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# EVALUATION OF WATER EFFICIENCY AND SUITABILITY FOR DRINKING IN WADI AL-ATHIR BASIN USING THE CANADIAN (CCME WQI) WATER QUALITY INDEX

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**Abstract**

The current study aims to evaluate water for drinking purposes in Wadi Al-Athir Basin, southeast of Al-Muthanna Governorate, using the Canadian Water Quality Index (CCME WQI), where (16) samples were collected from different locations from the wells of the study area as shown in and for the two periods (wet and dry). During the year 2021, (10) elements were analyzed, which are the total dissolved salts (TDS), acidity function (PH), total hardness (T.H), electrical conductivity (EC), positive ions (Anyons) and negative ions (Cations), and the results of the study reached a high Some of the measured characteristics, especially (EC, TDS, T.H, Ca, Mg, Na, Cl, So4), which will affect the values of the water quality index (CCME WQI).

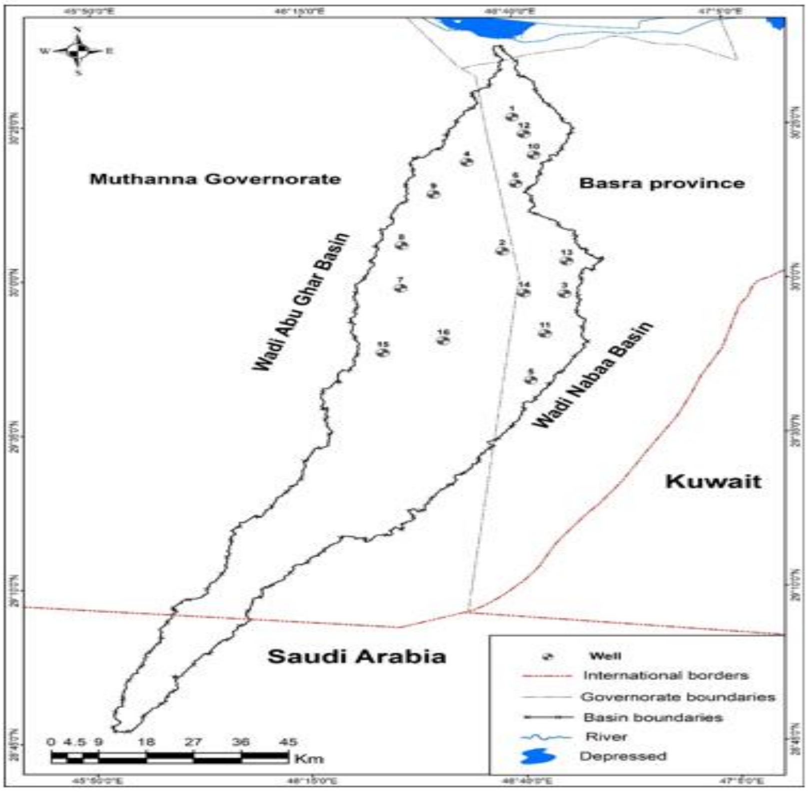
**Keywords:** Al-Muthanna, Canadian and Map

