Assessment The Suitable of The Groundwater for Civil uses in Kakhirta Village, Al-Ayadiyah Subdistrict, Iraq

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Abstract. The current research describes the application of the water quality index (WQI) based on the collection of 50 samples of water sample for 10 wells for five months in the village of Kakhirta in Al-Ayadiyah subdistrict, northwest of Nineveh Governorate. The model was applied using 13 parameters (pH, TDS (total dissolved salts), DO (dissolved oxygen), T.A (Total Alkaline), Cl, Ca, Na, Mg, K, PO₄, SO₄, TPC (Total Plate Count), and F. Colif. (Faecal coliform) depending on the results obtained from the model. The groundwater quality ranged between (218 - 765), which indicates deterioration in water quality due to the high numbers of bacteria TPC and F. Colif., as well as the high total alkaline T.A and hypoxia in the water more the recommended limits for drinking water.

1. Introduction

Water enters the soil naturally because of the hydrological cycle of water in nature. The quality of groundwater changes during its movement inside the soil and its cohesion with rocks, as the water interacts with some of its constituent elements and melts from them and deposits others according to the quality of the rocks, the quality of water and the nature of its movement[1]. As a result of natural factors, it is very little compared to the pollution that occurs from human intervention, as human activity affects water quality in one way or another on water quality, and humans have a direct and indirect influence in changing the quality and quantity of groundwater[2].

Groundwater is one of the most important parts of water resources as it constitutes 71.7% of the world’s drinkable water. Groundwater contains calcium, magnesium, and sodium salts, in high concentrations to make this water hardness due to its exposure to soluble substances in geological formations in addition to the salts transported in it [3]. The tremendous development in the development of agricultural and animal fields and the establishment of industrial and population gatherings around the wells have increased their pollution problems and have become a health threat to the consumers of these wells’ water[4].

The influence of sewage and industrial waste through the soil into the water layers is a source of danger for groundwater pollution and deterioration of its quality, which made it more exposure to contamination[5]. Therefore, the current study aimed to know the quality of groundwater by collecting groundwater samples for ten wells in the village of Kakhirta, analyzing them, and then determining their suitability for drinking water purposes Depending on the standard parameters applicable internationally.

Many researchers have been studied the qualitative characteristics of groundwater in various regions of Iraq. Al-Shanona and others[6] have studied the water wells of Abu Maria village of Tal Afar district to determine its suitability for drinking and household uses. The results of the study showed a high concentration of salts, as the total hardness concentration reached 2020 mg. l⁻¹, and sulfates...
reached 2136 mg. l⁻¹. The results also showed a decrease in WQI that water was of very poor quality for drinking and is not suitable for household uses according to the classification. Al-Saffawi[7] also studied the quality of the groundwater in the Al-Mahlabiah sub-district northwest of the city of Mosul, to evaluate it for drinking purposes. The results of the study reached a high concentration of some measured characteristics, especially solid dissolved salts and calcium ions. (3390, 673, 2271) mg. l⁻¹, respectively, which will affect the values of the Water Quality Index, this indicates that 83% of the studied water samples are of poor class after applying the Canadian model[7], and this is attributed to the geological formations that the water passes through, It requires some simple treatments, such as slow freezing and melting, to improve its quality before using it for drinking.

Jaafar and others[8] assessed the quality of water wells in the Rashidiya area, north of the city of Mosul, for drinking and domestic use, as water samples were collected from ten wells scattered in the study area for bacteriological and chemical examinations using the log. model to Evaluation the quality of well water using 11 parameters, the results of the Water Quality Index indicated that all well water is not suitable for domestic use and drinking this deterioration because of bacterial contamination. (Total number of TPC and F. coliform bacteria), high salt concentration, total hardness, and sulfate ions.

1.1.Geology of the study area
The region consists of the formation of the Fat’ha (the middle Miocene), the sediments of this formation were characterized by being periodic and containing different stones such as limestone. This formation's thickness ranges from (64-818) m. The containment of this formation on a large number of cracks and fractures filled with sand made it have a high capacity on the storage of groundwater, but its containment of gypsum in large quantities had a negative impact on the quality of the water contained within it, as the dissolution of the elements of limestone rocks in the water makes them rich in magnesium and calcium compounds[9,10].

