Application of the CCME water quality index to evaluate the groundwater quality of shouira village for drinking and domestic purposes in Nineveh governorate

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Abstract. In this research, the Water Quality Index (CCME) was used to determine groundwater suitability for drinking and domestic purposes. in the village of Shouira in Talafar district, northwest of Nineveh Governorate. This was carried out by subjecting 50 samples of groundwater to biological and chemical analysis. These parameters include pH, TDS, O₂, T.A, Ca, Mg, Na, K, Cl, PO₄, SO₄, TPC, and F. Colif. The results show that groundwater is not suitable for drinking. It was found that the low value of CCME, which ranged between (17.9 - 32.7), is mainly due to the high value of most of the values of the measured parameters and the low oxygen values.

Keywords: TDS, Water Quality Index, CCME, shouira, Talafar.

1. Introduction
The water budget in Iraq suffers from severe disturbances due to the low levels of water flowing in the Tigris and Euphrates rivers, and water security in Iraq must be strengthened through integrated management of water resources, through the development and management of water and land in a coordinated manner, and support plans for rational investment of water and the development of its surface and underground sources and reduce waste To as little as possible [1]. There are some facts about the water system in Iraq that can be reviewed before going into the details of groundwater, including that the general average of the annual rainfall depth is 100-1000 mm, and that the dates of the rainy season are in specific months between 10 - 4, that the national water resources reach 40% of its total, including 8% of groundwater sources, and the depth of rainfall fluctuates from year to year with the possibility of successive years of drought and fluctuation of the amounts of surface runoff, and lack of prior knowledge of the method of operation in the two rivers' source countries, equivalent to 60% of Iraq's water resources, and that Iraq must rely on stocks collected during several months of the year.

The presently accessible traditional water supplies, including surface water entering Iraq., surface water formed inside Iraq [2], and renewable groundwater, amounting to 70.86 billion m³/year, and the current agricultural, industrial, and municipal consumption, evaporation from reservoirs and marshes, and environmental runoff from the Shatt al-Arab reaches 72.12 billion m³/year. As for the future perspective, the traditional water supplies available in the future in 2035 will decline to 55.51 billion m³/year, which indicates the severity of the water situation in Iraq. Reports of the Ministry of Water Resources indicate that the current consumption of groundwater, which represents storage that can be withdrawn sustainably for municipal and industrial purposes, is 5%, and for agricultural purposes 67%, so the remainder that can be withdrawn is 28% [3].

Groundwater is one of the important water sources in arid and semi-arid regions, yet we find that groundwater is threatened by pollution due to long droughts and various human activities [4]. The current study provides information on the characteristics of groundwater in the village of Shouira in the Talafar district, which lacks surface water sources and therefore depends mainly on groundwater as the main source of water for domestic consumption, and aims to identify the suitability of groundwater for human consumption based on the calculation of the water quality factor. The water quality index is a set of parameters or parameters that can determine the overall quality of water. It is a mathematical formula for calculating a single value for multiple measurements or tests to give a parameter about the quality of groundwater in a region, and water quality gives a clear picture of the suitability of water for multiple purposes [5,6].
2. Study area
The village of Shouira, in Talafar district, is located in Nineveh Governorate, between latitude (36°25'01" to 36°30'07") to the north, and longitude (42°22'80" to 42°26'32") to the east. It is bordered on the north by Mount Sinjar and on the east by the Tel Afar district, which is 25 km away. Table 1 and Fig. 1. [7]

| Well No. | E          | N          | Altitude (m) | Depth (m) |
|---------|------------|------------|--------------|-----------|
| 1       | 42°22'86"  | 36°28'61"  | 324          | 70        |
| 2       | 42°24'04"  | 36°29'34"  | 313          | 100       |
| 3       | 42°24'24"  | 36°27'52"  | 317          | 80        |
| 4       | 42°24'26"  | 36°27'66"  | 318          | 85        |
| 5       | 42°24'94"  | 36°26'57"  | 310          | 90        |
| 6       | 42°25'01"  | 36°25'01"  | 308          | 133       |
| 7       | 42°22'80"  | 36°26'08"  | 320          | 100       |
| 8       | 42°25'59"  | 36°30'07"  | 325          | 80        |
| 9       | 42°26'53"  | 36°29'59"  | 319          | 90        |
| 10      | 42°26'32"  | 36°26'80"  | 304          | 70        |

3. Materials and methods
Fifty samples of underground water were collected from the village of Al-Shouira every month for ten wells distributed randomly using clean packages of polyethylene. TDs and pH were measured in situ while O2, TA, Ca, Mg, Na, K, Cl, PO4, SO4, TPC, and F. Colif. were measured Laboratory immediately after collection [8,9].

