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# Evaluating Groundwater Quality in Al-Hamdaniya District For Drinking Purpose Using the Canadian Water Quality Index Model (CCME WQI)

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**ABSTRACT**

Physical, chemical, and biological properties are criteria for evaluating water quality. Human and other activities often compromise water quality, making the source of life itself a threat to life. The current study aimed to apply the Canadian Water Quality Index (CCME WQI) model to groundwater in the district of Hamdaniya to determine the suitability of the water for drinking purpose. Thus, six wells at various sites were randomly selected for water sampling. The samples collected were subject to a comprehensive physical and chemical analysis. To calculate the WQI, 21 parameters were adopted: (turbidity, pH, dissolved oxygen (DO), biochemical oxygen demand ($BOD_5$), total dissolved solids (TDS), total hardness (TH), electrical conductivity (EC), alkaline (ALK), nitrate ($NO_3$), phosphate ($PO_4$), calcium hardness (Ca), magnesium hardness (Mg), sulfate ($SO_4$), potassium (K), sodium (Na)، chlorides (Cl)، cadmium (Cd), Iron (Fe), nickel (Ni), copper (Cu) and zinc (Zn). For the groundwater of the wells at sites under study, the values recorded of WQI ranged from 44.17 to 31.10 for sites 1 & 6, respectively. This indicates that the wells' water under study is unsuitable for drinking.

## INTRODUCTION

Drinking water plays a vital role in human health, and due to the lack of surface water facilities, non-potable water is a major source of transmitted **(Nwabor *et al*., 2016)**. For example, high levels of nitrate in drinking water cause serious diseases such as methemoglobinemia or "blue baby syndrome" and risks of cancer, central nervous system, diabetes, etc **(Olowe *et al*., 2016 ; Tiwari, 2017)**. While, diarrhea is associated with the consumption of water containing high levels of nitrate combined with magnesium **(Kalpana *et al*., 2014 ; Chukwuma *et al*., 2016)**.

Groundwater has a significant role meeting the needs of drinking and agriculture in both arid and semi-arid regions **(Khosravi *et al*., 2017)**. A growing demand for water resources has been markedly observed due to population growth, the rate of production of food stocks and the development of the industry. Groundwater is one of the most important global freshwater resources for its stability and significance **(Alexeis *et al*., 2016; Keraga *et al*., 2017)**.

Currently, water pollution is a major cause of rejected water quality. It is assumed that water pollution is related to the contamination of the water bodies, either by the emission of acid gases present in the atmosphere or by the release of industrial waste products into water bodies **(Wanasolo *et al*., 2018; Omara *et al*., 2019)**. Once the groundwater is polluted, its quality

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cannot be restored by stopping the pollutants from the source. Therefore, regular monitoring is highly recommended to address the quality of groundwater via research to determine applied ways to protect it **(Al-Saffawi, 2018)**.

Due to its negative effects on human health, protecting groundwater resources from pollution is highly demanded. Unfortunately, drinking polluted water is a critical problem for about half of the world's population; about 250 million cases of water-related diseases have been detected worldwide. An annual estimation of approximately 5- 10 million deaths include those caused by diseases resulting from drinking water polluted with industrial, agricultural and human wastes; in addition, 1.8 million people die every day, especially children because of contaminated groundwater **(Akoteyon *et al.*, 2011 ; Al-Saffawi, 2018)**.

Water quality is affected by the quantity and quality of supplies coming from different sources. Therefore, comprehensive national planning and resource management in relation to water are a necessity, with a focus on distributing priorities among different uses. Hence, it is important to study water quality in order to enhance our awareness and understanding of the environment. In recent years, the water quality index has been successfully applied to assess the quality of groundwater due to the services it provides for understanding water quality issues by integrating complex data and setting a standard for describing the status of water **(Al-hadithi, 2012; Chukwuma *et al.*, 2016)**.

## MATERIALS AND METHODS

The Canadian model for Water Quality Index is characterized by its high accuracy, and the evidence is found by calculating three factors as follows **(CCME, 2001)**:

$F_1$ (*Scope*): represents the percentage (number) of failed variables to the total number of variables (even if once during the study period).

$$\mathbf{F\,1} = \left(\frac{\textbf{number of failed variables}}{\textbf{total number of variables}}\right) \boldsymbol{x100} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(\mathbf{1})$$

$F_2$ (*Frequency*): represents the percentage (number) of individual failed tests to the total number of tests.

$$\mathbf{F2} = \left(\frac{\textbf{number of failed tests}}{\textbf{total number of tests}}\right) \boldsymbol{x100} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(\mathbf{2})$$

$F_3$ (*Amplitude*): represents the amount of exceeded tests and is calculated in two steps.