1.2.Description of the study area
The study area included the selection of 10 wells in the village of Kakhirta, affiliated to Al-Ayadiyah subdistrict in Nineveh governate, in the area Trapped between latitudes (36˚55ʹ06ʹʹ) and (36˚55ʹ90ʹʹ) to the north and between longitudes (42˚34ʹ45ʹʹ) and (42˚35ʹ01ʹʹ) to the east (Table 1, ‘Figure 1’)). This choice came because this village does not contain stations to purify drinking water, and the people depend on well water[11].

| Well | E    | N    | Altitude (m) | Depth (m) |
|------|------|------|--------------|-----------|
| 1    | 42˚34ʹ88ʹʹ | 36˚55ʹ90ʹʹ | 406  | 45  |
| 2    | 42˚34ʹ71ʹʹ | 36˚55ʹ87ʹʹ | 406  | 61  |
| 3    | 42˚34ʹ93ʹʹ | 36˚55ʹ73ʹʹ | 407  | 40  |
| 4    | 42˚34ʹ45ʹʹ | 36˚55ʹ68ʹʹ | 406  | 35  |
| 5    | 42˚34ʹ59ʹʹ | 36˚55ʹ45ʹʹ | 407  | 50  |
| 6    | 42˚34ʹ95ʹʹ | 36˚55ʹ60ʹʹ | 407  | 63  |
| 7    | 42˚35ʹ01ʹʹ | 36˚55ʹ34ʹʹ | 407  | 38  |
| 8    | 42˚34ʹ68ʹʹ | 36˚55ʹ31ʹʹ | 407  | 55  |
| 9    | 42˚34ʹ70ʹʹ | 36˚55ʹ12ʹʹ | 407  | 67  |
| 10   | 42˚35ʹ00ʹʹ | 36˚55ʹ06ʹʹ | 407  | 43  |
2. Materials and Methods
In the study, 50 water samples were collected from ten wells spread all over Kakhirta village using cleaned polyethylene bottles, and homogenized with each a sample before Filling. As for oxygen, samples were collected from them Water using special bottles installed in the field by Addition of a solution of manganese sulfate (Winkler A) and Alkaline iodide azide solution (Winkler B), as in Bacteriological examination samples and sterile vials used and samples were kept out of light Container until reaching the laboratory. It measures the pH of water and TDS values using the field device and, in the lab, every variable like O₂, TA, phosphate, Sulphate, Na, Ca, K, Cl, Mg, TDS, TPC, and F. colif. were measured. Based on international standard methods[12,13]. The following devices were used in the analyzes: spectrophotometer, flame photometer, pH meter, TDS meter, and turbidity meters.

2.1. WQI calculation
Several variables have been selected that have an impact on the use of drinking water for their use in finding the quality of water for drinking purposes. These variables pH, O₂, TDS, TA, Ca, Mg, Cl, Na, K, PO₄, SO₄, TPC, and F. Colif. And has been computed using the following equation[14-17]:

Figure 1. Map of Kakhirta village in Nineveh governorate showing the studied wells
\[ K = \frac{1}{\sum \frac{1}{S_{\text{TDS}}} + \frac{1}{S_{\text{O}_2}}} \]  

(1)

\[ W_n = \frac{K}{S_i} \]  

(2)

\[ q_n = 100 \times \frac{[V_n - V_i]}{[S_i - V_i]} \]  

(3)

\[ \text{WQI} = \sum q_n \times W_n / \sum W_n \]  

(4)

Where:

K: proportionality constant., Wn weight value for each property., Si: permissible normal concentration as seen in the Table 2, qn: consistency ranking for each parameter., Vn: calculated value., Vi: ideal values.

The WQI values are categorized into five categories: excellent quality water (IWQI 0-25), good (IWQI 26-50), poor (IWQI 51-75), very poor (IWQI 76-100), and Unfit for drinking (IWQI > 100)[18-20].

3. Results and Discussion

The health concerns associated with the chemical components of drinking water differ from those associated with microbial contamination and primarily stem from the ability of these chemical components to cause harm to health after long periods of drinking the water. Chemical composition of water can lead to health problems as a result of a single exposure, except for their effects through accidental, widespread contamination of the drinking water supply. Moreover, experience shows that in many such incidents, the water becomes unfit for drinking as a result of the unacceptable taste, smell, and appearance[21].

