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Study of qualitative properties of groundwater and its suitability for different uses in the Eastern of the Al- Dour city/ Salahaldin/ Iraq

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ABSTRACT

A study was conducted to evaluate the groundwater in Abo- Dalaf Area, far east of Al-Dour city, Salahaldin governorate. The field work included, field visits to the area to know the geological reality and to identify the most important geomorphological and structural phenomena, then **10** wells were selected, distributed over the study area. Laboratory work included physical and chemical tests of water samples, The physical characteristics included, Total hardness (TH), Total Dissolved Solid (TDS) Sodium Adsorption Ratio (SAR), Sodium Ratio (Na%), Temperature (T) and pH.

Chemical analyses, the main components of water samples, for Cations such as: Sodium (Na^{+}), Potassium (K^{+}), Calcium (Ca^{+2}), and Magnesium (Mg^{+2}), and Anions such as Chloride (Cl^{-}), Sulfate (SO_4^{-2}), Bicarbonates (HCO_3^{-}), and nitrate (NO_3^{-}), and some trace elements were measured such as Iron (Fe), Copper (Cu), Zinc (Zn), lead (Pb), Nickel (Ni), Cobalt (Co), Chromium (Cr) and Cadmium (Cd). A location map of the study area was prepared using ArcGIS.

The results showed a variation in the quality characteristics of groundwater in the study area. After comparing the results with local international standards, it was showed that the wells water of the study area was not suitable for human drinking, but suitable for irrigation except well **(1)**.

1. Introduction

Water is one of the most important requirement necessary for life and its survival on the plants, it's the most important and most fluid in nature and plays a key role in many vital processes in the body [1].

Water hydrochemistry is the science deals with chemical composition for groundwater which is the doubt result of the relationship between water quality which enters in the aquifer and the interaction with rock containing various minerals as well as other factors such as temperature, depth, speed of water movement and other [2].

Importance of hydrochemical water in the processes of assessing the quality of groundwater resources because quality of this water no less important than the quantity, in other words the chemical and physical properties are essential to determine the suitability of water for various uses, and there is no doubt that study of chemical and physical properties of groundwater is very important, where the decrease or increase in some of the qualities beyond the limit may be negative or harmful and some are hazardous or toxic to organism such as heavy metals [3].

The proportion of dissolved components in groundwater is higher than in surface water due to the high exposure to soluble substance in geological layers [4]. One of the most important reasons for doing this study is that the area suffers from lack of fresh water and there are a lot of people rely on groundwater wells for domestic and other purpose.

The aim of present study is to assess the groundwater quality in Abo- Dalaf, East Al-Dour, by conducting chemical analysis of major ions, minor, trace elements, salinity and hardness, and therefore, the results was compared with international and local standers to determine their suitability for

different uses, (potable water, animals drinking, and irrigation).

The study area is located in Abo-Dalaf far east of Al-Dour administratively affiliated to Salah al-Din province, between longitudes (43º 48` 00") (43º 51` 00") E, and latitudes (34º 27` 00") (34º 30` 30") N, figure1: site map of the study area.