1- **Step One**: The number of times the individual concentrations exceed the standard objective limits and is called (Excursion). It is calculated as follows:

$$\boldsymbol{Excursion} = \left(\frac{\textbf{failed test value}}{\textbf{guideline value}}\right) - \mathbf{1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots...(\mathbf{3})$$

For the cases in which the exceeded test value is greater than the standard object value, it is calculated by inverting the ratio.

2- **Step Two**: The number of the set of exceeded individual tests, and is calculated by adding the individual deviations and dividing it by the total number of tests (exceeded and non - exceeded). This variable is called the normalization of Excursion and is symbolized by (nse):

$$\mathbf{nse} = \frac{\sum_{i=1}^{n} \boldsymbol{Excursion}}{\textbf{number of tests}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(\mathbf{4})$$

3- **Stwp three** : $F_3$ (Amplitude) can be calculated according to the following equation:

$$\boldsymbol{F3} = \frac{\mathbf{nse}}{\mathbf{0.01\ nse + 0.01}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{5})$$

From equations (1), (2) and (5), the Canadian Water Quality Index is calculated according to the following equation:

$$\boldsymbol{WQI} = \mathbf{100} - \left(\frac{\sqrt{\mathbf{F1^2 + F2^2 + F3^2}}}{\mathbf{1.732}}\right) \ldots\ldots\ldots (\mathbf{6})$$

The constant 1.732 is used to modify the result of the index value and make it confined between values (0.0 - 100).

Water quality is classified into five criteria **(CCME, 2001; Kumar *et al*., 2014)** as in Table (1):

**Table 1.** CCME WQI categorization schema

| Criterion | WQI range |
|---|---|
| Excellent | 95 – 100 |
| Good | 80 – 94 |
| Fair | 65 – 79 |
| Marginal | 45 – 64 |
| Poor | 0 – 44 |

Table (2) shows the parameters and weights used in calculating the Canadian mathematical model **(Ott, 1978; Kumar & Alappat, 2009; Batabyal & Chakraborty, 2015; Ewaid *et al*., 2018)**:

**Table 2.** Parameters and weights of the Canadian mathematical model (CCME WQI)

| Parameter | Unit | Standard | Reference |
|---|---|---|---|
| Ph | mg·l–1 | 6.5–8.5 | - |
| Dissolved oxygen (DO) | | 4.0–6.5 | - |
| Biochemical oxygen demand (BOD5) | | 3 | WHO, 2017 |
| Phosphates (PO4) concentration | | 0.4 | IQS 417, 2009 |
| Nitrate (NO3) concentration | | 1 | - |
| Calcium (Ca) concentration | | 25 | - |
| Magnesium (Mg) concentration | | 50 | - |
| Total hardness (TH) | | 250 | - |
| Potassium (K) concentration | | 8 | - |
| Sodium (Na) concentration | | 20 | - |
| Sulfates (SO4) concentration | | 250 | IQS 417, 2009 |
| Chlorides (Cl) concentration | | 250 | - |
| Total dissolved solids (TDS) | | 450 | - |
| Electrical conductivity (EC) | µS·cm–1 | 1600 | - |
| Alkalinity (ALK) | mg·l–1 | 250 | WHO, 2017 |
| Turbidity (TRUB) | NTU | 5 | - |
| Copper (Cu) | µg / L | 100 | IQS 417, 2009 |
| Nickel (Ni) | | 20 | - |
| Zinc (Zn) | | 3000 | - |
| Cadmium (Cd) | | 3 | WHO, 2017 |
| Iron (Fe) | | 300 | - |

## The practical aspect

### *The study sites*

The study area includes the Hamdaniya district and its dependencies (Bartella - Karamlesh).

1- The first study area is the Hamdaniya district center (QaraQosh), located in the Nineveh Governorate in northern Iraq, about 32 km southeast of the city of Mosul and 60km west of the city of Erbil, between latitude (34.3319) and longitude (16.04425).
2- The second study area is the town of Karamlesh, located in the Nineveh Plain within the Hamdania district, located between latitude (36.30361) and longitude (43.41278).
3- The third study area is the town of Bartella, located east of the city of Mosul, within the borders of Nineveh Governorate. It has a latitude of 36.35222 and a longitude of 43.37972.

