Hydrochemistry and Water Quality Index of Groundwater in Abu-Jir Village in Al-Anbar, Western Iraq

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Abstract

A water quality index was used to estimate the quality of the groundwater in the Abu Jir village in Al-Anbar, all groundwater samples are taken in October 2021, fifteen groundwater samples are collected for the study area. Coordination of these samples was geographically determined by GPS between latitudes 33° 5′ 30″ - 33° 28′ 15″ and longitudes 42° 38′ 0″ - 42° 59′ 15″ to conduct electrical conductivity, pH and temperature at the site in addition to groundwater quality and validity to different purposes, the results show that the pH value ranges between 7.2 to 7.9 with an average of 7.5, Temperature values are between 22.4 to 28.5 °C with an average of 26.1 °C while electrical conductivity value between 2260-7250 μS/cm with an average of 3346.3, the range of the Total Dissolved Solids value is between 1410-4710 ppm, and TH values range between 653.4 to 1663.6 with an average of 924.22 ppm, The accuracy of the analyses for groundwater sampling in the study area is very high, error percentage is less than 5%, The dominated cation is Na+, while the predominant anion is SO4²⁻ according to the results of major element analysis (cations and anions), Na2SO4 occurrence ratio is 80%, the classification of groundwater samples depends on the Total Dissolved Solids, the class of water in the studied area is brackish water. The results showed values of Water ranges between 61.08 – 367.3 the most wells have good water, except well-1 and Well-14, which is not suitable. All groundwater samples in the study area are suitable for agriculture purposes. When using piper diagram for groundwater sample All of groundwater samples were classified as denotes earth alkaline water with a high alkaline content, sulfate and chloride content.

Keywords: Abu Jir; Water quality; Groundwater; Western Iraq; pH

1. Introduction

The quality and availability of water are important indicators of sustainable development, based on the great role that water plays in economic development (Al-Ozeer and Al-Abadi, 2022), the primary source of water for both domestic and agricultural use are groundwater. The quality and availability of groundwater are determined by the underlying geology in any area. Hydrochemistry of the suitability of groundwater for irrigation and to drinking. Water quality has become a major worry in developing countries in recent years due to fears that fresh water would become scarce in the future. Suitability of water for drinking is critical to human life, and the impact of water on health is mostly caused by the ingestion of water contaminated with pathogenic organisms or hazardous substances (WHO, 2012). In

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recent years, many studies have been conducted and will continue on suitability for water for various purposes, and among these studies (Awadh, 2018; Al-Dabbas et al., 2020; Al-Kubaisi 2020; and Al-Kubaisi, 2021). A water quality index (WQI) is method to providing a numerical expression that is obtained cumulatively and defines a specific degree of water quality (Bordalo et al., 2006). On a range of zero to hundreds, the water quality index provides information. at higher WQI score implies better water quality, whereas a lower value indicates as poor water quality. WQI is a mathematical technique that converts a large amount of water quality data into a single number, cumulatively determined numerical expression that indicates the level of water quality. Water quality influenced by the chemical reactions between water and its geological surroundings, such as groundwater and surface water reactions with water-retaining rocks and infiltration through soils, have an impact (Awadh and Ahmed, 2013). A water use for human consumption must be free of organic pollutants that may be harmful to human health, and chemical element concentrations must fall within the World Health Organization’s (WHO) global standards. It must also be free of turbidity, color, and any unpleasant taste or odor (Hem, 1985).

The study area is located in Al-Anbar, about 50 km to the west of Ramadi in the Western Desert of Iraq between latitudes 33° 5’30” - 33° 28’15” and longitudes 42° 38’0” - 42° 59’15”. (Fig.1) The total area is expanded over about 241 km². Many of previous studies are examining groundwater in Abu-Jir village, included previous study by Ahmad et al. (2020), Radon gas and effective dose in groundwater in Abu-Jir village in Anbar, western Iraq, and the study that was presented by Awadh, (2018) which is studded geochemical impact of surface water, groundwater and quality around a rural community, and studies by Hussein, (2010). and others studies by Fayydh et al., (2020). Evaluation of groundwater quality in al-Waffa and Kubaysa areas is performed by using multivariate statistical analysis, Al-Anbar, western Iraq.