The most common and widespread health risk associated with drinking water is biological contamination, the effects of which mean that great attention must always be paid for monitoring. Priority needs to be given to improve and develop drinking water supplies, which represent the greatest public health risk[22].

The pH values recorded in the study were moderate and within the permissible limits for drinking water, which ranged between (7.01 – 7.76) as in table (3), due to the distance of its water from the direct air changes that caused the dissolution of carbon dioxide in the water. In addition to the high regulatory capacity of hard and Alkaline water rich in bicarbonate, which resists change in pH[23].

The results shown in Table 3 indicated a decrease in the concentration of DO in well water, as 50% of the studied samples were less than the standard permissible limits for drinking water, which ranged between (2.40-8) mg. l\(^{-1}\), and the reason for the decrease in values is The percentage of oxygen saturation decreases due to the high salinity, as well as the lack of contact of water wells with the air. The great deficiency of this factor has a very negative impact on the aquatic ecosystem, as it leads to an increase in the activity of anaerobic microorganisms and changing the interaction paths for organic materials to produce substances harmful to the aquatic environment, and this explains for us the

| parameters | Standard limit (Si) | Wn |
|------------|--------------------|----|
| pH         | 6.5 -8.5           | 0.207792208 |
| TDS        | 1000               | 0.001558442 |
| O\(_2\)    | 5                  | 0.311688312 |
| T.A        | 150                | 0.010389610 |
| Ca         | 50                 | 0.007792208 |
| Mg         | 50                 | 0.010389610 |
| Cl         | 200                | 0.006233766 |
| Na         | 200                | 0.007792208 |
| K          | 12                 | 0.12987013 |
| PO\(_4\)   | 10                 | 0.155844156 |
| SO\(_4\)   | 400                | 0.003896104 |
| TPC        | 10                 | 0.155844156 |
| F. Colif.  | 0                  | 0 |
| \(\sum\)   |                    | 1.019516 |
emission of unpleasant odors from some water wells in the study area as shown in the equations The following[24].

Table 3 shown that all values of TDS in the groundwater of wells were within the permissible limits except for well No. (8) whose values exceeded 1000 mg. l⁻¹. This is because the concentration of total dissolved salts in groundwater depends on the type of rocks and soils that are in contact with them, and on the period that the contact process, movement, and source of groundwater take[25].

The results of the T.A in the water of the study wells did not come within the standard specifications for drinking and for all wells, which means ranged between (248 - 444) mg. l⁻¹. The high T.A of well water in the current study shown in Table 3 is due to alkaline bicarbonate, due to its abundance and resulting from the dissolution of lime materials, which is the main source for it[26]. High concentrations of the alkaline of drinking water reduce the secretion of gastric juice (inhibit the action of the enzyme pepsin), which results in an imbalance in the digestive process, vomiting, and nausea, as well as some research indicates delayed growth and weight loss[27].

High concentrations of sodium ions in drinking water lead to health problems for heart and kidney disease[28]. The results of the levels of sodium and potassium concentrations in this study were within the standard specifications for drinking water, which ranged between (48 - 97) mg. l⁻¹ and (2.20 – 9.2) mg. l⁻¹ except for well No. 2, 8, and 10 for sodium, and well No. 5 and 7 for potassium which exceeded the permissible limits for drinking.

Chlorides enter the human digestive system through drinking water and their taste is unpalatable if it exceeds its limits and also affects the osmotic pressure of the person. The concentration of chloride ions in groundwater depends on the type of rocks and geological layers in which the groundwater passes[27] and since 90% of the study wells found that the chloride ion is within the standard specifications of drinking water, which did not exceed 200 mg. l⁻¹ except for well No. (8.) The results of the calcium and magnesium ion concentration mean in well water was not within the drinking water standard specifications, which ranged between (80 - 129) mg. l⁻¹ and (55 - 87) mg. l⁻¹ respectively. The presence of dolomite and calcite rocks in the Fat’ha layer was attributed to the high values of ionic concentration in the study area[9].

