed for major cations and anions. Results indicated that groundwater samples in the study area are between neutral and light alkaline, slightly brackish, and highly mineralized. The hydrochemical formula of the groundwater samples indicates the Ca-SO₄ type dominance, except wells number 16 and 17 were of Ca-Cl water type. According to Piper diagram, the type of water is Earth-Alkaline waters. All groundwater samples are unsuitable for human drinking, industrial, and building uses, but it is suitable for livestock. For irrigation purposes, it is characterized by no Mg-harmful, good with SAR, Na%, RSC, and PI but unsuitable for salinity hazard due to very high salinity. The Water Quality Index for Euphrates aquifer in the study area in both periods are poor water for human drinking, except W-1 in dry period indicate very poor water and W-6, W-7, W-8, W-13, W-14, W-15, W-16 in wet period indicate good water.

Keywords: Groundwater; Piper diagram; Euphrates Aquifer; Water quality index

1. Introduction

Hydrochemical studies detect the quality of water in its chemical, physical and biological characteristics to obtain its suitability for human drinking, industrial and agriculture purposes (Al-Salih and Al-Kubaisi, 2016). The chemical composition of groundwater is influenced by several variables, including the lithological composition of the formation aquifer rocks, topography, precipitation and climate (Salar and Al-Kubaisi, 2009). The Hydrochemical of groundwater data gives evidence for the geologic history of rocks and shows the movement, recharge and storage of groundwater (Al-Sudani, 2019). Regional variations in water characteristics will result from variation of climate and geology and the most important factors related to irrigation and climate parameters (Awadh and Al-Kilabi, 2014). Water quality has an individual pattern of chemical and physical properties, which are determined largely by the geomorphological, climatic and geochemical conditions prevailing in the drainage basin and the underlying aquifer (Sen, 2015).

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2. Study Area and Hydrogeological Setting

The study area is located in the Western Desert 200 km away from Baghdad city in the northwest direction. It occupies almost 116 km² with an elevation of 191-160 m above sea level, between latitudes 34° 8' 0"–34° 12' 40" E, and longitudes 42° 8' 0"–42° 18' 40"N. The area is bordered on the north by Haditha Lake (Fig.1). The study area is located on the stable platform (Rutba - Jazeera Zone). The area is relatively flat rises gradually and gently westwards. Geologically. The largest part of the study area covers the Euphrates Formation (Lower Miocene), which consists of carbonate rocks mainly of limestone, dolomitic limestone and marly limestone (Abdul-Razzak and Zaynal, 2016). The Fatha Formation (Middle Miocene), which consists mainly of evaporating facies layers of anhydrite and gypsum interbedded with marl and limestone (Al-Jiburi and Al-Basrawi, 2014). These formations are covered by Quaternary deposits (Pleistocene-Holocene) which consist of: residual soil and slope sediments (Jassim and Goff, 2006) (Fig. 2). The Euphrates Formation in the region represents the upper groundwater aquifer, which represents the groundwater discharge regions (Jumma and Al-Shammaa, 2020). The Euphrates aquifer is exposed along both sides of the Euphrates River and deeply cut valleys south of Euphrates River (Fig. 1) show the direction of groundwater flow for dry season (29-30 September 2019), the groundwater movement toward the Euphrates River, from the southwest to northeast and following the earth surface topography in the study area. The recharge supply of the aquifer is mostly from the rainfall and the underlying aquifer due to the hydraulic connection between them (Al-Jiburi and Al-Basrawi, 2014).

Fig. 1. Location map and groundwater flow of the studied area

Fig. 2. Geological map of the studied area modified from (Sissakian and Qanber, 1993)

3. Materials and Methods

Eighteen groundwater sample were collected from the study area in the dry period (September, 2019) and wet period (April, 2020) (Fig.3). Total Dissolved Solids (TDS), water Temperature (T), Hydrogen Number (pH), and Electrical conductivity (EC) were measured directly after taking the sample. Laboratory tests were analysed for the major ions. The chemical analyses of samples were carried out in the laboratory of General Commission for Groundwater using a standard procedure of APHA, (2005).

