Assessment of groundwater quality using CCME water quality index in Caracosh distract, northeastern of Mosul city, Iraq.

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Abstract: The aim of this study is to determine the Caracosh (Al-Hamdannia district) groundwater water quality index (CCME WQI). This was calculated by taking groundwater samples and putting them into a thorough physicochemical examination. For calculating the WQI, the following 9 parameters have been considered: pH, TDS, T. Alkalinity, T. hardness, Ca, Mg, Chloride, Sulphate and Nitrate. The WQI for these samples ranges from 25.19 to 93.58. The low values of WQI has been found to be mainly from the higher values of TDS, Total hardness, T. Alkalinity and Sulphate in the groundwater. The analysis reveals that % 40 of groundwater samples of the area needs degree of treatment before consumption, and it also needs to be protected from the perils of contamination.

1. Introduction
“Water is life”, “Health is Wealth” and “Waste to Wealth” are popular sayings relating to life and wealth. However waste that is not properly managed in the vicinity of surface water and groundwater can be detrimental to life, health and wealth [1].

The miracle of natural life that God gave to all living creatures is water. Therefore, it is wise to say "No life without water". To preserve life, it is necessary to scientifically manage ground and surface water resources, which are available in large quantities and are a free reward from God to all mankind for their use for drinking (for humans and animals) and for civil, agricultural and industrial purposes [2].

The problem of water shortage is one of the most important pillars of national security for any country in the world, as it is facing many countries, especially in arid and semi-arid regions whose water sources are outside the borders, as is the case in Iraq.

Water resource countries may try to control the water springing in them and exploit them economically and politically to achieve strategic goals, in addition to the threats arising from the scarcity of rain due to climate change [3].

Today, Iraq is facing a stifling water crisis that cannot be ignored due to the scarcity of water from the Tigris and Euphrates rivers and a number of Iraqi tributaries. Crises have exacerbated the country and in these circumstances the principles of integrated water management and storage must be used, such as building dams on permanent rivers, dams for water harvesting and exploiting groundwater, and changing traditional irrigation methods with modern methods to address water scarcity with rationalizing consumption and conducting periodic studies of water resources to identify emergency situations to reduce pollution problems [4]. The studies that have been conducted on water resources using weighted mathematical models in Iraq and Nineveh Governorate are very limited, including:

Groundwater study of Nimrud district for drinking and civilian uses by [5] using the Canadian water quality model CCMEWQI, the study of [6] for the application of mathematical weighted model (WQI) to assess the quality of water wells in the Gleekwan village in Al-Hamdniya district. Likewise, a study of water in AL-Kasik district northwest of the city of Mosul in northern Iraq by [7], studying water quality of groundwater in the Rashidiyah region, northeast of the city of Mosul by [8].
and groundwater has also been studied for the left side of Mosul city in northern Iraq by [9,10,11,12]. Therefore, the current study aims to evaluate the groundwater of the Hamdaniya district (Qarqosh) for drinking and domestic use.

2. Materials and Methods

2.1. Description of the study area

The study was conducted on the groundwater of the Hamdaniyah district, whose center is called Qarah Qosh, and it is also called Baghdad, which is located thirty-five kilometers southeast of the city of Mosul, Iraq, between (36° 16´ 56.1" - 36° 15´ 26") North latitude and (43° 21´ 25.6" - 43° 23´ 33.4") East longitude respectively. As shown in ‘Figure 1’. These groundwater were using for drinking, washings, bathing, and irrigation.

![Figure 1: Map of the southern part of Iraq (Nineveh Province) showing the studied wells.](image)

2.2. Geology of the Hamdaniyah district

The geological formations in it contain Al-Fatha (Lower Fars) which consisting mainly of gypsum, anhydrite, evaporated salts, limestone, and marl, etc. [13,14]. Therefore, most of the water well contains a high concentration of sulfur compounds such as sulfate, sulfite which combined with other cations as Na, Ca and Mg[15], the Al-Pulaspi Formation (middle - upper Eocene) rich in limestone (CaCO3), in addition to the Anjana Formation (Upper Miocene), which consists of a succession of sandy and silt layers with clay layers etc.,
2.3. Methodology

Sixty water samples were taken from twenty different wells (through dry seasons, for three months) were collected in polythene bottles which were cleaned with distilled water; followed by rinsing the sample container with the water sample before it is filled [10]. The parameters like pH, Total dissolved solids (TDS), Total Alkalinity, Total Hardness (TH), Calcium, Magnesium, Chloride, Sulfate, and Nitrate were estimated by using standard methods [16,17].

