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

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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.

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 45°15'00” 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 km², 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)](image)
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
The coordinates for each sample were determined using GPS, including longitude, latitude and altitude.

\[ U\% = \left| \frac{r \sum \text{cations} - r \sum \text{anions}}{r \sum \text{cations} + r \sum \text{anions}} \right| \times 100 \]  

\[ A = 100 - U \]  

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
### 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 springs (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 S1 and 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 (164 and 167) ppm and (121 and 125) 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 (ppm) | 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               | SO₄²⁻ concentration (ppm) | Dry period | Wet period |
|--------------------------|---------------------------|------------|------------|
| Super sulfate water      | More than 58              | w5,w6,w7,w8,w12,w13,.w14,w15 and w16 | w5,w6,w7,w8,w12, w13,.w14,w15 and w16 |
| Sulfate water            | 24-58                     | w1,w2,w3,w4,w9,w10,w11,w17 and w18 | w1,w2,w3,w4,w9,w10,w11,w17 and w18 |
| Oligosulfate water       | 24-6                      | Less than 6 | s1 and s2. |
| Normal sulfate water     | Less than 6               | s1 and s2. |            |

| Water type               | HCO₃⁻ concentration (ppm) | 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,W1 7,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.
| Samples No. | Unit | Na⁺  | K⁺   | Ca²⁺ | Mg²⁺ | SO₄²⁻ | HCO₃⁻ | Cl    |
|------------|------|------|------|------|------|--------|--------|-------|
| W1         | ppm  | 194  | 15   | 128  | 41   | 415    | 175    | 211   |
|            | epm% | 8.4  | 0.40 | 6.4  | 3.4  | 8.64   | 2.9    | 6     |
| W2         | ppm  | 311  | 19   | 205  | 91   | 763    | 294    | 346   |
|            | epm% | 13.5 | 0.50 | 10.3 | 7.6  | 15.9   | 4.8    | 9.8   |
| W3         | ppm  | 183  | 15   | 138  | 43   | 432    | 194    | 217   |
|            | epm% | 7.9  | 0.40 | 6.9  | 3.6  | 9      | 3.2    | 6.2   |
| W4         | ppm  | 236  | 9    | 183  | 79   | 576    | 265    | 343   |
|            | epm% | 10.2 | 0.20 | 9.2  | 6.6  | 12     | 4.3    | 9.8   |
| 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  |
| W6         | ppm  | 284  | 11   | 285  | 132  | 926.4  | 281    | 431   |
|            | epm% | 12.3 | 0.30 | 14.3 | 11   | 19.3   | 4.6    | 12.3  |
| 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  |
| W8         | ppm  | 301  | 13   | 246  | 157  | 960    | 295    | 441   |
|            | epm% | 13.1 | 0.30 | 12.3 | 13.1 | 20     | 4.8    | 12.6  |
| W9         | ppm  | 322.7| 18.47| 206  | 94.3 | 801.6  | 303.5  | 359   |
|            | epm% | 33.76| 0.77 | 31.7 | 33.76| 53.5   | 12.8   | 33.7  |
| W10        | ppm  | 276  | 16   | 222  | 103  | 796.8  | 295    | 368   |
|            | epm% | 14   | 0.50 | 10.3 | 7.9  | 16.7   | 5      | 10.3  |
| W11        | ppm  | 281  | 16   | 220  | 100  | 797    | 202    | 341   |
|            | epm% | 12.2 | 0.40 | 11   | 8.4  | 16.6   | 3.3    | 9.74  |
| W12        | ppm  | 468  | 18   | 423  | 216  | 1474   | 406    | 683.9 |
|            | epm% | 20.3 | 0.50 | 21.2 | 18   | 30.7   | 6.7    | 19.5  |
| W13        | ppm  | 489  | 20   | 400  | 203  | 1416   | 458    | 690   |
|            | epm% | 21.3 | 0.50 | 20   | 16.9 | 28.9   | 7.5    | 19.7  |
| W14        | ppm  | 499  | 19   | 413  | 208  | 1474   | 395    | 756   |
|            | epm% | 21.7 | 0.50 | 20.7 | 17.3 | 30.7   | 6.5    | 21.6  |
### Table 7 - The concentrations of different ions in water models in the wet period (April, 2019)

| Samples No. | Unit | Na⁺ | K⁺ | Ca²⁺ | Mg²⁺ | SO₄²⁻ | HCO₃⁻ | Cl⁻ |
|-------------|------|-----|----|------|------|-------|-------|-----|
| W1          | ppm  | 164 | 13 | 114  | 36   | 382   | 155   | 164 |
|             | epm% | 36.05 | 0.83 | 34.39 | 28.74 | 52.2 | 11 | 36.5 |
|             | 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 |
| W2          | ppm  | 181  | 15.00 | 139 | 39  | 427.2 | 189 | 217 |
|             | epm  | 7.9  | 0.40 | 7.0  | 3.2  | 8.9  | 3.1  | 6.2 |
|             | epm% | 42.70 | 2.16 | 37.84 | 17.3  | 48.9 | 17 | 34 |
| W3          | ppm  | 148  | 14  | 118  | 37  | 359  | 145  | 199 |
|             | epm  | 6.5  | 0.40 | 5.9  | 3.0  | 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 |
| W4          | ppm  | 205  | 8 | 169  | 70  | 504  | 238  | 280 |
|             | epm  | 9.0  | 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 | 13.0 | 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 |
### 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 and 5 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]:

\[
\text{Anions (epm%) in decreasing order} \quad \text{TDS (mg/l)} = \frac{1}{\text{pH}} \quad (3)
\]

Cations (epm%) in decreasing order

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

| Water type | Dry period Frequency | Occurs Ratio (%) | Wet period Frequency | Occurs Ratio (%) |
|------------|---------------------|------------------|---------------------|------------------|
| Na$_2$SO$_4$ | 13                  | 65 %             | Na$_2$SO$_4$        | 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.

![Schoeller Diagram](image)

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

![Schoeller Diagram](image)

**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 Range | Mean | Exceeding limits for groundwater | Springs (S1 and S2) respectively | Exceeding limits for springs |
|------------|-----------|-----------|-------------------|------|----------------------------------|----------------------------------|-------------------------------|
| 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]:

\[ \text{SAR} = \frac{r \cdot \text{Na}}{\sqrt{r \cdot \text{Ca} + r \cdot \text{Mg}}} \]

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]:

\[ \text{Na\%} = \frac{r \cdot \text{Na} + r \cdot \text{K}}{r \cdot \text{Ca} + r \cdot \text{Mg} + r \cdot \text{Na} + r \cdot \text{K}} \times 100\% \]

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 |
|-----------|------------|------------|
|           | SAR        | 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      |
According to this classification, groundwater samples in the study area (w1, w3, w4, w11, w15, w17, and 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, w3, w4, w11, w15, w17, and 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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