![Fig.1. Location map of the study area showing the studied wells](image-url)
There is a relationship between water quality and climate in a region, in terms of increasing or decreasing the amount of water, and therefore abundance water improves the quality of water and vice versa (Al-Kubaisi and Al-Kubaisi 2018). Climatic data of the study area It was received from Iraqi Meteorological Organization for Al-Ramadi station shows that rainfall total is 108 mm, evaporation 2814.3 mm, while temperature average is 22.6 °C, sunshine duration 8.8 h/day, wind speed 2.2 mm, and relative humidity 52.7%. The average monthly values for each parameter were measured for thirty years 1990-2020, Geological settings are Nfayil Formation (Middle Miocene) and depression Full deposits, as show in Fig 2. As for the stratigraphic table of geological formations, it is shown in Fig 3, that consists tow aquifers, Euphrates and Dammam aquifers, confined the Aims of study are:

- study the physical and chemical properties of groundwater of Abu Jir village and attempts to evaluate groundwater quality for drinking purpose by using WQI.
- Evaluation of the hydrochemical characteristics of groundwater and suitability for different uses.

![Geological map of the study area](Fig.2. Geological map of the study area (Sissakian and Fouad, 2012))

![Hydrogeological section shows water table of aquifers](Fig.3. Hydrogeological section shows water table of aquifers)
2. Materials and Methods

Fifteen groundwater sample are collected, in October 2021 (Table 1), and the sampling sites are shown in Fig. 1. A global positioning system (GPS) sensor is used to precisely calculate the coordinates of each sample (longitude and latitude). and Electrical Conductivity (EC), the temperature T(°C), and Total Dissolve Solids (TDS) were measured in situ (Table 3). Groundwater samples were analyzed such as pH, TDS, TH, Na⁺, Ca²⁺, K⁺, Mg²⁺, SO₄²⁻, HCO₃⁻, Cl⁻, and NO₃⁻, groundwater samples are taken to the laboratory of the General Commission of Groundwater (GCGW) to analyzes were kept in one-liter plastic bottles, and put all samples in a refrigerator are taken to the laboratory after one day (Table 2).

| Well No. | Total depth (m) | Static Water level (m) | Elevation (m. a. s.l) |
|----------|----------------|------------------------|-----------------------|
| W.1      | 40             | 1.40                   | 93                    |
| W.2      | 45             | 3.10                   | 99                    |
| W.3      | 120            | 4.60                   | 103                   |
| W.4      | 60             | 7.0                    | 113                   |
| W.5      | 140            | 2.28                   | 128                   |
| W.6      | 100            | 6.0                    | 113                   |
| W.7      | 55             | 5.0                    | 117                   |
| W.8      | 90             | 7.98                   | 118                   |
| W.9      | 80             | 12.0                   | 126                   |
| W.10     | 90             | 11.30                  | 125                   |
| W.11     | 100            | 8.25                   | 123                   |
| W.12     | 45             | 5.20                   | 118                   |
| W.13     | 40             | 5.10                   | 117                   |
| W.14     | 50             | 3.10                   | 106                   |
| W.15     | 70             | 5.0                    | 96                    |

Table 1. Total depth, static water level and elevation of selected well

| Parameters | Methods of analysis |
|------------|---------------------|
| pH         | pH-Meter            |
| EC         | Conductivity mater, -Boyd 2000 |
| TDS        | Drying in 105°C - Boyd 2000) |
| Na⁺, K⁺    | flame photometer (APHA,1999) |
| Ca²⁺, Mg²⁺ | Titration method with EDTA |
| Cl⁻        | Technecon autoanlyzer(APHA,1999) |
| SO₄²⁻      | Technecon in ultra violet spectro photometer (U.V) |
| HCO₃⁻      | Titration method using indicator titrated with HCl |
| NO₃⁻       | Technical in volumetric |

Table 2. Parameters and their analysis methods.