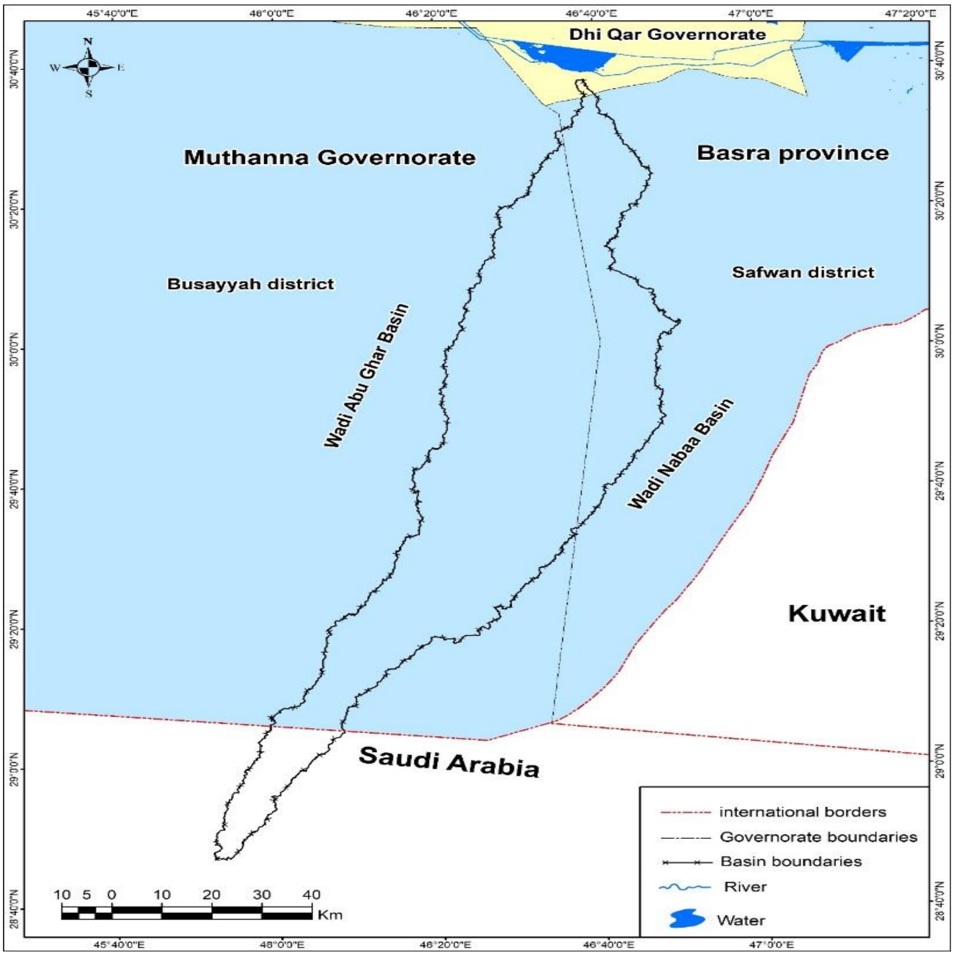
## INTRODUCTION

The basic elements of dissolved salts and the concentration of some positive and negative ions are among the basic bases on which it is relied upon for the purpose of determining groundwater for human drinking, and it must be within the permissible qualitative (physical and chemical) characteristics. Salinity and concentration limits for the main positive and negative ions because of their danger if they exceed the permissible limits according to those standards ().

To calculate the value of (CCME WQI) for the groundwater of the wells of the study area, (10) variables were applied to calculate the Canadian guide for assessing the suitability of drinking water according to international and Iraqi specifications as shown in Table (1).

We are required to have three variables for comparison. In order to achieve this goal, the research was divided into two main requirements, the first requirement was a statement of the qualitative characteristics of groundwater, and the second was the application of the Water Quality Index Index (CCME WQI).


Muthanna Governorate
Basra province
Wadi Abu Ghar Basin
Wadi Nabaa Basin
Kuwait
Saudi Arabia
Well
International borders
Governorate boundaries
Basin boundaries
River
Depressed
0 4.5 9 18 27 36 45
Km


Dhi Qar Governorate
Muthanna Governorate
Basra province
Busayyah district
Safwan district
Wadi Abu Ghar Basin
Wadi Nabaa Basin
Kuwait
Saudi Arabia
international borders
Governorate boundaries
Basin boundaries
River
Water
10 5 0 10 20 30 40
Km