Fig. 3. Locations of the selected wells in the study area

3. Results and Discussion

The physical characteristics of groundwater samples is shown in Table 1. Groundwater characterized in the study area as an odorless, colorless, as for the temperature ranged (26 - 30 °C) with an average of 27.9 °C for the dry season (23 - 25.6 °C) with an average of 24.2 °C for the wet season. The ranges of pH value during dry season from 6.9 - 7.5 with an average of 7.2. while a slight increase during wet season from 7 - 7.4 with an average of 7.1. The ranges of EC value during dry season from 3963 to 7873.5 with an average of 4757 µS/cm while a slight decrease during wet season from 3338.37 to 6995.73 with an average of 4104.64 µS/cm. The ranges of TDS value during dry season from 2649 to 5250 with an average of 3184.66 mg/l while a slight increase during wet season from 2289 - 4790 with an average of 2875.38 mg/l. As mentioned before, the main geological water bearing formation in the area is the Euphrates which is of marine depositional environments. The increase in EC and TDS is generally due to solution of calcium carbonate deposits by groundwater. The results of hydrochemical analysis of the groundwater samples in the study area for the two seasons are shown in Tables 2. The results show high concentrations of major ions where the cation Ca^{2+} is dominating while the anion SO_4^{2-} is dominating in both seasons. Depending on the formula of Ivanov et al. (1968), all the groundwater samples are Ca – Sulphate type, except samples number W.16 and W.17 where the water type is Ca – Chloride in two seasons. These results indicate the similarity of the hydrogeochemical processes. The availability of the calcium sulfate water type refers to the effect gypsum bed that exists in the Fatha Formation.

Table 1. Physical parameters of water samples in the two seasons

Well	Dry season (Sep.2019)				Wet season (Apr. 2020)			
	T (°C)	pH	EC µS/cm	TDS mg/l	T (°C)	pH	EC µS/cm	TDS mg/l
W.1	29	6.9	7873.5	5250	23.7	7	6995.73	4790
W.2	27.5	7.1	6397.5	4270	25.6	7.3	5512.5	3800
W.3	30	7.2	5365.5	3580	24.9	7.4	4646.67	3200
W.4	28.4	7.1	5113.5	3410	25	7	4360.02	3000
W.5	28.1	7.4	4786.5	3200	24.5	7.2	4135.11	2850
W.6	27.5	7.2	4329	2890	24	7	3720.57	3545
W.7	29	7.5	4111.5	2750	23.9	7.3	3560.34	2430
W.8	30	7.3	3963	2650	24.6	7.2	3338.37	2300
W.9	27	7.4	3966	2649	25	7.3	3339.84	2289
W.10	29.2	7.1	4951.5	3350	24.3	7	4301.22	3021
W.11	28.5	7.3	4660.5	3145	23.8	7.2	4138.05	2850
W.12	28	7	4552.5	3050	23.2	7	3932.25	2700
W.13	26.3	7.3	4074	2730	24.6	7.2	3582.39	2453
W.14	27	7.1	4147.5	2770	24	7	3592.68	2451
W.15	26	7.3	4261.5	2850	23.8	7.2	3573.57	2456
W.16	28.4	7.3	4267.5	2855	23	7.2	3679.41	2510
W.17	26.6	7.2	4419	2955	23.5	7.1	3724.98	2552
W.18	26.1	7.4	4389	2970	24.2	7.3	3749.97	2560

3.1. Classification of Groundwater Samples

Piper (1944) suggested a trilinear water-classification diagram. Analyzes are plotted based on the percentage of every cation and anion calculated presented in milli-equivalent per liter (meq /l). Piper diagram is hydrochemical classification to determine water types and quality in the study area indicates the water samples classified into class e which appears earth alkaline water with increase portion of alkali with prevailing chloride and sulfate. For the drawing of this diagram, Rock Ware version 1.1

program was used to show the relative concentrations of the various ions in groundwater samples from the study area (Fig. 4).