To calculate the total hardness.

\[
TH=2.497 \text{Ca} + 4.115 \text{Mg} \tag{1}
\]

Where: TH, Ca²⁺, Mg²⁺ is all measured in ppm (mg/L)
Table 3. Physiochemical parameters and total hardness of the groundwater samples in the study area

| Well No. | T (°C) | pH | EC (μS/cm) | TDS (ppm) | T.H (ppm) |
|---------|--------|----|------------|-----------|-----------|
| W-1     | 22.4   | 7.2| 7250       | 4710      | 1663.6    |
| W-2     | 24.9   | 7.5| 3130       | 2025      | 1060.7    |
| W-3     | 25.9   | 7.8| 2370       | 1535      | 692.6     |
| W-4     | 28.4   | 7.5| 2730       | 1763      | 938.1     |
| W-5     | 28.5   | 7.9| 3140       | 2032      | 763.7     |
| W-6     | 27.9   | 7.8| 2260       | 1462      | 653.4     |
| W-7     | 24.4   | 7.2| 3150       | 2040      | 778.7     |
| W-8     | 27.8   | 7.4| 2320       | 1510      | 749.9     |
| W-9     | 26.5   | 7.7| 2370       | 1538      | 699.2     |
| W-10    | 27.5   | 7.6| 3220       | 2987      | 1120.1    |
| W-11    | 25.9   | 7.8| 3510       | 2290      | 907.2     |
| W-12    | 24.8   | 7.5| 3730       | 2410      | 1143.5    |
| W-13    | 25.2   | 7.6| 3540       | 2298      | 1345.1    |
| W-14    | 27.2   | 7.3| 4720       | 3045      | 987.2     |
| W-15    | 25.4   | 7.7| 2760       | 1568      | 781.2     |
| Average | 26.1   | 7.5| 3346.6     | 2214.2    | 924.22    |
| Min.    | 22.4   | 7.2| 2260       | 1410      | 653.4     |
| Max.    | 28.5   | 7.9| 7250       | 4710      | 1663.6    |

To measure analytical accuracy of groundwater sampling in the study area, the ionic balance measure was used the equivalent per million (epm) values for the main anions and cations using the following formula (Baird, 2017)

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

(2)

\[
A\% = 100 - U
\]  

(3)

Where: U: Uncertainty (reaction error). r: (epm). A: Accuracy or certainty

Table 4. Accuracy classification and relative difference (Stoodly et al., 1980)

| U%       | A        | Acceptability  |
|----------|----------|----------------|
| U ≤ 5%   | A ≥ 95%  | Certain        |
| 5% ≤ U ≤ 10% | 90% ≤ A% ≤ 95% | Probable certain |
| U > 10%  | A < 90%  | Uncertain      |

If the error percentage is less than 5%, accuracy of the analyses is quite good; nevertheless, if error percentage is between 5% and 10%, caution should be exercised in terms of interpretation. Furthermore, if the value was greater than 10%, (Table 4). The hydrochemical interpretations cannot thus be based on the results. Also, (WQI) can be used to detect acceptability of water for drinking, which is particularly efficient because it is based on multiple digitally created variables that include effect of these variables on water quality (Awadh, 2018).
Table 5. Analytical accuracy of groundwater sampling in the study area

| Well No. | U%  | A    |
|----------|-----|------|
| W.1      | 2.31| 97.69|
| W.2      | 3.47| 96.53|
| W.3      | 3.02| 96.98|
| W.4      | 3.77| 96.23|
| W.5      | 0.12| 99.88|
| W.6      | 3.26| 96.74|
| W.7      | 0.57| 99.34|
| W.8      | 3.96| 96.04|
| W.9      | 3.47| 96.53|
| W.10     | 4.98| 95.02|
| W.11     | 0.29| 99.71|
| W.12     | 2.53| 97.47|
| W.13     | 1.44| 98.56|
| W.14     | 4.62| 95.38|
| W.15     | 2.90| 97.1 |