**Table 3. Specifications and locations of wells in the current study**

| Use | Year of drilling the well | Well depth/meter | Latitude | Longitude | Name of district or sub-district | Well site | Well No. |
|---|---|---|---|---|---|---|---|
| Irrigate the lands and crops and water the livestock | 2010 | 160 | 35.3867 | 40.25716 | Bartella | Noah Rafoo Shaana plantation | **1** |
| Irrigate lands and crops and water the livestock | 2007 | 28 | 35.3619 | 40.22826 | Bartella | Ramy Shafoo plantation | **2** |
| Irrigate lands and crops and water the livestock | 2013 | 190 | 35.6599 | 40.16218 | Karamlesh | St. Barbara's Church Farm | **3** |
| Irrigate lands and crops and water the livestock | 2019 | 49 | 35.6257 | 40.19337 | Karamlesh | Jesus the Redeemer Monastery Farm | **4** |
| Irrigate lands and crops and water the livestock | 2010 | 100 | 36.2533 | 43.35289 | Qaraqosh | Salem Hana Butrus Farm | **5** |
| Irrigate lands and crops and water the livestock | 2020 | 90 | 36.2460 | 43.3912 | Qaraqosh | Adam AbdulSalam Farm | **6** |

### *Methodology*

Water sampling for the current investigation began in the early morning as shown in Table (3) and Fig. (1) from wells (1- 6) once per month from October 2021 till March 2022, with three replications for each sample. Each sample was placed in a closed bottle of plastic (polyethylene), washed and cleaned with distilled water, and dried before filling it with the water of the well concerned. Each sample of groundwater was analyzed according to the Canadian model of water quality index (CCME WQI), measuring 21 parameters and using the standard methods recommended by **WHO (2006)**. The parameters considered were: turbidity, pH, dissolved oxygen (DO), biochemical oxygen demand ($BOD_5$), total dissolved solids (TDS), total hardness (TH), electrical conductivity (EC), basicity (ALK), nitrate ($NO_3$), phosphate ($PO_4$), calcium hardness (Ca), magnesium hardness (Mg), sulfate ($SO_4$), potassium (K), sodium (Na), Chlorides (Cl)، cadmium (Cd), iron (Fe), nickel (Ni), copper (Cu) and zinc (Zn).

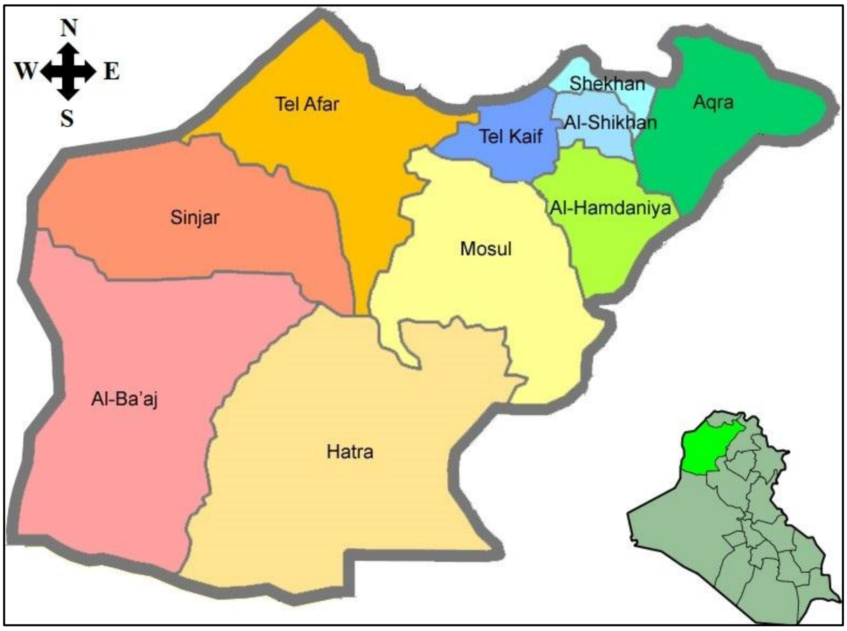


**Fig. 1.** A map showing areas where wells under study are located

## RESULTS AND DISCUSSION

The main objective of calculating the water quality index is to facilitate judgment on water quality by converting the vast amount of data and complex analyses of water properties into easy and understandable information that can be used by both specialists and non-specialists **(WHO, 2017)**. The quality of water from the wells of Al-Hamdaniya district and its dependencies was classified using 21 variables for water quality. The water quality index depends on some important properties and criteria that are considered as a preliminary guide to determine water quality, giving a general idea of the potential water problems in any area or location **(Etim *et al.*, 2013)**.

