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 (Ca²⁺), and Magnesium (Mg²⁺), and Anions such as Chloride (Cl⁻), Sulfate (SO₄²⁻), Bicarbonates (HCO₃⁻), and nitrate (NO₃⁻), 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 (43° 48’ 00”) (43° 51’ 00”) E, and latitudes (34° 27’ 00”) (34° 30’ 30”) N, figure1: site map of the study area.

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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 layers [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 gravelly 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 C°) 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].

\[
E\% = \left( \frac{\sum r.\text{Cat} - \sum r.\text{Ani}}{r.\text{Cat} + \sum r.\text{Ani}} \right) \times 100 \quad \text{(1)}
\]

Where Concentrations of ions in epm

\[
A = 100 - E\% \quad \text{(2)}
\]

Where:

- \(E\%\): Percentage of error.
- \(\sum r.\text{Cat}\): Total concentrations of Cations in units (epm).
- \(\sum r.\text{Ani}\): 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

Table 1: The Accuracy classification

| Result          | Accuracy (%) | 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:

\[ T.H = 2.5 \text{ Ca} + 4.1 \text{ Mg, in ppm} \ldots (3) \]

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;

\[ \text{SAR} = \frac{\sqrt{r(\text{Ca} + \text{Mg})}}{2} \ldots (4) \]

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]:

\[ \text{Na}^+\% = \frac{\text{Na}^+ + \text{K}^+}{\text{Ca}^{2+} + \text{Mg}^{2+} + \text{Na}^+ + \text{K}^+} \times 100 \ldots (5) \]

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. | Na % | T.C | T.H/ppm | PH/ppm | TDS/ppm |
|-----|------|-----|---------|--------|---------|
| W1  | 72.92| 26  | 1550    | 7.81   | 439     |
| W2  | 76.15| 26  | 1560    | 8.02   | 300     |
| W3  | 70.08| 25.5| 1690    | 7.92   | 333     |
| W4  | 77.19| 25  | 1420    | 7.85   | 261     |
| W5  | 70.40| 23  | 1420    | 7.96   | 279     |
| W6  | 73.77| 25.5| 1423    | 8.5    | 246     |
| W7  | 77.34| 24  | 1410    | 7.85   | 260     |
| W8  | 70.02| 26.5| 1692    | 8.1    | 355     |
| W9  | 74.72| 26.5| 1550    | 8.05   | 323     |
| W10 | 78.38| 23.5| 1553    | 7.78   | 327     |

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

| No. | Cations | Anions | Accuracy % |
|-----|---------|--------|------------|
|     | ppm     | epm    | ppm        | epm |
| 1   | 71.2    | 63.7   | 526.1      | 31.1 | 100.06 |
|     | 3.55    | 5.24   | 22.89      | 0.79 | 96.6   |
| 2   | 56.1    | 38.9   | 425.3      | 25.5 | 95.5   |
|     | 2.8     | 3.2    | 18.5       | 0.65 | 95.3   |
| 3   | 63.3    | 47.5   | 365.5      | 25.4 | 96.8   |
|     | 3.16    | 3.91   | 15.9       | 0.64 | 95.7   |
| 4   | 47.4    | 34.8   | 394.7      | 20.6 | 96.2   |
|     | 2.37    | 2.86   | 17.17      | 0.52 | 99.6   |
| 5   | 59.6    | 31.8   | 289.5      | 27.5 | 93.1   |
|     | 2.97    | 2.62   | 12.59      | 0.73 | 93.1   |
| 6   | 59.9    | 23.5   | 301.8      | 28   | 95.7   |
|     | 2.99    | 1.93   | 13.13      | 0.71 | 99.6   |
| 7   | 46.1    | 35.2   | 395.1      | 21.5 | 93.1   |
|     | 2.3     | 2.9    | 17.19      | 0.54 | 93.1   |
| 8   | 64.5    | 47.2   | 366.1      | 25.3 | 93.1   |
|     | 3.12    | 3.80   | 15.92      | 0.66 | 93.1   |
| 9   | 65.1    | 39.1   | 424.2      | 25.7 | 93.1   |
|     | 3.25    | 3.22   | 18.45      | 0.65 | 93.1   |
| 10  | 71.1    | 36.4   | 577        | 31.2 | 93.1   |
|     | 3.55    | 2.99   | 22.92      | 0.79 | 93.1   |
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       | SO₄²⁻ (ppm) | 410 – 510       |
| E.C (μmols/cm) | 2788 – 3360   | Cl⁻ (ppm)  | 350 – 491       |
| TDS (ppm) | 1410 – 1692     | HCO₃⁻ (ppm) | 79.3 – 175      |
| T (°C)   | 23 – 26.5       | NO₃⁻ (ppm) | 17.3 – 39.19    |
| TH (ppm) | 246 – 439       | Fe (ppm)   | 0 - 0.2         |
| SAR (ppm) | 7.53 - 12.68     | Cu (ppm)  | < 0.01          |
| Ca²⁺ (ppm) | 46.1 – 71.2     | Cd (ppm)  | <0.05           |
| Mg²⁺ (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           |                 |          |             |          |
| Ca²⁺              | 100             | --       | 50          |          |
| Mg²⁺              | 125             | --       | 50          |          |
| Na⁺               | 200             | 200      | 200         |          |
| K                 | 12*             | --       | --          |          |
| Anions            |                 |          |             |          |
| SO₄²⁻             | 250             | ≤ 500    | 250         |          |
| HCO₃⁻             | 350*            | --       | --          |          |
| Cl⁻               | 250             | 250      | 250         |          |
| NO₃⁻              | 50              | 45       | 50          |          |
| Trace Elements    |                 |          |             |          |
| Cu²⁺              | 2               | 1        | 1           |          |
| Pb²⁺              | 0.01            | 0.01     | 0.01        |          |
| Fe²⁺              | 0.3*            | ≤ 0.3    | --          |          |
| Zn²⁺              | 3               | ≤ 5      | 3           |          |
| Cd²⁺              | 0.003           | 0.005    | --          |          |
| CO₂⁺              | 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 drink it, [19].