Table 6. Comparison of water in the Studied Area with the Iraqi standards (2009) and WHO, (2008) standard of human drinking purposes

| Components | Iraqi Standard (2009) | (WHO, 2008) | Concentrations of the groundwater samples (ppm) |
|------------|----------------------|-------------|-----------------------------------------------|
| PH         | 6.5-8.5              | 7-8         | 7.2 -7.9                                      |
| EC         | 1500                 | 1530        | 2320 -7250                                    |
| TDS        | 1000                 | 1000        | 1510 -4710                                    |
| TH         | 500                  | 100-500     | 653.4-1663.6                                 |
| Ca^{2+}    | 100                  | 75-200      | 140 -426                                      |
| Mg^{2+}    | 50                   | 30-150      | 61 -161                                       |
| Na^{+}     | 200                  | 200         | 232 -879                                      |
| K^{+}      | ---                  | 12          | 4 -90                                         |
| Cl^{-}     | 350                  | 250         | 213 -941                                      |
| SO_{4}^{2-} | 400               | 250         | 527 - 1850                                    |
| HCO_{3}^{-} | ---                | ---         | 153 – 583                                     |

Table 7. Classification of groundwater samples depending on TDS according to Davis and Dewiest, (1966)

| Water Class | TDS (ppm) [Davis and Dewiest, (1966)] | Range of TDS in the study area | Class of water in the study area |
|-------------|---------------------------------------|---------------------------------|----------------------------------|
| Freshwater  | 0-1000                                | 1510 -4710                      |                                  |
| Brackish water | 1000-10000                             |                                 | Brackish water                   |
| Salty water | 10000-100000                          |                                 | Saline water                     |
| Saline water | .............                           |                                 |                                 |
| Brine water | >1000000                               |                                 |                                 |

According to the hydrochemical formula, the ratio of main ions, (cations and anions) are arranged in descending order and measured in epm %, that have more than 15% ratio of availability, the anions are located above and cations are at a base. Furthermore, TDS values and pH values are put as in following formula taken from Ivanov et al. (1968) as following
TDS (mg/l) = \frac{\text{Anions (ppm) in decreasing order}}{\text{Cations (ppm) in decreasing order}} \times pH \quad (4)

TDS 2214.1(mg/l) = \frac{SO_4^{2-}(46.72) \text{ Cl}^-(36.57) \text{ HCO}_3^-(16.49)}{\text{Na}^+(42.79) \text{ Ca}^+(29.12) \text{ Mg}^{2+}(26.85)} \times pH \quad (5)

Cations should be first mentioned to express the chemical composition and then anions, the sequence must be according to the increase in the values of their concentration.

Table 8. The percentage ratio of the dominant water type of the groundwater samples in the study area

| Water type | Frequency | Occurrence % |
|------------|-----------|--------------|
| Na_2SO_4   | 12        | 80%          |
| NaCl       | 1         | 6.66         |
| CaSO_4     | 1         | 6.66         |
| MgSO_4     | 1         | 6.66         |

3. Water Quality Index

WQI was calculated using drinking water quality principles proposed by IQS, (2009) and WHO, (2008), which involved three steps: first is to assign a precise weight to a chemical property that affects water quality for drinking reasons, such as, the nitrate parameter which has a greater impact on groundwater quality than other metrics like sulfate, pH, TDS, Mg^{2+}, Na^+. Because these are not hazards to water quality for drinking purposes, they were given a lower weight than the NO_3^- parameter. second step to calculate relative weight (Wr) (Ramakrishnala, 2009).

\[ Wr = \frac{wi}{\sum_{n=1}^{n} wi} \quad (5) \]