### Physical properties

The results in Table (4) show that the average values of pH ranged from 8.42 to 7.23 for site (3) and site (4), respectively. The reason for the decrease in values goes to the distance of the water well from the direct atmospheric change, causing the dissolution of carbon dioxide in water. These values are less than those reported in the study of **Al-Tarshan (2017)**, recording ranges between 7.35 & 7.45. On the other hand, the lowest average values of electrical conductivity (982.35µmhos/ cm) were recorded at site 6, while the highest (6492.02µmhos/ cm) was registered at site 2. This is due to the high total dissolved solid (TDS) values at sites 2 & 6. This result is higher than that of **Al-Jubouri (2017)** examining some wells in Laylan district in Kirkuk Governorate, recording ranges between 475.00 & 1581.00µmhos/ cm.

The total soluble solid values ranged between 473.00 & 3196.83mg/ L for the sites 2 & 6, respectively. The reason for the high values of total dissolved solids may be due to the rapid leaching of the rocks through which the groundwater passes, and the geological nature of the study area. The results are relatively higher than those reported in the study of **Fattah (2015)** , who assessed value rates ranging between 707.80 & 1205.50mg/ L. In addition, for turbidity the higher value (15.31mg/ L) was recorded in well 4, while the lower value (3.12mg/ L) was that of site 5. The high turbidity values may be attributed to the rainfall in the areas under study, which causes the formation of suspended particles in water wells. The results of this study are higher than those obtained by **Mohammed (2015)** in a study conducted on the quality of groundwater in Kirkuk Governorate, which recorded turbidity values ranging between 5.2 & 41.3mg/ L.

**Table 4.** Physical properties of water in wells of Al-Hamdaniya district and its dependencies (mg/L)

| Well | pH | Ec | TDS | Tur |
|---|---|---|---|---|
| **1** | 8.41a | 1134.30c | 546.10c | 4.66 cd |
| **2** | 7.37d | 6492.00a | 3196.80a | 11.07 b |
| **3** | 7.23e | 3777.40b | 1799.90b | 6.18 c |
| **4** | 8.42a | 1091.70c | 522.50c | 15.31 a |
| **5** | 7.78b | 1165.70c | 550.10c | 3.12 d |
| **6** | 7.54c | 982.30c | 473.00c | 5.32 c |

**Letters inserted (a, b, c, d, e, cd) express the interactions between well sites and time of field work (The period of collecting and examining water samples).**

## Chemical properties

Table (5) displays a significant variation amongst the studied sites for DO values that ranged from 3.23 to 5.72 for sites 1 and 3, respectively. The difference in the values of dissolved oxygen may relate to the depth of the wells, the proximity of the water level to the surface of the earth, and the weather conditions to which the wells are exposed at the studied sites such as temperature and rain. These results are higher than those of **Dalaas and Abduljabar (2018)** who investigated a number of wells in the village of Samra belonging to the Al-Alam sub-district within Salah Al-Deen Governorate. The dissolved oxygen values were between 2.75 & 5.37mg/ L.

The values of the biological oxygen demand rate ($BOD_5$) recorded the lowest value (0.17mg/ L) at site 6 and the highest value (3.83mg/ L) at site 1. The increase may be due to the arrival of pesticides, fertilizers and types of organic pollutants with the arrival of plant residues, herbs and plant leaves through rain when falling. These results are higher than the findings of **Sirajudeen *et al.* (2014)**, with values recorded from 1.1– 1.6mg/ L.