4. CCME
After collecting the results and disaggregating them according to time and place, the Canadian Council of Ministers of the Environment (CCME) model was used. The Canadian Water Quality Index gives researchers freedom. Choose the variables included in the model and the freedom to set limits Standard, at which water specifications are acceptable. The model relies on mixing three mathematical factors in calculating the final number expressing a specific condition Water is the field, frequency, and abundance, as it is calculated from equations specific to each variable, and then the final number obtained expresses the state of water quality as follows [10,11]:
- The first factor (F1) (Scope): represents the ratio Between the number of variables whose values do not match the objectives set for the model (Objective), and the number the total of the variables is calculated from the equation below.

\[
F_1 = \frac{\text{number of failed variables}}{\text{total number of failed variables}} \times 100
\]

The second factor (F2) (Frequency): represents the ratio between the number of tests that did not meet with the goal values set for the form Objectives and the total number of tests from the equation below.

\[
F_2 = \frac{\text{number of failed test}}{\text{total number of failed test}} \times 100
\]

The third factor (F3): (Amplitude) represents values Failed tests that do not match the objectives is calculated by the following steps:
- Excursion measure: which means the number times the test value moves further away from the target the required is calculated from the following equation:

\[
\text{Excursion} = \frac{\text{failed test value}}{\text{objective}} - 1
\]
Figure 1. Location and sampling of the study area

The accumulated number of tests that did not match Specifications are calculated using the sum of the deviations (excursion) for these tests divided by total of tests) include matched and non-matched the result is what is known as excursions, or nse (normalized sum of), and it is calculated as follows [12]:

\[
NSE = \frac{\sum \text{Excursion}}{\text{number of tests}}
\]

Then you calculate F3 from the following equation:

\[
F3 = \frac{\text{NSE}}{0.01 \times \text{NSE} + 0.01} \times 100
\]

By calculating the three main steps, an index is calculated Water quality from the following equation:
CCME = 100 − \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}

Classification of the scale of the CCME index of water quality in Table 2. [13].

Table 2. classification of the water quality index scale depending on the quantity of the CCME

| Rating   | CCME Values |
|----------|-------------|
| Excellent | 95 - 100    |
| Good     | 80 - 94     |
| Fair     | 60 - 79     |
| Marginal | 45 - 59     |
| Poor     | 0 - 44      |

5. Results and Discussions

The value of pH affects the quality of water and causes its effect on the carbonate balance and the water content of metallic elements. As the decrease in the values will lead to an increase in the melting of the toxic mineral elements in the rocks of the geological formations that pass through the water, such as aluminum, and thus increase the negative effects of the water. In general, the water from the studied wells is within the appropriate limits for drinking [13].

The most important measure for determining water quality is dissolved oxygen in water, despite the poor solubility of oxygen in water, its presence is essential in the natural balance, and as a result of producing anaerobic conditions, the great deficiency of this element has a detrimental effect on the aquatic environment. and the formation of unhealthy compounds of water [14]. Drinking. The results of the study shown in Figure 5. and Table 3. showed that the recorded values of dissolved oxygen concentrations in the groundwater of the wells range (0.80 – 8.00) mg. l\(^{-1}\) as it is noticed that 36% of the concentrations of the studied samples were less than the permissible limits for drinking, and the reason for the decrease is due to the high salinity as well as the lack of Friction of water wells with air [15].

TDS are an important component as a measure of water salinity. According to the results shown in table 6. that the concentration of solid dissolved substances water studied ranged from (1142-2306) mg. l\(^{-1}\) was due to a rise in the concentration to the nature of the geological formations that include the composition of the Fat’ha and structure salts evaporite, gypsum, dolomite and composition of Anganh consisting of sequences of Stones of sand, and silts, and these differences are reflected on the quality of the water passing through it. And all values were exceeding the permissible limits for drinking (1000 mg. l\(^{-1}\)) [16].