The sulfate ion present in the groundwater and formed as a result of the dissolution and Disintegration of gypsum and anhydrite rocks. High concentrations of sulfates in drinking water produce a noticeable taste and can also degrade the piping system[29]. The recommended upper limit is 400 mg. l⁻¹ in water intended for human use, and the values of the studied well water ranged between (80-880) mg.l⁻¹ where 50% of the well water was outside the recommended limits for drinking, the high concentrations of sulfates in the groundwater in the research area are attributed to the presence of mucin deposits that contain gypsum and limestone[9], as in the Table 4.

| wells | pH | TDS | O₂ | T.A | Cl | Na | K |
|-------|----|-----|----|-----|----|----|---|
| 1 Min | 7.16 | 470 | 4.00 | 270 | 62 | 92 | 2.50 |
| Max | 7.49 | 779 | 6.40 | 370 | 84 | 96 | 4.90 |
| Mean | 7.28 | 649 | 5.04 | 328 | 69 | 94 | 3.16 |
| SD± | 0.14 | 128 | 0.88 | 38 | 9 | 2 | 0.98 |
| 2 Min | 7.36 | 549 | 2.30 | 296 | 76 | 48 | 2.70 |
| Max | 7.52 | 545 | 6.40 | 400 | 170 | 245 | 5.70 |
| Mean | 7.44 | 476 | 4.32 | 342 | 112 | 189 | 3.46 |
| SD± | 0.06 | 93 | 1.53 | 30 | 38 | 80 | 1.26 |
| 3 Min | 7.29 | 591 | 3.60 | 380 | 60 | 90 | 5.50 |
| Max | 7.76 | 765 | 6.80 | 430 | 86 | 93 | 9.20 |
| Mean | 7.50 | 666 | 5.04 | 408 | 70 | 92 | 6.88 |
| SD± | 0.20 | 70 | 1.28 | 19 | 10 | 1 | 1.52 |
| 4 Min | 7.25 | 384 | 2.40 | 368 | 38 | 71 | 3.80 |
| Max | 7.54 | 497 | 6.80 | 410 | 44 | 75 | 6.40 |
| Mean | 7.39 | 433 | 5.44 | 388 | 41 | 74 | 4.62 |
As for phosphate ions PO₄, studies indicate that it is non-toxic to humans and animals unless it is present in high levels, which may cause digestive problems. The results in table (4) showed a decrease in the content of phosphate ions in the studied well water, which ranged between (0.00 - 1.54) mg. l⁻¹.

It is also noted that the phosphate concentrations decreased compared to the negative ions studied, and in general, the concentration of phosphate ions is within the permissible limits for drinking[30].

| wells | PO₄  | SO₄  | Ca²⁺ | Mg²⁺ | TPC | F. Colif |
|-------|------|------|------|------|-----|---------|
| 1     | Min  | 0.00 | 220  | 80   | 17  | 20      | 0       |
|       | Max  | 0.26 | 510  | 138  | 77  | 508     | 23      |
|       | Mean | 0.05 | 360  | 104  | 62  | 231     | 5       |
|       | SD±  | 0.12 | 110  | 21   | 25  | 186     | 10      |
| 2     | Min  | 0.00 | 200  | 64   | 7   | 66      | 0       |
|       | Max  | 1.05 | 820  | 125  | 91  | 1632    | 7       |
|       | Mean | 0.21 | 504  | 87   | 58  | 640     | 1       |
|       | SD±  | 0.47 | 267  | 23   | 32  | 604     | 3       |
| 3     | Min  | 0.00 | 110  | 80   | 19  | 88      | 3       |
|       | Max  | 0.00 | 320  | 130  | 96  | 1440    | 240     |
|       | Mean | 0.00 | 210  | 109  | 68  | 545     | 108     |
|       | SD±  | 0.00 | 80   | 21   | 30  | 528     | 121     |
| 4     | Min  | 0.00 | 80   | 80   | 30  | 112     | 0       |
|       | Max  | 0.15 | 220  | 120  | 82  | 2720    | 15      |
|       | Mean | 0.03 | 146  | 96   | 55  | 801     | 8       |
|       | SD±  | 0.07 | 59   | 16   | 23  | 1083    | 7       |
| 5     | Min  | 0.00 | 170  | 88   | 20  | 41      | 0       |
|       | Max  | 0.49 | 470  | 189  | 115 | 3040    | 4       |
|       | Mean | 0.10 | 300  | 127  | 87  | 899     | 2       |
|       | SD±  | 0.22 | 113  | 37   | 38  | 1227    | 2       |
Water is contaminated with microbes as a result of the infiltration of human or animal waste into it. This bacterial contamination leads to an increase in infectious diseases. It is one of the most important types of bacteria that are considered evidence of water pollution with *F. coli*. bacteria, which is one of the causes of disease, foremost among which is diarrheal diseases that kill approximately 5500 people around the world, most of them children under the age of five[31]. Through the results of the detection of TPC and *F. Coli* bacteria and their comparison with standard specifications, whose rates ranged between (231-935) $10^2$ cell. ml$^{-1}$ and (1-122) $10^2$ cell. ml$^{-1}$, it appears that all well water is not suitable for drinking, which means contamination of groundwater with samples of sewage or leakage in septic tanks for the study area[7].