On the other hand, it was noted that the average of the total basal values ranges between (5.01- 6.85) mg / L in the sites (2, 4), respectively. The decline may be due to the dry season and the consumption of bicarbonates. These results are lower than the results obtained by **Al-Saffawi (2019)** in Nimrud district, south of Mosul with values of (648.00 - 123.00) mg/L. As for the average values of total hardness, they range between the lowest value (663.33) mg/liter and the highest value (3693.33) mg/L in the two sites (1, 2), respectively. The reason for this discrepancy in the concentration of total hardness from one region to another is due to the effect of these concentrations in the processes of withdrawal and pumping of groundwater and its uses in irrigation and watering animals. The results are less than the results reached by **Al-Janabi (2020)** when studying the effect of the environment on the water of some wells in the Al-Zab district, as the rates of total hardness values in the well water samples are between (239.50 – 3199.00) mg / L.

The results of the same table revealed that the values of values for calcium and magnesium hardness rang between (251.11 - 1498.89) mg /L For sites (2, 4) and (388.89 - 2081.22) mg / L in sites (1, 2), respectively. The reason for the increase in the values of calcium hardness in the summer and autumn may be due to the increase in the concentration of carbon dioxide and with the increase in temperature, as it causes the formation of dissolved bicarbonates as a result of a shift in calcium ions under the influence of heat **Zangana (2016)**. The results Theses result were agree with those rcorded higher than those reached by **Al-Tarshan (2017)** in his study, as the calcium hardness values range between (568.00 - 667.00) mg / L, respectively. As for the reason regarding the high values of magnesium hardness, this is due to the washing of neighboring lands as a result of rain, which leads to the leakage of salts into the groundwater, and this in turn increases the proportion of the presence of magnesium ion in more quantities **Dalas (2017)**. These results are higher than **Al-Tarshan (2017)** results, Which show that the concentration rates of magnesium hardness range between (386.33 - 505.92) mg / L, respectively. The average site values for chlorides range between (49.55 - 279.58) mg/L at sites (1, 3), respectively. This discrepancy may be due to the climatic change and difference in summer and winter, the drainage of wells and the dilution of well water with rain water during the study period. The results are relatively higher than those of **Al-Tarshan (2017)** as the concentrations of chloride ion in his study range between (63.87 - 88.78) mg / L, respectively.

The results of the reactive phosphate showed that its concentration was significantly affected by site (6), as it recorded the lowest rate of phosphate values (0.108) gμ, with the highest rate recorded in site (5) by (0.110) gμ. The decrease in phosphate values may be due to the ability to precipitate phosphate in the form of calcium phosphate, in addition to its adsorption by the surfaces of clay particles, which reduces its transfer to the aquatic environment. The results of the study are less than those reached by **Fattah (2015)** in his study, as the concentration rates of phosphate range between (0.022-0.249) microgram atom phosphorous-phosphate / L, respectively. As for the average rates of sulfate sites, the values range between (14.91- 15.76) mg / L in sites (1, 4), respectively. The reason for the decrease in sulfate values may be due to the climatic changes that have occurred during the study period. It is clear from the results that they are less than what has been found by **Ibrahim (2015)** in her study, as the sulfate concentration rates range between (477.00 - 630.70) mg /L, respectively.

The average site rate for sodium ion values ranges between (1.58 - 8.58) mg / L at sites (2, 6), respectively. The lack of sodium compounds in the groundwater may be attributed to the lack of rock salt and shale in the geological formations. These results are lower than the results obtained by the researchers Awadh and **Al-Kilabi (2014)** in their study to estimate the validity of groundwater in Hawija district in Kirkuk Governorate for irrigation purposes, as the sodium ion values range between (28.10 - 74.50) mg/L, respectively. The average site rate for potassium ion values ranges between (0.38 - 0.57) mg / L at the sites (3, 6), respectively. The reason for the low potassium ion in the studied well water is that an increase in the concentration of calcium and magnesium ions leads to a low potassium ion concentration in groundwater. The results of the current study show that they are of less value than the results reached by **Mohammed (2018)** in her study of some physical and chemical properties of some wells, springs, and the Awe Sebi River in Qader Karam district and determining their suitability for drinking and irrigation purposes. The lowest value for potassium is recorded as (0.90 - 3.50) mg /L, the lowest rate of nitrate (14.90) microgram nitrogen atom_ nitrate / L is recorded in the site (3) and the highest rate (20.45) microgram nitrogen atom _ nitrate / L in the site (2), respectively. The reason for the low concentration of nitrates in most of the studied water wells is due to the lack of decomposing plant residues, which is an important source of organic nitrogen compounds and is one of the main sources of nitrates in groundwater. The results are less than the results reached by **Ibrahim (2015)** in her study, as the concentration rates of nitrate are recorded by (156.60 -236.70) micrograms of nitrogen atom _ nitrates / L, respectively.