The results of the high T.A concentration, as shown in figure (4), showed that this increase in concentration has a positive role for aquatic ecosystems as it works to prevent a large fluctuation in pH values, and this relative rise in the concentration is due to the reactions that take place in the water during its passage through the technology. As in the following equations:

\[
\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 \\
\text{CaCO}_3 + 2\text{H}_2\text{CO}_3 \rightarrow \text{Ca(HCO}_3)_2
\]

The high concentrations of the T.A of drinking water cause the reduction of the secretion of gastro-digestive juices and the inhibition of the action of the enzyme pepsin, which results in an imbalance in the digestive process, vomiting, and nausea in some cases [17,18], and the Alkaline results exceeded 96% of the values allowed for drinking.

Calcium ion, which is the most concentrated element in groundwater mostly due to the abundance of limestone in the upper layers, and calcium salts contribute to filling part of the body's need for building bones and teeth, but in return, it is responsible for water hardness that affects the work of washing machines and cleaning powders, as well as It causes calcifications in water systems and boiling vessels [19]. As for the magnesium ion, it is present in less than calcium and its main source is dolomite rocks, and it is very useful for the work of some organs of the body and it enters into a large number of nutrients, but like calcium, it leads to hardness of water, the high concentration of magnesium in
drinking water, especially when the ion is accompanied with the sulfate ion. It causes diarrhea in consumers [20]. The concentrations of calcium and magnesium ions for the water samples ranged between (480 - 688) mg. l\(^{-1}\) and (96 - 528) mg. l\(^{-1}\), respectively, and all the ionic values exceeded the permissible limits for drinking, as shown in the figure 4. and the table 3. For the normal functioning of the body, sodium is essential. It can be present in all tissues and body fluids and is not commonly considered to be unhealthy at usual food consumption levels from shared sources of food and drinking water. However, when the level is greater than 200 milligrams per liter, people should be careful of the sodium level in drinking water: People who track high-blood pressure salt consumption and people with heart disease or cardiovascular disease People with kidney disorders or low-sodium diets [21]. The results showed that 80% of the values exceeded the permissible limits for drinking, as shown in Figure 3. The reason for the relatively high values is attributed to the nature of the geological formations of the layers of the earth through which the water and the melting of salts pass, as well as the weathering processes, as when the water reaches the sodium minerals and in the presence of bicarbonate and water ions, sodium ions will be released as shown in the following equation [22]:

\[2NaAlSi_3O_8 + 2H_2CO_3 + 9H_2O \rightarrow Al_2Si_2O_5(OH)_4 + 2HCO_3^- + 2Na^+ + 4H_4SiO_4\]

Potassium is present in well water in lesser amounts than sodium, especially in the water in areas with igneous rocks. As the potassium concentration varied between (3.00 – 39.10) mg. l\(^{-1}\) (table 3.). The reason for the low concentration of potassium in some areas relative to the rest of the elements may be due to the high resistance of potassium mineral to dissolution and its ability to adsorption and ion exchange with Soil minutes, which makes it less soluble than the rest of the ions, the areas where high potassium is observed is its proximity to farms where fertilizers containing potassium are used [23,24]. In general, half of the wells were groundwater unsuitable for drinking (2, 3, 4, 7, and 9).

Chloride is one of the indicators of water salinity, as the water earns a salty taste when associated with the sodium ion, and studies indicate that the chloride ion has a laxative effect on the intestine and has a negative effect on kidney function and high blood pressure [25]. The results of the study showed that all samples of well water for the chloride ion were within the permissible limits for drinking except for well No. 4 and 5 as in Table 3., but as an average, all of them were drinkable as in the figure 3. The results of the study shown in table 3. and figure (6) indicated the high sulfate concentration ion in groundwater samples, That ranged between (1633 - 7389) mg. l\(^{-1}\) which were not suitable for drinking and the reason is due to the type of geological rocks to the composition of the Fat'ha village of the village of Shouira, through which the water passes, as the dissolution of sedimentary rocks carrying gypsum led to this increase in concentrations [12].

Phosphate is one of the important substances in the human body because it is part of DNA, RNA, ATP, and ADP, and it also contributes to the distribution of energy aspects. It is not toxic to humans unless it is found in large quantities because it causes problems in the digestive system [26]. Phosphate concentration in the water samples ranged between (0.00 – 1.32) mg. l\(^{-1}\), all water sample values were valid for domestic and drinking purposes.