## First: The Qualıtatve Characterıstıcs Of Groundwater In The Study Area

The accuracy of the analysis results is an important aspect in water evaluation. Where the concentrations of the basic elements were converted from the unit (ppm) to the unit (epm), and through the law of salt balance, which depends on the group of concentrations of positive ions (cations), which must equal the sum of the concentrations of negative ions (Anions), as the accuracy of the results is measured by the relative difference (Relative Difference) between them and the unit (epm) through the following equation ( ):

$$R.D\ \% = \frac{(\sum rCations - \sum rAnions)}{(\sum rCations + \sum rAnions)} \times 100$$

Since

$Balance\ error\%$. balance error :

$\sum rCations$ ) the total concentrations of positive ions in units :epm (

$\sum rAnions$ The sum of the negative ion concentrations in( epm) units

) When applying the steps of the law from converting units fromppm ) to units (epm and then applying the equation to positive and negative ions, the results of the ( accuracy of the analyzes appear, so if the relative difference is less than (5%) this means the results are of high accuracy, and if the difference is The relative range is between (5-10%), because the results have potentials that may be important, and in this case they are within the acceptable range. When analyzing the results of the table for the samples of the study area, it becomes clear that the calculated values of the () balance error are less than (5%), except for the sample (1-2-3-9-16), which was within the category (5-10%) for the wet period. The same applies to the dry period, as well water samples in the study area were within the category of (5%), except for wells (1-.(which were within the category of (5-10% (16-14-12-9-3-2

## pH

(ph) is the negative logarithm of the hydrogen ion concentration and is usually used to determine the acidity or basicity of water, and is one of the factors that have an important and dominant role in chemical reactions ( ) .

The value is determined between (0-14). When the value of (PH) is less than (7) , the solutions are acidic, but if it is greater than (7) it is basic, and when it is equal to (7) , the solutions are neutral at normal temperature and pressure. There are factors that affect the pH value, which are temperature, the presence of bicarbonate, calcium and plants. The process of photosynthesis reduces the amount of CO 2 and then works to increase the pH ( ) . The ( ph ) was measured by a PH-meter ) device during the field visit In addition to its measurement in the laboratory, as it is noted from Table ( 65 ) that the value of ( ph ) ranged between (7.2-8) for the dry period and between ( 7.3-7.7 ) for the wet period.

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**Table 1: pH ) of well water samples studied in the study area for the period (wet and dry)**

| Total Thickness ) TH ( | | pH _ _ | | sample number |
|---|---|---|---|---|
| dry duration | wet duration | dry duration | wet duration | |
| 1708 | 1637 | 7.7 | 7.5 | 1 |
| 1709 | 1740 | 7.4 | 7.6 | 2 |
| 2260 | 1977 | 8 | 7.7 | 3 |
| 1830 | 1331 | 7.6 | 7.5 | 4 |
| 2181 | 1993 | 7.7 | 7.7 | 5 |
| 2459 | 2328 | 7.7 | 7.6 | 6 |
| 2170 | 2235 | 7.4 | 7.7 | 7 |
| 1247 | 1084 | 7.7 | 7.3 | 8 |
| 1927 | 1637 | 7.7 | 7.5 | 9 |
| 1879 | 1742 | 7.6 | 7.3 | 10 |
| 1300 | 1234 | 7.6 | 7.4 | 11 |
| 1654 | 1039 | 7.2 | 7.1 | 12 |
| 1192 | 1250 | 7.4 | 7.5 | 13 |
| 1943 | 1895 | 7.4 | 7.7 | 14 |
| 2351 | 1972 | 7.8 | 7.7 | 15 |
| 2180 | 2207 | 7.4 | 7.6 | 16 |

**Total Hardness TH ( Total Hardness)**

The hardness of the water is due to the amount of calcium and magnesium salts dissolved in it Ca , Mg and has an important role in determining its suitability for various purposes ( ) . The aqueous gypsum and pebble rocks, which are in direct contact with water, are among the main sources of hardness, which supply groundwater with calcium and magnesium ions .