2.4. Calculation of the water quality index

The use of WQI to assess quality for various purposes is the important and modern means of judging water quality, as it takes different interventions between the studied parameters to give a single value for the quality that is understood by specialists and non-specialists. The Canadian CCME WQI was applied for human use using the parameters: pH, TDS, T. Alkalinity, T.Hard., Calcium, Magnesium, C/hloride, Sulfate, and Nitrate, Compared with global standard limits permitted for drinking and domestic use [18]. The CCME WQI calculation and formulation included the following [19,20].

Factor 1: $A_1 = \frac{\text{Number of failed variables}}{\text{Total numbers of variable}} \times 100 ..............(1)$

The measure for scope is $A_1$. This represents the degree of water quality guideline non conformity over the time period of interest in percentage.

Factor 2: $A_2 = \frac{\text{Number of failed variables}}{\text{Total numbers of tests}} \times 100 ..............(2)$

$A_2$ is the frequency scale. This is the number of individual assessments that fail to achieve their goals (failed tests).

The amplitude is calculated by factor 3($A_3$). This is the proportion of failed test qualities that do not achieve their targets. This is done in three steps:

Step 1 : Calculation of Excursion. Excursion is the number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective.

When the test value must not exceed the objective:

$$\text{excursion} = \frac{\text{failed test value}_i}{\text{objective}_j} - 1 \quad .............(3a)$$

When the test value must not fall below the objective:

$$\text{excursion} = \frac{\text{objective}_j}{\text{failed test value}_i} - 1 \quad .............(3b)$$

Step 2 : Calculation of Normalized Sum of Excursions. The normalized sum of excursions, ($nse$) is the collective amount by which individual tests are out of compliance. This is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives).

$$nse = \frac{\sum_{i=1}^{n} \text{excursion}}{\text{Number of Test}} \quad .............(4)$$

Step 3 : Calculation of $A_3$ by an asymptotic function that scales the normalized sum of the excursions from objectives to yield a range from 0.0 to 100.

$$A_3 = \frac{nse}{0.01 nse+0.01} - 1 \quad ............. (5)$$
The CCME WQI is finally calculated as:

\[
\text{CCME WQI} = 100 - \left[ \sqrt{\frac{A_1^2 + A_2^2 + A_3^2}{1.732}} \right] 
\]  

(6)

Once the CCME WQI value has been determined, water quality is ranked by relating it to one of the following categories [5]:

1- Excellent: (95-100)- Water consistency is virtually unaffected or compromised, resulting in environments that are very similar to normal standards.

2- Good: (80-94)- Only small threats or impairments to water quality exist; circumstances seldom deviate from normal or optimal standards.

3- Fair: (65-79)- Water quality is generally preserved, although it can be endangered or damaged on rare occasions; circumstances can sometimes deviate from normal or ideal standards.

4- Marginal: (45—64)- Water safety is often jeopardized or affected, and conditions often deviate from normal or acceptable values.

5-Poor: (0-44)- Water quality is almost often jeopardized or harmed, and conditions often deviate from ideal or normal values.

3. Results and Discussion

Average values and standard deviation of the physical and chemical properties listed in (Table 1).

The pH measurement reflects the change in the quality of the water source. In this study, the average pH values ranged from 6.96 to 7.54 which are within permissible limits [18]. Slight acidity of some samples may be due to the presence of dissolved carbon dioxide and organic acids in groundwater derived from the decomposition of leached organic matter [21].

Dissolved solids in water are a measure of the dissolved ions in water, and high concentrations can cause heart and kidney disease [21]. TDS values varied from 331 to 6446 ppm, 40% of values are well above the standard limit [18].

As for the alkalinity of water in the current study, the rates fluctuated between 355 to 137 mg.l^-1 during the study period, 95% of these values were well above the standard permissible drinking limit. This rise is due to the weathering processes of rocks in the geological formations. Thus, it will lead to an increase in the acid Neutra -lization acidity ANC[3].

Total hardness of water represents a reflection of major ions like Ca+2, Mg+2, HCO3-, SO4=, Cl- etc., present in the water, and these ions enter the groundwater by weathering processes of minerals such as calcite, gypsum, and dolomite [10]. T. Hardness, Ca and Mg are found to be in a range of 3333 to 177, 529 to 36 and 537 to 20 ppm. So, about 50%, 55% and 55% respectively of all the data satisfy the objective values [18]. A potential link between water hardness and mortality from ischemic heart disease (IHD) or stroke, myocardial infarction, hypertension, liver cirrhosis, thyroid disease, and cancer has been identified in several studies. [22].