The groundwater containing bacteria is an indication of its contamination and it may range from several hundred to several million per cm\(^3\). This number decreases with increasing depth and bacteria appear in the groundwater as a result of its contamination with various wastes. The measurement of bacteria colonies was carried out by dilution method on all samples of well water in the studied area [27], and the results showed that 100% of the samples were contaminated with TPC, while F. colif. was 40%, as in table 3, and figure 8.

5.1. CCME

According to the standards of the World Health Organization, polluted water causes 80% of human diseases. Therefore, the quality of groundwater must conform with the health specifications and be subject to periodic monitoring to protect it. The water quality parameter is one of the most effective means of giving information about water quality to the population and those interested in environmental affairs, and thus it has become an important determinant for assessing and managing groundwater. Water quality as a measure that expresses the combined effect of various water quality determinants, is calculated from the point of view of the suitability of water for human consumption, and is used as a basis for environmental assessment of local water quality categories and to determine the most appropriate use for purposes. Based on the water quality factor, the water quality is classified into five
categories, starting with Excellent water and ending with Poor water, with high pollution [12], as shown in Table 2. The values listed in the Canadian Water Quality Index that the groundwater in the study area, which ranged between (17.9 - 32.7), is considered poor according to the classification and for all wells, and therefore it cannot be used for domestic and drinking purposes. The reason is the high values of F1, F2, and F3, which are inversely proportional to the final values of the model. As in figure 9.

| Table 3. Variations of the chemical and bacterial results of groundwater (mg. l⁻¹) |
|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
|                           | 1             | 2             | 3             | 4             | 5             | 6             | 7             | 8             | 9             | 10            |
| pH                        | Min 7.16      | 7.03          | 7.04          | 7.10          | 7.22          | 7.27          | 7.19          | 7.11          | 7.11          | 7.10          |
|                           | Max 7.67      | 7.25          | 7.41          | 7.36          | 7.29          | 8.20          | 7.64          | 7.63          | 8.10          | 7.87          |
|                           | SD± 0.19      | 0.11          | 0.14          | 0.11          | 0.03          | 0.38          | 0.18          | 0.19          | 0.36          | 0.28          |
| O₂                        | Min 0.80      | 1.60          | 0.80          | 0.80          | 0.80          | 0.80          | 0.80          | 0.80          | 0.80          | 0.80          |
|                           | Max 6.40      | 6.80          | 8.00          | 8.00          | 7.20          | 8.00          | 8.00          | 8.00          | 8.00          | 8.00          |
|                           | SD± 2.27      | 1.97          | 3.00          | 3.07          | 2.62          | 3.03          | 3.05          | 2.44          | 2.76          | 2.71          |
| TDS                       | Min 1575      | 1846          | 1962          | 1142          | 1909          | 2049          | 2152          | 1937          | 1945          | 1495          |
|                           | Max 1676      | 1875          | 2583          | 2306          | 2301          | 2207          | 2239          | 2011          | 2234          | 1571          |
|                           | SD± 39        | 14            | 249           | 426           | 162           | 58            | 34            | 28            | 108           | 28            |
|                           | T.A           | Min 120       | 220           | 200           | 200           | 120           | 160           | 180           | 180           | 180           |
|                           | Max 340       | 420           | 400           | 380           | 300           | 320           | 360           | 360           | 360           | 320           |
|                           | SD± 82        | 77            | 83            | 78            | 76            | 62            | 52            | 76            | 87            | 70            |
|                           | Ca            | Min 536       | 552           | 552           | 528           | 480           | 560           | 584           | 552           | 584           |
|                           | Max 656       | 680           | 656           | 632           | 624           | 664           | 680           | 672           | 688           | 600           |
|                           | SD± 48        | 48            | 41            | 42            | 58            | 41            | 43            | 43            | 45            | 7             |
|                           | Mg            | Min 110       | 110           | 187           | 269           | 197           | 144           | 149           | 96            | 206           |
|                           | Max 197       | 245           | 293           | 528           | 240           | 403           | 365           | 365           | 451           | 197           |
|                           | SD± 33        | 51            | 40            | 110           | 21            | 92            | 78            | 99            | 103           | 21            |
|                           | Na            | Min 93        | 155           | 235           | 230           | 205           | 155           | 210           | 130           | 105           |
|                           | Max 160       | 220           | 275           | 450           | 455           | 370           | 360           | 395           | 350           | 245           |
|                           | SD± 25        | 26            | 19            | 93            | 107           | 91            | 93            | 71            | 83            | 55            |
|                           | K             | Min 6.00      | 10.70         | 11.80         | 11.10         | 6.20          | 5.00          | 7.50          | 7.00          | 7.30          |
|                           | Max 7.80      | 14.10         | 39.10         | 33.30         | 11.40         | 11.40         | 31.60         | 9.70          | 18.50         | 8.40          |
|                           | SD± 0.79      | 1.30          | 12.65         | 9.64          | 2.17          | 2.46          | 10.19         | 1.08          | 4.60          | 2.31          |
|                           | Cl            | Min 54        | 72            | 108           | 102           | 107           | 68            | 134           | 104           | 62            |
|                           | Max 64        | 104           | 184           | 270           | 301           | 176           | 216           | 152           | 182           | 72            |
|                           | SD± 4         | 13            | 33            | 72            | 87            | 44            | 32            | 19            | 43            | 5             |
|                           | PO₄           | Min 0.00      | 0.00          | 0.00          | 0.00          | 0.00          | 0.00          | 0.00          | 0.00          | 0.00          |
|                           | Max 0.34      | 0.15          | 0.08          | 0.15          | 0.79          | 0.56          | 0.56          | 0.60          | 0.75          | 1.32          |
|                           | SD± 0.15      | 0.07          | 0.03          | 0.07          | 0.35          | 0.27          | 0.25          | 0.27          | 0.33          | 0.55          |
|                           | SO₄           | Min 2321      | 1633          | 1941          | 2557          | 2629          | 2454          | 2456          | 2752          | 1777          |
|                           | Max 4824      | 4998          | 4270          | 4968          | 4178          | 7389          | 6127          | 4947          | 4968          | 3378          |
|                           | SD± 952       | 1209          | 839           | 940           | 842           | 1958          | 1441          | 925           | 927           | 665           |
|                           | TPC           | Min 74        | 70            | 67            | 50            | 190           | 51            | 38            | 130           | 30            |
|                           | Max 1456      | 2240          | 2144          | 1040          | 3360          | 1888          | 896           | 1600          | 2560          | 1024          |
|                           | SD± 533       | 985           | 738           | 404           | 1256          | 786           | 413           | 657           | 1147          | 523           |
|                           | F. coli       | Min 0         | 0             | 0             | 0             | 0             | 0             | 0             | 0             | 0             |
|                           | Max 15        | 3             | 43            | 243           | 4             | 23            | 460           | 23            | 460           | 0             |
|                           | SD± 7         | 1             | 19            | 106           | 2             | 10            | 198           | 11            | 204           | 0             |