**Table (5): The Chemical Properties of Water Wells in Al-Hamdaniya District and its Dependencies (mg / L).**

| Well | DO | $BOD_5$ | $HCO_3$ | TH | CaH | MgH | Cl | $PO_4$ | $SO_4$ | Na | K | $NO_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 5.72 a | 3.83 a | 6.58 a | 663.33 d | 288.89 c | 388.89 c | 49.55 b | 0.109c | 15.76 a | 3.25 d | 0.50 c | 17.34 c |
| **2** | 3.94 d | 1,33 c | 6.86 a | 3693.33 a | 1498.89 a | 2081.22 a | 274.78 a | 0.109e | 15.66 c | 8.58 a | 0.48 d | 20.45 a |
| **3** | 3.23 e | 1.67 b | 6.72 a | 1982.22 b | 655.56 b | 1154.62 b | 279.58 a | 0.109d | 15.21 d | 6.50 b | 0.57 a | 14.90 f |
| **4** | 4.57 c | 1.67 b | 5.01 b | 675.56 d | 251.11 c | 424.44 c | 65.46 b | 0.108b | 14.91 f | 4.58 c | 0.55 b | 16.70 d |
| **5** | 5.07 b | 1.67 b | 5.09 b | 830.00 cd | 325.56 c | 504.44 c | 50.44 b | 0.110a | 15.72 b | 2.92 e | 0.40 e | 16.51 e |
| **6** | 4.86 bc | 0.17 d | 5.55 ab | 925.56 c | 402.22 c | 498.03 c | 70.04 b | 0.108f | 14.98 e | 1.58 f | 0.38 f | 17.38 b |

**a,b,c,d,e,f,ab,cd Means the interactions between well sites and the time of field work (The period of collecting and examining water samples).**
**CaH. / Calcium Hardness.**
**MgH./ Magnesium Hardness.**

## Heavy Elements

Table (6) shows that the contents of Zn ,Cdand Fe significantly varaited amongs the wells except the contents of Ni and Cu show non significant variation the sites for the zinc (Zn) element value ranges between (0.711 – 0.425) mg /L in the two sites (1 and 6), respectively. The reason for the decline may be due to the complete control of the low-soluble elements **Boyed (2000).** The results are lower than what is obtained by **Fattah (2015)** which amounted to (0.89 - 2.00) mg/L, while the lowest value for cadmium is (0.015) mg/liter in site (2) and the highest value is (0.045) mg/L in site (4). The reason for the decrease in its content in well water is due to its distance from sewage water. The results have recorded values less than the results reached by **(Ibrahim, *et al*., 2021)**, which ranged between (0.00 - 0.70) mg / liter, respectively.

As for site (4), nickel (Ni) has recorded the lowest value of (0.035) mg /L, and the highest value in in site (3) reaching (0.060) mg /L. The reason for the high percentage of nickel may be due to anthropogenic inputs into the soil from different sources, such as agricultural amendments, atmospheric deposition, or phosphate fertilizers. The results are less lower the results reached by **(Hammash and Abed, 2022)**, as the values range between (0.008 - 0.003) mg/L, respectively, while the average site values for copper (Cu) are (0.062 - 0.045) mg/L at sites (1, 5), respectively. The decrease in its content may be due to its presence in small percentages in the original, or it has been deposited at the bottom of the well **Al-Mashhadani (2019)**. The results are lower than the results recorded by **Shartooh (2017)**, which have varied between (0.010 - 0.080) mg/L. The average site average values for iron (Fe) are (0.27 – 0.49) mg / L in the sites (2, 4), respectively. The reason for its high contents may be human factors or the geological nature of the area. The results are higher than the results reached by **Al-Jubouri (2017)** in an environmental study of some artesian wells in Laylan sub-district, Kirkuk governorate, whose rates reached between (0.02 - 0.05) mg / L, respectively.