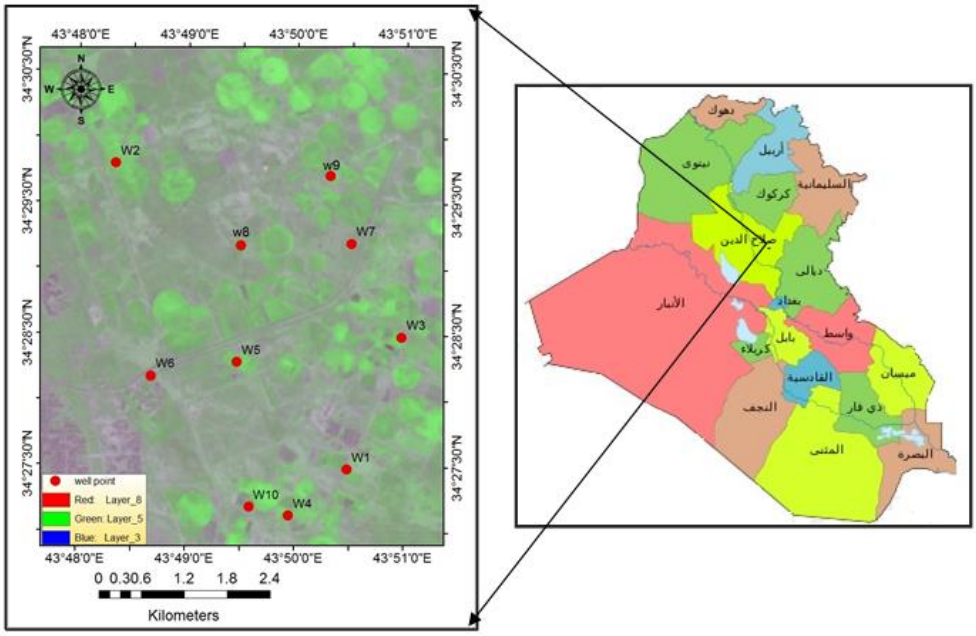

Fig. 1: The location of the study area

The study of geological formations is very important because of its direct effect on groundwater quality. The chemical composition of groundwater is the double result of water entering the aquifer, and the interactions with rock containing different minerals, so it is necessary to identify geological system of the study area.

The outcropped rocks in the study area related to middle Miocene– recent which is represented Fatha Formation, Injana Formation and Quaternary deposits, the following is a description of these geological formation:

Fatha Formation: consists of two upper and lower members separated by a layer of mass gypsum, the lower member consists of several sequences of green and gray limestone successive with gypsum and limestone rocks [5]. The contact surface with Injana Formation is determine by the disappearance of gypsum layers and appearance of red sandstone layers [6].

Injana Formation: consists of clastic rocks and alternating succession of clay stone, sandstone and siltstone as a sediment cycle, clay stone account for a higher proportion of sandstone [7].

Quaternary Deposits: consisting of stripped sediments of older formation and containing gravely sand, silt and clay it appear as alluvial fans in other areas. Quaternary deposits were divided into gravely fans, river terraces, valleys and depressions, all this types of sediments called polygenetic deposits in syncline areas [8].

2. Material and Methods

The field work consists of:

1- A first exploratory trip was conducted to study the geomorphological phenomena and rock outcrop for geological formations.

2- A second field trip was conducted, and during it they were:

- Determine the locations and coordinates of the well by using the (Garmin) GPS.
- Collect (10) samples taken from wells distributed over the study area in April 2019, (Covered the area as much as possible).

Physical parameters (EC, TDS, pH, and Cº) were measured in the field, using (multimeter).

Chemical analysis were measured in the laboratory of the chemical engineering department – Engineering college – Tikrit university.

Accuracy (A) was measured, which is a measure of the appropriateness and proximity of the results to their true values, is calculated by **(Ionic Balance)** in epm, [9].

E%=(∑ r. Cat -∑ r. Ani\ r. Cat +∑ r. Ani) *100 ….. (1)

Where Concentrations of ions in epm

A = 100 – E% …. (2)

Where:

E%: Percentage of error.

∑ r. Cat: Total concentrations of Cations in units (epm).

∑ r. Ani: Total concentrations of Anions in units (epm).

A: Accuracy

If the accuracy (A) is less than 90%, the results of the analysis cannot be adopted in the evaluation of water.

When comparing the percentage of error with table 1,[10], it was found that the water samples in the study area fall within the validity limits of the analysis except, **(W1, and W10)** have increased by a very small percentage that can be neglected

Table1: The Accuracy classification

Result	A% (ACCURACY)	E% (Error)
Certain	A ≥ 95%	E ≤ 5%
Probable certain	90% ≤ A ≤ 95%	10% ≥ E ≥ 5%
Uncertain	A < 90%	E > 10%

The concentrations of total dissolved solids **(TDS)**, were compared with Heath classification [11], and shows that the majority of well water are **Slightly water.**

Total Hardness was calculated using the following equation:

T.H = 2.5 Ca + 4.1 Mg, in ppm … (3)

After comparing the results with the Hardness classification of water, [12], showed that the study area water is **Hard** – **Very Hard**.

Sodium Adsorption Ratio **(SAR)** was calculated by;

$$SAR = \frac{rNa}{\sqrt{r(Ca + Mg)/2}} \quad \text{..... (4)}$$

Where:

SAR: Sodium Adsorption Ratio

r (Na , Ca , Mg); Concentrations of ions in epm.