* 10⁷ cell. ml⁻¹
**Figure 2.** Mean of pH values for well water

**Figure 3.** Mean values of Na and Cl ions for well water

**Figure 4.** Mean values of Ca, Mg ions, and T.A for well water

**Figure 5.** Mean values of K, O₂, and PO₄ for well water

**Figure 6.** Mean values of TDS and SO₄ for well water

**Figure 7.** Mean values of TPC for well water

**Figure 8.** Mean values of F. Colif. for well water

**Figure 9.** Mean (F1, F2, and F3) for the water quality parameter for well water
Table 4. Water quality index drinking for the studied wells

| well No. | CCME  | Ranking |
|---------|-------|---------|
| 1       | 30.91 | Poor    |
| 2       | 24.60 | Poor    |
| 3       | 21.24 | Poor    |
| 4       | 17.96 | Poor    |
| 5       | 22.96 | Poor    |
| 6       | 27.42 | Poor    |
| 7       | 21.32 | Poor    |
| 8       | 24.92 | Poor    |
| 9       | 20.58 | Poor    |
| 10      | 32.75 | Poor    |

6. Conclusions
1. It is concluded from the study that the concentration of positive ions, especially calcium, magnesium, and sodium, was high. As for the negative ions, it was sulfate, as well as the TDS, as well as the total bacterial contamination of all samples, this led to the not validity of water in these wells for drinking and domestic purposes.
2. The well-studied well water was characterized by its hardness, which led to its waste in consuming detergents due to the difficulty of forming foam.
3. This study focused on the suitability of water for domestic consumption, based on the application of the Canadian Water Quality Index. The values of the water quality factor were adopted based on thirteen parameters. The results of the analysis showed that the quality of the groundwater for all wells was of the poor category and is not suitable for domestic purposes, especially drinking.

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