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    |
| SO₄     | 1000            | 2500       | 3000         | 4000     | 6000    |
| TDS      | 3000            | 5000       | 7000         | 10000    | 15000   |
| TH       | 1500            | 3200       | 4000         | 4700     | 54000   |

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], 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      | μmhos/cm      | 0-3000                        |
| Total Dissolved Solids | TDS    | ppm           | 0-2000                        |
| pH                 | pH      | 1-14          | 6-8.5                         |
| Sodium Adsorption Ratio | SAR    | ppm           | 0-15                          |
| Calcium            | Ca⁺²   | ppm           | 0-20                          |
| Magnesium          | Mg⁺²   | ppm           | 0-5                           |
| Sodium             | Na⁺    | ppm           | 0-40                          |
| Potassium          | K⁺     | ppm           | 0-2                           |
| Bicarbonates       | HCO₃⁻  | ppm           | 0-10                          |
| Chloride           | Cl⁻    | ppm           | 0-30                          |
| Sulfate            | SO₄²⁻  | ppm           | 0-20                          |
| Nitrate            | NO₃⁻   | ppm           | 0-2                           |

4. Conclusions
1. Water of study area was classified Slightly Water, according to TDS in comparison 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 permisible limits.

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

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المملخص

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

شمل العمل المختبري اجزاء الفحوصات الفيزيائية والكيميائية للمياه الجوفية المتمثلة في اجراء اختبارات سيروا الكلية (Total Dissolved Solids) (TDS) (Electrical Conductivity) (EC)، والميكرو تحليل وقياسات الجزيئية والمتمثلة بالصوديوم (Na⁺)، والبوتاسيوم (K⁺)، الكالسيوم (Ca²⁺)، والكالسيوم (Mg²⁺)، وتشمل أيونات الصوديوم (Na⁺)، البوتاسيوم (K⁺)، الكالسيوم (Ca²⁺)، والمغنيسيوم (Mg²⁺)، وكذلك الأيونات السالبة (Cl⁻)، (NO₃⁻)، (SO₄²⁻)، (HCO₃⁻)، وبعض العناصر الثقيلة مثل النيكل (Ni) (كادميوم (Cd)، النحاس (Cu)، البوتاسيوم (K)، الهالوجينات (Cl)، النحاس (Cu)، النحاس (Cu)، البوتاسيوم (K)، الكالسيوم (Ca)، والنيكل (Ni)، والكادميوم (Cd)، والنيكل (Ni)، والكادميوم (Cd)، والنيكل (Ni)، والكادميوم (Cd).

توصيت النتائج إلى وجود تباين في خصائص ونوعية المياه الجوفية في منطقة الدراسة، وبعد مقارنتها مع المعايير العالمية والمتوسطات القبائية الحالية والمحلية تبين عدم صلاحية المياه الابار في منطقة الدراسة للشرب لكنها تصلح لشرب الحيوان، وتصلح لزراعة الأشجار، ولالأغراض المحيطة، باستثناء البئر (1) لارتفاع تركيز المغنيسيوم عن الحدود المسموح بها.