TH=2.49(Ca + 2 ) +4.11(Mg +2 )

It is clear from Table 65 that there is a variation in the total hardness concentrations, as it ranged between (1192-2459 ppm ) for the dry period, while it ranged between (1039-2328 ppm )

**Electrical Conductivity** -2 ( EC ) .

It expresses the ability of water to have an electrical conductivity, which ranges from (1 cm 3 ), as the rates of conductivity vary in different seasons because it is affected by temperature, as heat works to dissolve salts ( TDS ), meaning that there is a direct relationship between dissolved salts and the electrical conductivity, the higher the amount of dissolved salts, the higher With electrical conductivity rates ( ) .

The electrical conductivity of the groundwater samples of the well water of the study area was calculated during the field work as well as measured in the laboratory. When analyzing Table ( 68 ) of the values of the electrical conductivity of the well water

**Total dissolved salts TDS ) Total Dissolved Salinity) :**

TDS ) includes all dissolved solids in ionized and non-ionized solutions and does not include suspended matter, colloidal matter and dissolved gases. The contact process takes ( ) . The values ranged between (1798-4025 ppm ) for the wet period and between (1946- 4397 ppm ) for the dry period, as the highest concentrations were recorded in the samples of wells ( 6-5 ), reaching ( 4001-4026 ppm ) for the wet period.

For the same samples, it reached (4205-4397 ppm ) for the dry period. While the lowest concentrations were recorded in well water samples (11-8-12), where the values in the wet period were (1798-2128-2150 ppm ), While the values in the dry period for the same samples were (1946 - 2461 - 2554 ppm

**Table 2: ( Electrical conductivity EC ) and total dissolved salts ( TDS ) for well water samples studied in the study area**

| dry duration | | wet duration | | sample number |
|---|---|---|---|---|
| TDS (ppm) | Ec (μc/cm) | TDS (ppm) | Ec (μc/cm) | |
| 3341 | 5220 | 3121 | 4877 | 1 |
| 2742 | 4284 | 2942 | 4597 | 2 |
| 3843 | 6300 | 3542 | 5806 | 3 |
| 3334 | 5210 | 2915 | 4555 | 4 |
| 4205 | 6675 | 4001 | 6350 | 5 |
| 4397 | 6980 | 4026 | 6390 | 6 |
| 3535 | 5795 | 3727 | 6110 | 7 |
| 2461 | 3845 | 2128 | 3325 | 8 |
| 3341 | 5220 | 3121 | 4877 | 9 |
| 3712 | 5800 | 3373 | 5270 | 10 |
| 1946 | 3040 | 1798 | 2810 | 11 |
| 2554 | 3990 | 2150 | 3360 | 12 |
| 2630 | 4110 | 2896 | 4525 | 13 |
| 3111 | 5100 | 3542 | 5806 | 14 |
| 4154 | 6810 | 3782 | 6200 | 15 |
| 3699 | 5780 | 3982 | 6222 | 16 |

**POSITIVEIONS _**

**Calcium ion ( Ca + 2 )**

The main source of calcium ion in water comes from the chemical weathering of carbonate sedimentary rocks represented by calcareous and calcareous rocks. It is also present in different proportions in igneous and metamorphic rocks ( ) . Calcium is the major contributor to water hardness along with magnesium ion, as calcium ion combines with bicarbonate to form calcium bicarbonate, which causes temporary hard water ( ).

It is clear from Table ( 62 ) and ( 63 ) the variation in the concentration of calcium ion for the samples of the study area, as its concentrations increased in the well water samples (16-6-3-14-10 ) , reaching ( 599-585-20-5-490 ppm ) . In the wet period, while in the dry period, it was ( 598-5 3 5- 531 - 530 ppm ) for the same samples. As for the lowest concentrations, they were recorded in well water samples ( 12-8-13 ), when they reached (235-258-285 ppm ) in the wet period, while in the dry period they reached ( 332-269-280 ppm ) for the same samples .