When comparing **SAR** values of the study area wells with the limits proposed by Subramani, [13], the water quality was **Good to Excellent** type.

Percentage of sodium **Na%** was calculated by the following equation [14]:

$$Na^+\% = \{\frac{Na^+ + K^+}{Ca^{++} + Mg^{++} + Na^+ + K^+}\} * 100 \quad \text{..... (5)}$$

The concentrations of ions (Ca^{+2}, Mg^{+2}, Na^+, K^+) in epm.

3. Results and Discussion

The results of field, calculated parameters, and analyses are tabulated in tables (**2,3, and 4**), as shown below:

Table 2: Physiochemical Tests Results of water samples

No.	Ec ms	TDS ppm	PH ppm	T.H. ppm	SAR epm	Na %	T C°
W1	3110	1550	7.81	439	10.91	72.92	26
W2	2790	1560	8.02	300	10.68	76.15	26
W3	3360	1690	7.92	353	8.46	70.08	25.5
W4	2920	1420	7.85	261	10.62	77.19	25
W5	2980	1420	7.96	279	7.53	70.40	23
W6	2970	1423	8.5	246	8.37	73.77	25.5
W7	2930	1410	7.85	260	10.66	77.34	24
W8	3360	1692	8.1	355	8.45	70.02	26.5
W9	2788	1550	8.05	323	10.26	74.72	26
W10	3112	1553	7.78	327	12.68	78.38	23.5

Table 3: Chemical analyses Results of water samples in the study area

No.		Cations				Anions				Accuracy %
	Con.	Ca^{+2}	Mg^{+2}	Na^+	K^+	SO_4^{-2}	HCO_3^-	Cl^-	NO_3^-	
1	**ppm**	71.2	63.7	526.1	31.1	480	175.8	490	27.58	**91.06**
	epm	3.55	5.24	22.89	0.79	9.99	2.88	13.82	0.44	
2	**ppm**	56.1	38.9	425.3	25.5	460	153.5	480	27.29	**96**
	epm	2.8	3.2	18.5	0.65	9.58	2.52	10.72	0.44	
3	**ppm**	63.3	47.5	365.5	25.4	510	79.3	470	39.19	**95.5**
	epm	3.16	3.91	15.9	0.64	10.62	1.3	13.26	0.63	
4	**ppm**	47.4	34.8	394.7	20.6	420	85.4	370	17.35	**95.3**
	epm	2.37	2.86	17.17	0.52	8.74	1.4	10.44	0.28	
5	**ppm**	59.6	31.8	289.5	27.5	410	82.35	350	21.94	**96.8**
	epm	2.97	2.62	12.59	0.73	8.54	1.35	9.87	0.35	
6	**ppm**	59.9	23.5	301.8	28	411	88.45	360	18.13	**95.7**
	epm	2.99	1.93	13.13	0.71	8.56	1.45	10.16	0.29	
7	**ppm**	46.1	35.2	395.1	21.5	410	100.65	375	31.11	**96.2**
	epm	2.3	2.9	17.19	0.54	8.54	1.65	10.58	0.5	
8	**ppm**	64.5	47.2	366.1	25.9	420	100	460	38.77	**99**
	epm	3.22	3.88	15.93	0.66	8.74	1.64	12.98	0.63	
9	**ppm**	65.1	39.1	424.2	25.7	450	132	390	25.59	**94.6**
	epm	3.25	3.22	18.45	0.65	9.37	2.16	11	0.41	
10	**ppm**	71.1	36.4	527	31.2	461	161.24	491	19.19	**93.1**
	epm	3.55	2.99	22.92	0.79	9.6	2.64	13.82	0.31	

Table 4: Trace elements concentrations of water samples

No.	Cd ppm	Ni ppm	Pb ppm	Fe ppm	Cu ppm	Zn ppm
W1	<0.05	<0.05	<0.05	0.198	<0.1	0.23
W2	<0.05	<0.05	<0.05	0.106	<0.1	0.38
W3	<0.05	<0.05	<0.05	<0.1	<0.1	0.16
W4	<0.05	<0.05	<0.05	0.143	<0.1	0.21
W5	<0.05	<0.05	<0.05	<0.1	<0.1	0.18
W6	<0.05	<0.05	<0.05	0.2	<0.1	0.17
W7	<0.05	<0.05	<0.05	0.152	<0.1	0.22
W8	<0.05	<0.05	<0.05	0.12	<0.1	0.17
W9	<0.05	<0.05	<0.05	0.105	<0.1	0.37
W10	<0.05	<0.05	<0.05	0.199	<0.1	0.22