Table 2. Chemical analysis of water samples in two seasons

Well No.	In dry season (ppm)							WQI
	Ca ²⁺	Na ⁺	Mg ²⁺	K ⁺	SO ₄ ²⁻	Cl ⁻	HCO ₃ ⁻	
W.1	800	543	234	27	2456	845	344	207.35
W.2	645	453	200	18	1987	510	452	155.65
W.3	567	412	134	21	1423	600	420	153.21
W.4	523	400	125	24	1289	634	414	158.80
W.5	540	378	145	23	1287	623	395	161.48
W.6	440	345	112	16	998	567	408	116.88
W.7	411	350	96	18	860	578	428	127.55
W.8	412	300	97	16	855	556	406	118.84
W.9	401	321	98	24	860	567	373	148.20
W.10	560	321	99	20	1420	543	338	138.91
W.11	460	345	150	25	999	700	428	163.12
W.12	450	378	112	22	967	654	452	139.51
W.13	400	312	89	17	865	545	463	120.60
W.14	412	323	88	19	940	543	440	121.80
W.15	423	344	83	18	890	556	527	123.64
W.16	430	367	77	18	865	645	443	125.89
W.17	402	389	132	20	879	654	470	137.30
W.18	400	367	98	17	1115	444	485	123.19
Well No.	In wet season (ppm)							WQI
	Ca ²⁺	Na ⁺	Mg ²⁺	K ⁺	SO ₄ ²⁻	Cl ⁻	HCO ₃ ⁻	
W.1	740	498	203	21	2234	770	293	177.5
W.2	590	402	180	13	1812	443	310	134.85
W.3	512	378	113	14	1323	525	296	125.68
W.4	487	350	105	17	1100	560	347	123.12
W.5	450	311	113	18	990	560	371	125.23
W.6	388	300	99	11	889	475	369	87.55
W.7	367	298	89	12	754	500	402	95.65
W.8	356	245	80	10	723	480	377	86.83
W.9	345	289	82	17	722	475	342	112.49
W.10	501	287	81	15	1280	450	312	109.7
W.11	467	295	113	18	889	632	401	127.79
W.12	390	324	100	16	878	643	324	110.48
W.13	360	278	95	12	834	443	415	96.22
W.14	367	299	76	14	812	453	423	94.61
W.15	369	289	65	14	756	461	477	98.21
W.16	387	312	77	13	732	565	417	99.83
W.17	356	334	93	16	743	549	443	108.93
W.18	378	289	79	14	978	378	435	103.16

Fig. 4. Type of water according Piper, (1944). **A)** In dry season; **B)** in wet season

3.2. Drinking-Water Quality Index (WQI)

WQI is an important method for demarcating the quality of groundwater and its suitability for human consumption (Rashid, et al., 2016). WQI is a mathematical instrument used to converting large quantities of water quality data into single number which represents water quality level. The WQI gives a general idea of water problems in any area, so it is considered is a primary indicator of water quality (Al-Kubaisi, 2020). In this study chemical parameters TDS, pH, Calcium, Sodium, Magnesium, Potassium, Sulfate, Chloride and Nitrate ions have been used for assessment of groundwater suitability for drinking purposes to develop WQI model. For calculation of WQI model, the standards for drinking purposes, as recommended by World Health, Organization Standard (WHO, 2011). The WQI for all

groundwater samples in dry period are poor water for human drinking, except W1 is very poor water for human drinking. While the WQI for all groundwater samples in wet period are Poor water for human drinking, except W6, W7, W8, W13, W14, W15, and W16 is good water for human drinking According to Vasanthavigar et al., (2010), (Table 2) and (Fig 5).