### 3.1. WQI

The WQI model was applied on 13 parameters as shown in Table 2 to evaluate the water of the studied wells for drinking and household uses, and the results are shown in Table 5 indicate that the values of WQI ranged between (218 - 765), When comparing the results of water classification, we found that 100% of the groundwater of the study area was of unfit for drinking quality for drinking and household uses, and this deterioration was mainly due to the studied standards exceeding the permissible limits according to the standard specifications, especially oxygen and TPC, which affects the high (qn×Wn) values. Which is directly proportional to the WQI values.

| para. | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| pH    | qn  | 52  | 63  | 67  | 60  | 47  | 43  | 47  | 60  | 56  | 48  |
|       | qn×Wn | 10.76 | 13.01 | 13.85 | 12.40 | 9.69 | 9.00 | 9.70 | 12.39 | 11.73 | 9.96 |
| TDS   | qn  | 31  | 9   | 33  | 4   | 61  | 29  | 28  | 105 | 11  | 50  |
|       | qn×Wn | 0.05 | 0.01 | 0.05 | 0.01 | 0.09 | 0.04 | 0.04 | 0.16 | 0.02 | 0.08 |
| O$_2$ | qn  | 99  | 123 | 99  | 85  | 85  | 109 | 88  | 109 | 125 | 88  |
|       | qn×Wn | 30.75 | 38.23 | 30.75 | 26.60 | 26.60 | 34.08 | 27.43 | 34.08 | 39.06 | 27.43 |
| T.A   | qn  | 357 | 383 | 516 | 475 | 478 | 514 | 587 | 195 | 463 | 435 |
|       | qn×Wn | 3.71 | 3.98 | 5.36 | 4.94 | 4.96 | 5.34 | 6.10 | 2.03 | 4.81 | 4.52 |
| Cl    | qn  | 18  | 45  | 19  | 1   | 52  | 24  | 16  | 153 | 8   | 34  |
|       | qn×Wn | 0.11 | 0.28 | 0.12 | 0.00 | 0.33 | 0.15 | 0.10 | 0.95 | 0.05 | 0.21 |
| Ca    | qn  | 217 | 149 | 236 | 184 | 309 | 317 | 197 | 288 | 121 | 312 |
|       | qn×Wn | 1.69 | 1.16 | 1.84 | 1.43 | 2.41 | 2.47 | 1.53 | 2.24 | 0.95 | 2.43 |
| Mg    | qn  | 48  | 32  | 73  | 20  | 146 | 124 | 106 | 149 | 23  | 75  |

* 10$^2$ cell. ml$^{-1}$

Table 5. Results of overall WQI calculation with corresponding water quality status

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IOP Publishing
Journal of Physics: Conference Series

doi:10.1088/1742-6596/1879/2/022060
1. The TDS was suitable for drinking water for all well water except for Well No. 8.

2. The T.A is above the permissible limits for drinking water for all wells.

3. Low DO values up to 50% of well water at standard specifications.

4. A large increase to TPC for all well water is considered one of the most influential parameters in the results that all well water is not suitable for drinking and household uses.

5. The potential health consequences of bacterial contamination must be of great importance and not be tolerated.

**4. Conclusions**

The study has concluded the following:

1. The TDS was suitable for drinking water for all well water except for Well No. 8.

2. The T.A is above the permissible limits for drinking water for all wells.

3. Low DO values up to 50% of well water at standard specifications.

4. A large increase to TPC for all well water is considered one of the most influential parameters in the results that all well water is not suitable for drinking and household uses.

5. The potential health consequences of bacterial contamination must be of great importance and not be tolerated.

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