Table 5: The range of the Hydrochemical variables of water samples in the study area

Variables	Properties Range	Variables	Properties Range
pH	7.7 – 8.5	SO_4^{-2} (ppm)	410 – 510
E.C (µmohs/cm)	2788 – 3360	Cl^- (ppm)	350 –491
TDS (ppm)	1410 –1692	HCO_3^- (ppm)	79.3 – 175
T (C^o)	23 – 26.5	NO_3^{-2} (ppm)	17.3 – 39.19
TH (ppm)	246 – 439	Fe (ppm)	0 - 0. 2
SAR (epm)	7.53 - 12.68	Cu (ppm)	< 0.01
Ca^{++} (ppm)	46.1 – 71.2	Cd (ppm)	<0.05
Mg^{++} (ppm)	23.5 – 63.7	Zn (ppm)	0.16 - 0.38
Na^+ (ppm)	289 – 527	Ni (ppm)	<0.05
K^+ (ppm)	20.6- 31.2	Pb (ppm)	<0.05

Groundwater Uses

1. Groundwater Suitability as potable water

The basic divisions of drinking water depend on, major, minor and trace ions, as well as inorganic chemical properties and organic compounds, and biological and radiological properties. Drinking water should be free from harmful chemicals and its physical characteristics as turbidity, taste and smell should be good, [15].

After comparing the results of physical test and chemical analysis, Table (2, 3, and 4), with the limits and specifications proposed by the Iraqi Standards (IRS) [16], World Health Organization (WHO) [17], and the Canadian specifications, [18] (Table, 6), shows that the water in the study area is not suitable for drinking purposes.

Table 6: set of standards and classifications (global and local) for drinking water

Types	Parameters (ppm)	WHO 2017	Canada 2017	IRS 1996
Physio-chemical	**TDS**	600	500	1000
	pH	8.5	6.5-8.5	6.5-8.5
	T.H.	500	500	500
	Alk	200	--	--
Cations	**Ca^{++}**	100	--	50
	Mg^{++}	125	--	50
	Na^+	200	200	200
	K^+	12*	--	--
Anions	**$SO_4^=$**	250	≤ 500	250
	HCO_3	350*	--	--
	Cl^-	250	250	250
	NO_3^-	50	45	50
Trace Elements	**Cu^{2+}**	2	1	1
	Pb^{2+}	0.01	0.01	0.01
	Fe^{2+}	0.3*	≤ 0.3	--
	Zn^{2+}	3	≤ 5	3
	Cd^{2+}	0.003	0.005	--
	CO^{2+}	0.002	--	0.002

*** WHO, 2006**

2. Groundwater suitability for animal drinking

Water limits for animals drinking are different from humans. Acceptable limits for humans drinking are very good limits for animals drinking, because they can drink water with (TDS) much higher than human can drunk it, [19].

After comparing the analyses results with the specifications proposed of Altoviski, [20], which depends on some cations and anions, total dissolved salts (TDS) and total hardness (T.H.), Table 7, and standards for public veterinary services in the United States, [21] Table 8 shows that water is suitable for animal drinking and to a very good degree.

Table 7: shows water specifications for animal drinking in ppm [20]

Elements	Very good water	Good Water	Medium Water	Can Used	Maximum
Na	800	1500	2000	2500	4000
Ca	350	700	800	900	1000
Mg	150	350	500	600	700
Cl	900	2000	3000	4000	6000
SO_4	1000	2500	3000	4000	6000
TDS	3000	5000	7000	10000	15000
TH	1500	3200	4000	4700	54000

Table 8: Classification of water salinity for drinking animals according to the standards of public veterinary services in the United States of America [21]

Animals	TDS (ppm)
Poultry	Less than 2860
Horses	Less than 6435
Cattle (Dairy)	Less than 7150
Cattle (Beef)	Less than 10000
Sheep	Less than 12900

3. Groundwater suitability for Irrigation

Water used for irrigation depends on the Hydrochemical variables: Major (Cations and Anions), Minor components, as well as electrical conductivity (EC), Total Dissolved Solid (TDS), Sodium Adsorption Ratio (SAR), and Sodium Ion Percentage (Na%). Irrigation water standards (Ayres & Westcot), [22], table 9, were used, and showed that water is suitable for irrigation purposes, except well (1), because magnesium ion concentration exceeded the limit.