**ion ( Mg +2 ) ( Magnesium )**

It is classified as one of the main and positive ions present in groundwater, and the minerals and rocks that include magnesium in its chemical composition (such as dolomite, lime) and dissolved clay and calcareous minerals (such as ferromagnesium, pyroxene) are among the main reasons for the presence of the element magnesium ( ) It is noted in Table ( 62 ) and (63) the variation of magnesium ion concentrations in the well water samples of the study area, as it ranged between (107-228 ppm ) for the wet period, and between ( 119-235 ppm ) for the dry period

**Sodium ion ( Na + )**

The sodium ion is produced in igneous rocks from feldspar and the weathering of clay and other minerals. It also results from washing the soil layers and then filtering the water to the bottom. In addition, the pollution resulting from the interference of salty sea water located in the far depths of the aquifers feeding the reservoirs above them increases the ion. Sodium in ground water ( ) . It is clear from Tables ( 62 ) and (63) that the ion concentrations Sodium ranged between (120-482 ppm ) in the wet period, and ranged between (148-495 ppm during the dry period .

**Potassium ion ( k + )**

The presence of potassium is associated with the presence of the sodium ion in nature, but the concentration of potassium in water is less than the concentration of sodium because its stability towards weathering factors is different and it is easily absorbed by clay minerals ( ) and is the most abundant in all sedimentary rocks ( ) . It is evident from Tables ( 62 ) and (63) the variation of the potassium ion, as it ranged from (17-50.72 ppm ) for the wet period and between (20-49.42 ppm ) for the dry period, as the highest concentrations were recorded in well water samples (7-16), when they reached (16-7). 46-50.72 ppm ) for the wet period, while it was in the dry period (46.63-49.42 ppm ) for samples (6-10). While the lowest concentrations were recorded in well water samples (11-4-13), as they reached (17-19-20 ppm ) in the wet period, while they were recorded in the dry period (18-20-22 ppm ) for samples (13-11-4.

**Negativeions**

The study of the chloride ion, sulfate and bicarbonate includes the following

**ion Cl- ) Chloride)**

The ion ( CL ) is one of the important negative ions in groundwater, and the water acquires a salty taste, especially when it is associated with other ions such as magnesium and calcium. ( ) . And that the source of chloride in the groundwater is from the ancient marine water confined within the sediments or from the evaporation processes of rain water, which concentrates the chloride available in it ( ) . It is evident from Tables ( 62 ) and (63) a variation in the rates of chloride ion concentrations, as it ranged between (355-853 ppm ) for the wet period, while it ranged between (363-899 ppm ) .

**The sulfate ion ( $SO_4^{-2}$**

Sulfates are found in groundwater mainly from gypsum layers or oxidation of sulfides (iron sulfur), and water usually has a taste that tends to bitterness, and if it contains magnesium and sodium sulfate salts ( ) It is clear from Tables ( 62 ) and (63) that the sulfate ion is one of the most common ions in the study area and map ( 35 ). It is also noticed that it increased during the two periods, as its values ranged between (810-1974 ppm ) for the wet period and between (930-2150) . ppm ) for the dry period .

**Bicarbonate ion $HCO^{3-}$**

The bicarbonate ion is one of the main negative ions in groundwater, which comes from the dissolution of limestone rocks and salt deposits of geological formations ( ) , as well as rainwater that contains carbon dioxide. Therefore, these two factors are considered a source of alkalinity, as bicarbonate is affected by the pH, so if its value is less than (8.2) The carbon ion combines with the hydrogen ion and turns into bicarbonate ( ) .