Where: Wr is the relative weight; n is number of parameters, and wi is weight of each parameter.

value of Wr of each parameter are given in Table 9

quality rating scale (qi) of each parameter is calculated by dividing its concentration in each sample by its respective standard, as established by the Iraqi standard in Table 9, and then multiplying the result by 100 (Awadh et al., 2018)

\[ qi = \frac{(C_i - C_0)}{(Si - C_0)} \times 100 \quad (6) \]

Where qi is quality rating; Ci concentration each parameter in water sample in ppm C_0 is ideal values of parameter in pure water (C_0=0 except for pH =7), and while Si, is the Iraqi drinking standard for each chemical parameter. to calculate WQI, first determine Sli for each chemical parameter, which will be used to calculate WQI later using equation below:

\[ Sli = Wr \times qi \quad (7) \]
\[ WQI = \sum Sli \quad (8) \]

Sli: is a parameter's sub-index; Wr is rating based on each parameter's concentration, and n is the number of parameters. standards for drinking purposes as recommended by Iraqi Standard (2009) which applied for estimating WQI. Chemical parameters of water samples in mg/l are listed in Table 9.
Table 9. Iraqi standards, relative weight, and weight for each parameter (Ramakrishnalah et al., 2009)

| Chemical parameter (mg/l) | Si (Iraqi standard) (2009) | (WHO, Standard) (2008) | Weight (wi) | Relative weight (Wr) |
|--------------------------|-----------------------------|-------------------------|-------------|----------------------|
| pH                       | 6.5-8.5                     | 7-8                     | 4           | 0.1212               |
| TDS                      | 1000                        | 1000                    | 4           | 0.1212               |
| TH                       | 500                         | 100-500                 | 2           | 0.0606               |
| Ca^{2+}                  | 100                         | 75-200                  | 2           | 0.0606               |
| Mg^{2+}                  | 50                          | 30-150                  | 2           | 0.0606               |
| Na^{+}                   | 200                         | 200                     | 2           | 0.0606               |
| k^{+}                    | -                           | 12                      | 2           | 0.0606               |
| Cl^{-}                   | 250                         | 250                     | 3           | 0.0909               |
| SO_{4}^{2-}              | 250                         | 250                     | 4           | 0.1212               |
| HCO_{3}^{-}              | -                           | 200                     | 3           | 0.0909               |
| NO_{3}^{-}               | 50                          | 50                      | 5           | 0.1515               |
| **Total**                |                             |                         | $\sum wi=33$ | $\sum = 0.99$       |

Table 10: Results of groundwater sampling (mg/l) of the study area

| Well NO. | pH  | Ca^{2+} | Mg^{2+} | Na^{+} | K^{+} | Cl^{-} | SO_{4}^{2-} | HCO_{3}^{-} | NO_{3}^{-} | WQI  |
|----------|-----|---------|---------|--------|-------|--------|-------------|-------------|------------|------|
| W1       | 7.2 | 426     | 146     | 879    | 82    | 941    | 1850        | 311         | 311        | 1.3  |
| W2       | 7.5 | 216     | 127     | 387    | 12    | 522    | 749         | 420         | 420        | 0.8  |
| W3       | 7.8 | 177     | 61      | 240    | 5     | 294    | 584         | 153         | 153        | 1.1  |
| W4       | 7.5 | 185     | 116     | 261    | 7     | 413    | 603         | 234         | 234        | 1.2  |
| W5       | 7.9 | 171     | 82      | 342    | 12    | 382    | 660         | 359         | 359        | 0.3  |
| W6       | 7.8 | 140     | 74      | 249    | 6     | 213    | 568         | 193         | 193        | 1.3  |
| W7       | 7.2 | 177     | 82      | 345    | 12    | 385    | 652         | 359         | 359        | 1.1  |
| W8       | 7.4 | 154     | 89      | 264    | 6     | 228    | 648         | 283         | 283        | 1.4  |
| W9       | 7.7 | 178     | 62      | 241    | 5     | 295    | 580         | 153         | 153        | 1.2  |
| W10      | 7.6 | 145     | 136     | 396    | 14    | 437    | 595         | 460         | 460        | 0.6  |
| W11      | 7.8 | 212     | 152     | 264    | 44    | 534    | 752         | 285         | 285        | 1.2  |
| W12      | 7.5 | 236     | 135     | 354    | 6     | 568    | 604         | 480         | 480        | 1.7  |
| W13      | 7.6 | 274     | 161     | 232    | 10    | 554    | 812         | 220         | 220        | 1.5  |
| W14      | 7.3 | 162     | 142     | 592    | 90    | 522    | 924         | 583         | 583        | 1.6  |
| W15      | 7.7 | 178     | 136     | 250    | 10    | 290    | 640         | 480         | 480        | 0.6  |