**Table (6): Heavy Metals Concentration of for Water Wells in Al-Hamdaniya District and its Dependencies (mg / L).**

| Well | Zn | Cd | Ni | Cu | Fe |
|---|---|---|---|---|---|
| **1** | 0.425b | 0.016bc | 0.049a | 0.062a | 0.36ab |
| **2** | 0.519ab | 0.015c | 0.051a | 0.059a | 0.27b |
| **3** | 0.453ab | 0.035bc | 0.060a | 0.060a | 0.31ab |
| **4** | 0.485ab | 0.045a | 0.035a | 0.054a | 0.49a |
| **5** | 0.610ab | 0.039ab | 0.057a | 0.060a | 0.37ab |
| **6** | 0.711a | 0.034ab | 0.044a | 0.045a | 0.37ab |

**a,c,b,ab,bc Means the interactions between well sites and the time of field work (The period of collecting and examining water samples).**

The results shown in Figure (2) indicate that the values of the wells water quality index in the areas under study range between (31.10 - 44.17). The wells (2, 3, 4, 5 and 6) Were classified as samples of the poor type and not suitable for the purposes of drinking .The well No. (1) is of the secondary type (Marginal), which is not suitable for drinking, as it exceeds the permissible Thus water under study may be use for another purpose after treatements **(WHO, 2004)**.

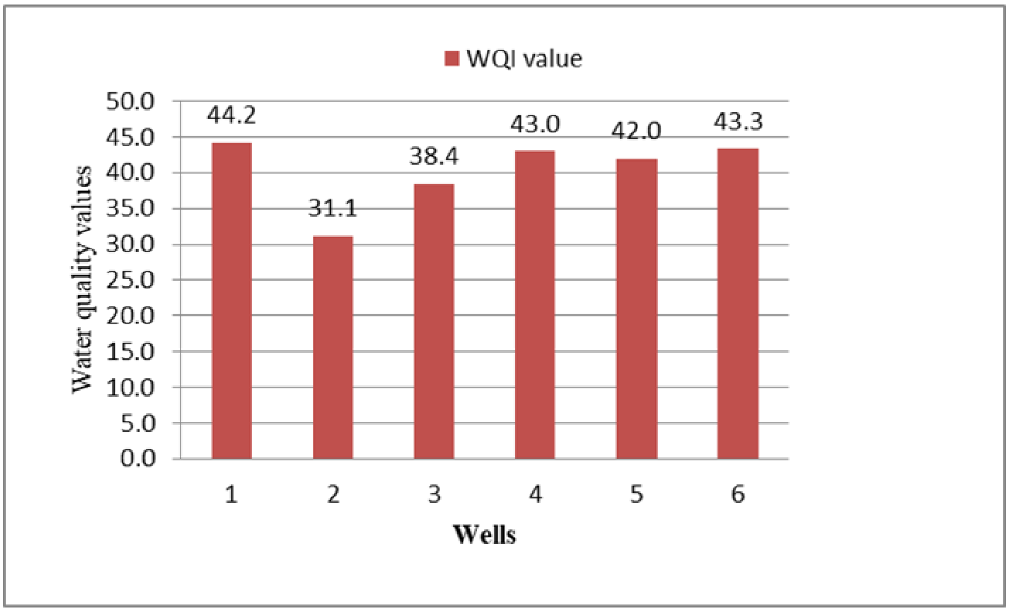


**Figure (2): Water Quality Values of Wells in Al-Hamdaniya District and its Dependencies.**

The deterioration in water quality is mainly due to the high concentrations of total dissolved solids, total hardness, sulfates, nitrates and chlorides, which are responsible for the deterioration of the wells water under study. The results are less than the results obtained by **Al-Safawi (2018)** in his study of the application of the Canadian Water Quality Index (CCME WQI) to assess the quality of water for drinking purposes when studying the condition of groundwater quality in the Al-Mahalabiya sub-district in Nineveh Governorate. He collected samples for (12) wells whose water quality values range between (46.77 - 60.45) for the wells (1, 2, 4, 5, 6, 7, 8, 9, 11 and 12), which represent 83% of the water samples, as they are of questionable water and unsafe for drinking due to their poor quality. The rest of the water samples from the well water sites (3 and 10) are of the poor type and not suitable for drinking purposes. This deterioration in the water level was mainly attributed to the high concentrations of solid dissolved substances, total hardness, calcium ions and sulfates.

## CONCLUSION

1- Well (1) is of the secondary type (marginal), while the rest of the wells are of the poor type for drinking purposes.
2- Drought and lack of rain have had a significant impact on the deterioration of the drinking water quality.
3- The Canadian Water Quality Index (CCME WQI) is affected by high values of total dissolved solids, total hardness, nitrates, sulfates and chlorides.
4- The use of untreated groundwater sources for drinking purposes causes harm to people's health.

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