It is evident from Table ( 62 ) and (63) the variation in the concentration of the bicarbonate ion, and it ranged between (31-131 ppm ) . for the wet period and between (43.92-135 ppm ) for the dry period, where the highest concentration was recorded for well water samples (15-2-3) as it reached (131-126-97 ppm ) for the wet period, while in the dry period it reached (135-122-98 ) for the same samples. As for the lowest concentrations, they were recorded in well water samples (10-9-7), when they reached (31-32.3-44.4 ppm ) for the wet period, while in the dry period they reached (39.4-43.92-48-49.54 ppm ) for the samples. ( 7-16-10-14-11 )

**Second : Ground Water Suitability for Human Drinking :**

The water quality index can be defined as that tool through which data can be collected and summarized and converted into a simple method and put into easy and simple mathematical formulas that can be understood by others. quality) which necessitates preserving these characteristics through permanent follow-up ( ) , and the Canadian model ( WQI ) is considered one of the good models as it has a different approach and distinctive characteristics from among the traditional models, as it has the ability to take into account all variables of water quality in addition to its flexibility in choosing the important variable In the application, it allows the researcher the freedom to choose the variables included in the model, as well as the freedom to set the standard limits at which the water specifications are acceptable, and it consists of three factors for the evaluation process, which are (range, frequency, capacity) and are calculated as follows ( ) :

**The first factor ( F1) scape, range :** represents the percentage of the number of variables exceeding the standard limits compared to the total number of variables.

$$F1 = \left[ \frac{\text{The number of overridden}}{\text{The total number of variables}} \right] \times \mathbf{100}$$

**The second factor, F2** ( frequency ) : represents the percentage of individual examinations exceeding standard limits compared to the total number of variables.

$$F2 = \left( \frac{\text{Number of checks passed}}{\text{Number of variables}} \right. \times \mathbf{100}$$

**The third factor , F3 ( Amplitude ), represents the passed tests, and it has two stages:**

**1-The first stage:** the number of times the individual concentrations exceed the standard limits and it is called the deviation ( excursion ) and it is calculated as follows

$$\text{Excursion} = \left( \frac{\text{Exceeded check value}}{\text{Core value}} \right) \mathbf{1}-$$

**2-The second stage:** the group of individual tests passed, and it is calculated by adding the individual deviations and dividing them by the total number of examinations (passed and non - passed ) .

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$$NSE| = \frac{\text{Deviation of each component}}{\text{Total number of checks}}$$

F3 :is calculated through the following equation

$$F\,3 = \left( \frac{NSE}{0.01\,NSE + 0.01} \right)$$

As for the table below (71), it shows us the international and Iraqi standards for water ) drinking, irrigation) that were adopted in order to calculate the value of the index) CCME WQI .

**Table 3: Standards for drinking water**

| Iraqi specifications for drinking | The Worker | T |
|---|---|---|
| nothing | the color | 1 |
| acceptable | Taste | 2 |
| acceptable | Odor | 3 |
| - | temperature | 4 |
| 8.5-6.5 | PH | 5 |
| 1500 | EC | 6 |
| 1000 | TDS | 7 |
| 500 | TH | 8 |
| 50 | Can | 9 |
| 50 | mg | 10 |
| 200 | No | 11 |
| , | K | 12 |
| 250 | CI | 13 |
| 250 | SO4 | 14 |
| 200 | Hco3 | 15 |

Source: Republic of Iraq, Ministry of Planning, Central Organization for Standardization And quality control, Iraqi standard specifications for drinking water, No. (417): first update, 2009, pg. 4-

(2) WHO, Guide line for drinking water quality, 3rd Edition , vol3 Geneva, 2011.

(3) Drinking water standard public, 969 Washington, USEPA, Public Health Service, 1975, pp: 61.

While table (72) allows us to know the groundwater quality in the study area by comparing it with the water index standards ( CCME WQI ), which consists of five categories.

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**Table 4: Water Index Scale CCME WQI**

| General Description | CCME WQI directory value | Directory classification | directory category |
|---|---|---|---|
| The water is well protected, far from pollution, and close to ideal | 100 - 95 | Excellent | The first |
| The waters are less protected and rarely deviate from ideal | _ _ 94–80 | good | the second |
| Water is often protected, but is exposed to pollution and is sometimes far from ideal | 65 - 79 | neutral | Third |
| Water is frequently polluted and is often far from ideal | 64 - 45 | questionable | Fourth |
| Water is constantly exposed to pollution and is far from ideal all the time | 0 - 44 | lousy | Fifth |

and it must be within the permissible qualitative (physical and chemical) characteristics. Salinity and concentration limits for the main positive and negative ions because of their danger if they exceed the permissible limits according to those standards ( ) .