The total of the sub-index Sli computed in formula 7 and 8 equation above is representing the WQI value for the sample. Sli and WQI values are listed in Table 11.

Table 11. The value of Sli and WQI for each parameter for groundwater samples in October 2021

| Well No. | TDS | PH | Ca^{2+} | Mg^{2+} | Na^{+} | K^{+} | Cl^{-} | SO_{4}^{2-} | NO_{3}^{-} | WQI |
|----------|-----|----|---------|---------|--------|-------|--------|-------------|------------|-----|
| W1       | 1.41| 5.51| 26.1    | 20.44   | 7.47   | 287.0 | 5.27   | 10.36       | 0.18       | 363.74 |
| W2       | 0.61| 13.77|13.2    | 17.78   | 3.29   | 42.00 | 2.92   | 4.19        | 0.11       | 97.87 |
| W3       | 0.46| 22.03|10.8    | 8.54    | 2.04   | 17.50 | 1.65   | 3.27        | 0.15       | 66.44 |
| W4       | 0.53| 13.77|11.3    | 16.24   | 2.22   | 24.50 | 2.31   | 3.38        | 0.17       | 74.42 |
| W5       | 0.61| 24.78|10.4    | 11.48   | 2.91   | 42.00 | 2.14   | 3.70        | 0.04       | 98.06 |
| W6       | 0.44| 22.03|8.59    | 10.36   | 2.12   | 21.00 | 1.19   | 3.18        | 0.18       | 69.08 |
| W7       | 0.61| 11.01|9.45    | 12.46   | 2.24   | 21.00 | 1.28   | 3.63        | 0.20       | 61.72 |
| W8       | 0.45| 19.27|10.9    | 8.68    | 2.05   | 17.50 | 1.65   | 3.25        | 0.17       | 63.93 |
| W9       | 0.46| 16.52|8.89    | 19.04   | 3.37   | 49.00 | 2.45   | 3.33        | 0.08       | 103.58 |
| W10      | 0.90| 22.03|13.0    | 21.28   | 2.24   | 154.0 | 2.99   | 4.21        | 0.17       | 220.61 |
| W11      | 0.72| 13.77|14.4    | 18.90   | 3.01   | 21.00 | 3.18   | 3.38        | 0.24       | 78.6  |
| W12      | 0.69| 16.52|16.8    | 22.54   | 1.97   | 35.00 | 3.10   | 4.55        | 0.21       | 101.38 |
| W13      | 0.91| 8.26 |9.94    | 19.88   | 5.03   | 315.0 | 2.92   | 5.17        | 0.22       | 367.34 |
| W14      | 0.47| 19.27|10.9    | 19.04   | 2.13   | 35.00 | 1.62   | 3.58        | 0.08       | 92.10 |
4. Results

Table 10, lists the individual and statistical physio-chemical parameters, as well as the computed WQI. In groundwater, the pH is slightly alkaline, with an average of 7.5. The values of TDS in groundwater are high than that suggested by WHO as showing in Table 9. Water quality classification according to the WQI values (Ramakrishnalah et al., 2009). groundwater sampling is classified into five classes, good water in ten wells, WQI values are between 50 to 100, Whereas, poor water in two wells. W10 and W13, and unsuitable water in W1 and W14. because of increasing sodium concentration and sulphate. The WQI values are classified into five classes, according to Ramakrishnalah et al. (2009). Table 12. When using piper diagram for groundwater sample. All of the water samples were classified as denotes earth alkaline water with high alkaline, sulfate and chloride content (Fig. 6).