High levels of chloride (> 250 ppm) Chloride are leached from various rocks in the geological information and water by weathering [10] Average chloride values ranged from 17 to 508 ppm (75% of samples were within tolerable tolerable limit).

Sulfates are naturally present in groundwater as a result of dissolving gypsum and anhydrite [14], which present in parts of the study area. Sulfate levels fluctuated between 94 to 2227 ppm with 50% of samples exceeding the standard limit. High levels of sulfates in drinking water may cause diarrhea [9].

(19)

| Well No. | pH | TDS | T.alk | T.H | Ca | Mg | Cl | SO4 | NO3 |
|----------|----|-----|-------|-----|----|----|----|-----|-----|
| DW1      | 7.47 | 3874 | 163   | 2217 | 529 | 214 | 213 | 1477 | 4.90 |
| Sd ±     | 0.02 | 83.9 | 2.49  | 101  | 27.5 | 16.5 | 8.96 | 563  | 0.03 |
The high levels of nitrate in groundwater may cause serious illnesses such as methemoglobinemia or "blue baby syndrome", birth defects, and deterioration of the immune system, cancer risks like bladder-ovarian, testicular, and brain cancers etc. [23] Nitrate in the water samples are found to be in a range of 15.7 to 0.43 ppm, all data are within the recommendations of the World Health Organization.
and the increase in nitrate ion concentrations is due to the effect of agricultural fertilizers and organic wastes.

Water quality index based on very important and approved criteria can provide an indicator of water quality. WQI is considered as a good and modern way to evaluate its quality for various uses by means of the various interferences of the parameters used in its calculation to produce a single value instead of the vast amount of data and results to give the public a general idea of the water quality and potential problems of the studied water environment. According to the classification based on the water quality index and the values of the factors calculated to estimate the WQI and the water quality category during the study period are clarified in (Table 2).

| Table 2: | A₁, A₂, A₃ and Water Quality Index at each well. |
|----------|--------------------------------------------------|
| Well     | A₁      | A₂      | A₃      | WQI    | Category |
| DW1      | 66.666  | 66.666  | 53.252  | 37.48  | Poor     |
| SW2      | 66.666  | 66.666  | 58.420  | 36.00  | Poor     |
| SW3      | 77.778  | 77.778  | 58.260  | 28.13  | Poor     |
| SW4      | 77.778  | 77.778  | 51.998  | 29.75  | Poor     |
| SW5      | 77.778  | 74.074  | 46.260  | 32.48  | Poor     |
| SW6      | 77.778  | 74.074  | 59.900  | 29.00  | Poor     |
| DW7      | 77.778  | 77.778  | 68.500  | 25.19  | Poor     |
| DW8      | 66.666  | 66.666  | 58.440  | 35.96  | Poor     |
| DW9      | 66.666  | 59.259  | 48.89   | 41.29  | Poor     |
| DW10     | 33.333  | 44.440  | 15.077  | 66.77  | Fair     |
| DW11     | 11.111  | 11.111  | 8.101   | 89.79  | Good     |
| DW12     | 11.111  | 7.410   | 0.614   | 90.92  | Good     |
| DW13     | 11.111  | 0.037   | 0.137   | 93.58  | Good     |
| DW14     | 22.222  | 14.81   | 4.096   | 84.40  | Good     |
| SW15     | 11.111  | 7.407   | 2.198   | 92.19  | Good     |
| SW16     | 11.111  | 11.111  | 4.737   | 90.52  | Good     |
| DW17     | 11.111  | 11.111  | 6.639   | 91.15  | Good     |
| DW18     | 22.222  | 11.111  | 3.590   | 90.69  | Good     |
| DW19     | 11.111  | 11.111  | 15.62   | 87.21  | Good     |
| DW20     | 11.111  | 11.111  | 5.063   | 90.47  | Good     |

As WQI values ranged from 25.19 at well 7 to 93.58 at well 14. so that the quality of the groundwater in wells 1 to 9 was of the poor quality category, while the water in wells 11 to 20 was of good quality, and the water in well 10 was of the fair type. Groundwater of poor quality is mainly caused by high levels of dissolved solids, total hardness, calcium, and magnesium, meaning that 45% of the poor quality water samples are not suitable for drinking and domestic purposes in their current form.

4. Conclusions and Recommendations

% 50 of the water wells in the Hamdaniyah district were characterized by high most of the studied parameters, which led to a deterioration in its quality for drinking and household purposes. Therefore, we recommend periodic monitoring of water sources, and for rural families, it is possible to use the technique of total or partial freezing and slow thawing by the home refrigerator, which is a simple and easy technique to remove salts from well water and improve its quality for drinking purposes [24].

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