To calculate the value ( CCME WQI ) of the groundwater of the wells of the study area, (10) variables were applied to calculate the Canadian guideline for assessing the suitability of drinking water according to international and Iraqi specifications as shown in Table (71), and the comparison was made on the basis of the two periods (dry and wet) because the mechanism of the indicator works We are required to have three variables for comparison.

The Canadian Water Quality Index CCME WQI ) for drinking water in the study area for the two periods (wet and dry) was recorded within the fifth index category within the classification of poor water, as it is permanently exposed to pollution and is far from ideal at all times, due to the number of variables that exceed the permissible limits.

It is within the global and Iraqi determinants, where most of the wells of the study area recorded the number of exceeded variables (8) out of (10) and were represented by the elements ( EC, TDS, TH, Ca, Mg, Na, Cl, So4 ), where the high of these concentrations is responsible for the deterioration of The studied well water, which led to an increase in the factors ( F1, F2, F3 ), and thus was reflected in a decrease in the qualitative indicator values, Table

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**Table 5: Values and classification of the water quality of the studied wells in the study area drinking water**

| Classification of categories | WQI value | F3 | F2 | F1 | Well No |
|---|---|---|---|---|---|
| lousy | 23.28 | 69.69 | 80 | 80 | 1 |
| lousy | 23.56 | 68.75 | 80 | 80 | 2 |
| lousy | 21.83 | 74.35 | 80 | 80 | 3 |
| lousy | 23.56 | 68.75 | 80 | 80 | 4 |
| lousy | 21.43 | 75.60 | 80 | 80 | 5 |
| lousy | 20.89 | 77.27 | 80 | 80 | 6 |
| lousy | 21.83 | 74.35 | 80 | 80 | 7 |
| lousy | 26.98 | 56.52 | 80 | 80 | 8 |
| lousy | 23.00 | 70.58 | 80 | 80 | 9 |
| lousy | 22.50 | 72.22 | 80 | 80 | 10 |
| lousy | 34.74 | 54.54 | 70 | 70 | 11 |
| lousy | 26.06 | 60 | 80 | 80 | 12 |
| lousy | 25.24 | 62.96 | 80 | 80 | 13 |
| lousy | 22.50 | 72.22 | 80 | 80 | 14 |
| lousy | 21.24 | 76.19 | 80 | 80 | 15 |
| lousy | 21.62 | 75 | 80 | 80 | 16 |

Source: The researcher's work based on the water index equation  CCME WQI

## CONCLUSIONS

1. It was found through the results of the accuracy of the chemical analyzes and the percentage of error in them that the calculated values of the balance error are less than (5%), except for a sample (1,2,3,9,16), which was within the category (5-10%) for the wet period, The same was the case with regard to the dry period. The well water of the study area was within the category (5%), except for samples (1,2,3,9,12,14,16), which were within the category (5-10%).
2. The results of the chemical properties analyzes showed that the pH value ranged between (7.2-8) for the dry period and between (7.3-7.7) for the wet period.
3. As for the total hardness (T.H), all the studied wells were within the category (very hardness) according to the classification (Boyd 2000).
4. As for the total dissolved salts (TDS), the water was classified from (slightly salty) to (highly saline) according to the classification (Klimentov, Todd).

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5. With regard to positive ions (Cations) and negative ions (Anions), the results of the analyzes showed that they vary spatially and temporally in the studied wells, as well as the results of the statistical analysis, as it indicated that there is a (positive) correlation between them.
6. It was found through the application of the water quality index model (CCME WQI) that the well water of the study area is not suitable for human drinking and for the two periods (dry and wet).

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