Table 9: Classification of Irrigation Water (Ayres and Westcot) [22]

Variables	Symbols	Unit	The range of irrigation water
Electrical Conductivity	EC	µmohs/cm	0-3000
Total Dissolved Solids	TDS	ppm	0-2000
pH	pH	1-14	6-8.5
Sodium Adsorption Ratio	SAR	epm	0-15
Calcium	Ca^{+2}	epm	0-20
Magnesium	Mg^{+2}	epm	0-5
Sodium	Na^{+1}	epm	0-40
Potassium	K^{+1}	epm	0-2
Bicarbonates	HCO_3^{-1}	epm	0-10
Chloride	Cl^{-1}	epm	0-30
Sulfate	SO_4^{-2}	epm	0-20
Nitrate	NO_3^{-1}	epm	0-2

4. Conclusions

1. Water of study area was classified **Slightly Water**, according to TDS in comparison with with (Todd, and Mays, 2005) and (Klimentove, 1983) classifications.
2. Comparing T.H. with the classification of Todd, 2005 hardness, it was found that the water of the study area is **Hard–Very Hard type**.
3. Comparing of physical tests and chemical analyses results with the international and local standards, shows that the water of the study area is **not suitable** for drinking, but **suitable** for drinking animal, as well as suitable for irrigation except **well (1)**.
4. The results of trace elements concentrations, indicated that there is **no pollution** of groundwater with these elements, their values were within the permissible limits.

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دراسة الخواص النوعية للمياه الجوفية وتحديد صلاحيتها للاستخدامات المختلفة شرق مدينة الدور/ صلاح الدين/ العراق

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الملخص

اجريت دراسة لتقييم المياه الجوفية اقصى شرق مدينة الدور التابعة اداريا الى محافظة صلاح الدين شمل العمل الحقلي زيارات ميدانية الى المنطقة لمعرفة الواقع الجيولوجي والتعرف على اهم المظاهر الجيومورفولوجية والتركيبية، وبعدها تم جمع (10) نماذج مائية من أبار المياه الجوفية في المنطقة (غطت منطقة الدراسة قدر الامكان).

شمل العمل المختبري اجراء الفحوصات الفيزيائية والكيميائية للنماذج المائية متمثلة بالتوصيلية الكهربائية (Electrical Conductivity) (EC)، والمواد الصلبة الكلية المذابة (Total Dissolved Solids) (TDS)، والرقم الهيدروجيني (pH)، ونسبة امتزاز الصوديوم (SAR)، والنسبة المئوية للصوديوم (Na%)، فضلا عن حساب العسرة الكلية (TH)، واجراء التحليلات والقياسات الكيميائية والمتمثلة بالأيونات الموجبة (Cations)، وتشمل أيونات الصوديوم (Na^{+})، البوتاسيوم (K^{+})، الكالسيوم (Ca^{+2})، والمغنيسيوم (Mg^{+2})، وكذلك الأيونات السالبة (Anions)، وتشمل الكلورايد(Cl^{-})، الكبريتات (SO_4^{-2})، والبيكاربونات (HCO_3^{-})، والمكونات الثانوية مثل النترات(NO_3^{-})، وبعض العناصر الثقيلة أو النادرة (Trace Elements)، مثل الحديد (Fe)، النحاس (Cu)، الخارصين (Zn)، الرصاص (Pb)، النيكل (Ni)، والكادميوم (Cd)، وتم اعداد خارطة موقعية لمنطقة الدراسة باستخدام برنامج ArcGIS .

توصلت النتائج الى وجود تباين في خصائص ونوعية المياه الجوفية في منطقة الدراسة، وبعد مقارنتها مع المعايير العالمية والمواصفات القياسية المحلية والعالمية تبين عدم صلاحية مياه ابار منطقة الدراسة للشرب لكنها تصلح لشرب الحيوان، وتصلح للري ولأغلب المحاصيل، باستثناء البئر رقم (1) لارتفاع تركيز المغنيسيوم عن الحدود المسوح بها.