Table 12. Water quality classification according to the WQI values (Ramakrishnalah et al., 2009).

| WQI value | Class | Water quality | Sample No. |
|-----------|-------|---------------|------------|
| ≤50       | I     | Excellent     |            |
| 50-100    | II    | Good water    | W2, W3, W4, W5, W6, W7, W8, W9, W12, W15 |
| 100-200   | III   | Poor water    | W10, W13   |
| 200-300   | IV    | Very poor water | W11      |
| ≥300      | V     | Unsuitable water | W1, W14  |

When comparing the groundwater sampling with Brown Classification that based on WQI value. All Groundwater samples are not suitable for human drinking.

Table 13. Classification of Brown et al. (1972)

| WQI Value | Water Quality | Water Samples |
|-----------|---------------|---------------|
| 0 -25     | Excellent     |               |
| 26-50     | Good          |               |
| 51-75     | Poor          | W3, W4, W6, W8, W9 |
| 76-100    | Very Poor     | W2, W5, W7, W12, W15 |
| Above 100 | Unsuitable    | W1, W10, W11, W13, W14 |

According to Wilcox, (1948) all Groundwater sample are suitability irrigational water based on SAR (Wilcox, 1948) as show in Fig 4 and Fig 5.

Table 14: Sodium hazard of water based on SAR (Wilcox, 1948)

| 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 |
according to Nagaraju et al., (2006) all groundwater sample are suitability irrigational water based on permeability index (PI) as show in Fig. 5

**Table 15.** Classification of permeability index (PI) for irrigation according to Nagaraju et al. (2006)

| PI %  | Class     | Water quality                  |
|-------|-----------|--------------------------------|
| < 25  | Class-III | Unsuitable for irrigation      |
| 25-75 | Class-II  | Good quality for irrigation    |
| >75   | Class-I   | Very good quality for irrigation|

When using piper diagram (Fig.6) for groundwater sample All of the water samples were classified as class e, which denotes earth alkaline water with a high alkaline content and a high sulfate and chloride content.
5. Discussion

From the Results, some of wells have unsuitable water because of increasing sodium concentration and Sulfate (high concentration) main source of sodium in groundwater is erosion of evaporite rocks, alkalinity feldspar, and ionic exchange of clay minerals which has a high solubility and sulfate in groundwater. human, agricultural and activities represent as a significant source of sulfate, especially that the study area is agricultural regions. As for the difference in temperature, this is according to the difference in depths. Deep wells have the highest temperature, and vice versa for wells with lower depths. The Class of water are Brackish water because TDS values range from 1510 to 4710.

6. Conclusions

Fifteen wells distributed in the studied area are classified as good water in wells, W-2, W-3, W-4, W-5, W-6, W-7, W-8, W-9, W-12 and W-15, while poor water in, W-10, and W13, Whereas very poor water in W11 and unsuitable water in W1 and W14 because of increasing sodium concentration and sulfate. Results show that a predominant cation is Na+ ion followed by Ca2+, Mg2+ and K+ whereas dominant anions are SO42- followed by Cl- then HCO3-. The results of twelve sample showed Na2SO4 with an occurrence ratio of 80% and class of water depending on TDS in the study area is Brackish water, the TDS values ranges from 1510-4710. The analytical accuracy of groundwater sampling in the study area is extremely high, with an error rate of less than 5%. When using the piper diagram for groundwater samples, all of the water samples were classified as class e, which denotes earth alkaline water with high alkaline content and a high sulfate and chloride content.

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