Fig. 5. WQI classification for groundwater in the study area in two periods

3.3. Groundwater Uses

According to IQS (2009) and WHO (2007) indicating the groundwater samples for two seasons was unsuitable for human drinking to most parameters. Groundwater samples compared with these specifications is found to be between very good water to good water for animal drinking in two seasons. The comparison of the groundwater samples with the standards is suggested by Hem, (1991) shows unsuitability of water in study area for all industrial purposes in two seasons. Groundwater water samples are unsuitable for building, because Ca^{+2} and HCO_3^- concentrations in two seasons exceed the recommended limit. To evaluate water quality for irrigation, there are several most popular criteria, these are: salinity hazard, sodium percentage (Na %), sodium adsorption ratio (SAR), residual sodium carbonate (RSC) and permeability index (PI), (Table 3). The salinity hazard in groundwater samples in the study area for two seasons was very high saline (C4) in all wells according to Turgeon, (2000). While based on Don (1995) classification of irrigation water, according to Na % values, the groundwater samples in the study area is good irrigation water class in two seasons. Wilcox, (1948) Has classified water for irrigation water depends on SAR values, where the samples showed that they are located within S1 (Use on sodium sensitive crops) in two seasons. Whereas, classification of irrigation water based on RSC values, groundwater samples in the study area are good and non-hazard category in two seasons according to Turgeon, (2000). On the other hand, permeability index (PI) was good quality for irrigation purposes in two seasons according to Nagaraju et al., (2006).

Table 3. The calculated values of SAR, Na%, RSC and PI of samples

Well	Dry season (Sep.2019)				Wet season (Apr. 2020)			
	SAR	Na%	RSC	PI	SAR	Na%	RSC	PI
W.1	4.32	28.99	-53.85	31.25	4.17	29.15	-49.1	31.55
W.2	3.98	29.18	-41.49	32.67	3.70	28.58	-39.42	31.82
W.3	4.02	31.83	-32.63	35.75	3.92	32.41	-30.16	36.22
W.4	4.06	32.99	-29.77	37.06	3.74	32.10	-27.42	36.41
W.5	3.71	30.34	-32.6	34.18	3.38	30.46	-25.83	35.18
W.6	3.78	32.96	-24.64	37.95	3.50	32.52	-21.6	38.09
W.7	4.02	35.44	-21.54	40.80	3.60	33.98	-19.18	40.08
W.8	3.44	31.92	-22.03	37.43	3.04	30.83	-18.28	37.41
W.9	3.71	34.05	-22.1	38.95	3.62	35.05	-18.48	40.73
W.10	3.27	28.52	-30.71	32.47	3.12	28.79	-26.68	33.27
W.11	3.56	30.58	-28.49	34.94	3.16	28.85	-26.19	33.74
W.12	4.11	34.81	-24.42	39.68	3.77	34.24	-22.52	39.09
W.13	3.66	33.80	-19.82	39.82	3.35	32.35	-19.11	38.66
W.14	3.75	34.21	-20.72	39.85	3.70	35.11	-17.75	41.48
W.15	3.99	35.45	-19.42	41.59	3.63	35.12	-16.05	42.15
W.16	4.27	37.03	-20.65	42.50	3.77	35.03	-18.92	41.13
W.17	4.28	35.91	-23.39	41.005	4.06	36.88	-18.29	42.96
W.18	4.25	36.78	-20.21	42.55	3.52	33.65	-18.35	40.03

4. Conclusions

- The Euphrates Formation is considered the main aquifer in the study area. Groundwater moves from the southwest to the northeast, towards the Euphrates River.
- Groundwater in the study areas is dominated by calcium and sulphate ions due to the carbonate dissolution of the Euphrates Formation.
- The type of groundwater samples area is Ca-sulphate type, except samples number W.16 and W.17 where the water type is Ca-chloride in both seasons refers to the effect gypsum bed that exists in the Fatha Formation.
- Piper diagram classified the type of groundwater as Earth-Alkaline waters.
- All groundwater samples are unsuitable for human drinking, industrial and building purposes.
- All groundwater samples are suitable for livestock uses.
- The suitability for irrigation purposes for the study area is characterized by no Mg-harmful, good with SAR, Na%, RSC and PI but unsuitable for salinity hazard (EC and TDS) due to very high salinity.
- The WQI indicates that groundwater samples are poor water for human drinking, except W-1 in dry period indicate vary poor water and W-6, W-7, W-8, W-13, W-14, W-15, W-16) in wet period indicate good water.

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