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# Hydrochemical evaluation of groundwater in the Sharbazir district in the Sulaymaniyah Governorate/Iraq

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## Abstract :

This study is concerned with evaluating the validity of the groundwater in the Sharabazir district in the Sulaymaniyah / Iraq Governorate for multi –consumption (human, animal, agricultural, industrial), The water samples were taken from (11) wells during two seasons of (2022), which represented the winter season with January, while it was monitored the month of August, the summer season, Quality analyzes have been conducted (Physical and Chemical) has in laboratories (Ministry of Science and Technology / Laboratory Department) and in (Karbala Governorate Health Directorate / Karbala Health Laboratory), These analyzes included ions (EC, TDS, PH, T.H, Ca, MG, NA, K, CL, SO4, No3, HCO3), then the sodium addation rate (SAR) was calculated, And the percentage of sodium (NA%) to compare it with the global standard specifications. The study concluded that the qualitative hydrological properties in the Sharbazir district vary in time and space in the study area, The study also showed that all samples taken of groundwater are suitable for human consumption, while all samples and both seasons are within the classification (S1 Sodium) in relation to the value of (SAR), And its water is appropriate to irrigate most crops and for almost most of the soil varieties except for the very sensitive crops for sodium, As for the TTOD classification and the American salinity laboratory, all well samples were suitable for agricultural consumption, While all the studied samples were valid for animal consumption after comparing them with the required global measurements according to the Crist and Lowry classification, With regard to industrial consumption, all well samples were valid for all industries according to the classification of (Salvato) classification and for both seasons (except for the paper industry) that were outside the borders of both seasons because of the high concentrations of chemical variables.

## The introduction :

Groundwater is one of the important sources of human use and irrigation purposes, It requires serious attention as a result of its pollution due to human and industrial activities, Especially since recently, and as a result of the scarcity of Iraq in surface water, the attention of groundwater began, so this study came to analyze the properties of groundwater and indicate the extent of its suitability for the various uses in the Sharbazir district within the Sulaymaniyah Governorate, The main problem in the study area lies in the insufficient surface water resources to meet the various needs, and as a result dependence on groundwater in many areas, and the qualitative properties of the groundwater in the study area are directly affected by the geological nature as well as climatic elements, The research also aims to give a clear picture of the distribution of groundwater wells and analyze its qualitative characteristics to show the extent of their suitability for various uses, as well as an indication of the possibility of relying on groundwater as an alternative source for the scarcity of surface resources in the study area.

## the study Problem :

1- Is there a variation in the properties of the groundwater in the study area?

2- What is the amount of groundwater and its validity for the various uses?

## Research hypothesis :

The research hypothesis is the initial solution to the studied problem, the main hypothesis is:

1- There is a variation in the properties of the groundwater in the study area.

2- The study also assumes that the hydrological properties in the study area are suitable for all uses at all times.

## research aims

1- Evaluating the groundwater resources in the search area (in terms of quantitative and qualitative specifications).

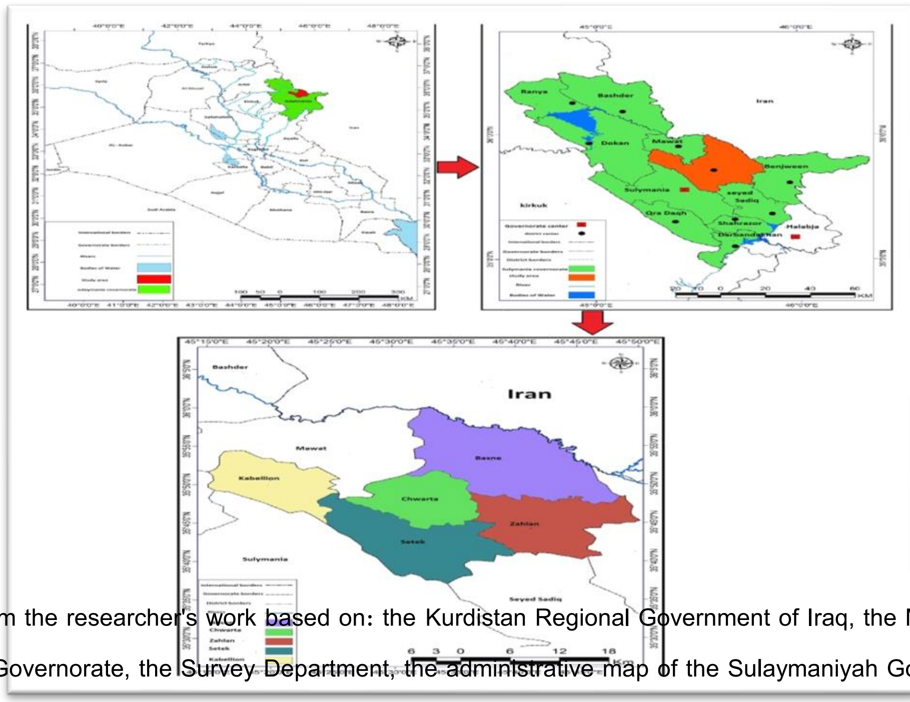
2- Knowing the hydrochemical qualities of groundwater and the ability to use this water for various purposes.

3- Determine the urban and agricultural uses and various purposes.

Geographical and astronomical location:

The study area (Sharbazir District) is administratively located within the Sulaymaniyah Governorate, between the two lines of (°35.21.00 – 36.01.00°) east and between the circuit (45.16.00° – 45.51.00°)[1].and It occupies the eastern part of it, and its area is (1056.6) as 2, including (9.09%) of the total area of the governorate[2]. Note Map (1).

**Map (1) The geographical location of the study area for Iraq**




Source: From the researcher's work based on: the Kurdistan Regional Government of Iraq, the Ministry of Interior, Sulaymaniyah Governorate, the Survey Department, the administrative map of the Sulaymaniyah Governorate, a scale of 1: 100,000, 2018.

## Field work:

Eleven wells were chosen to study within the region and their coordinates were determined by GPS (GPS), as water samples were collected for two seasons (winter, summer).

The summer season represented one measurement during August, While the winter season represented one measuring measuring during January, sterile and closed plastic bottles were used, after which a few drops of formalin were added to it and kept in a field refrigerator until it was transported and kept in the laboratory, Then chemical analyzes were made, while the electrical connection value was measured And the total dissolved salts For water directly using field devices,

## 1 : The hydrological properties of the groundwater in the Sharbazir district :

The chemical composition of the groundwater represents the result of the interaction between these water and the rocks in which it applies or that water runs, so the study of chemical properties is of great importance in assessing the quality of water, as it helps to determine its validity for the various uses of home, agricultural and industrial purposes, In the study of hydro –chemical properties, it was relied on identifying ions (positive and negative), through which the validity and pollution of this water can be known, as well as the physical properties were measured, as the increase in ion concentrations from the permissible limit has a negative impact on the lives of living organisms.

## 1.1 : Physical properties of groundwater:

### 1.1.1 : Electrical Conductivity : EC

Electrical values during the winter season ranged between (470 – 661) Microscopes/m, While the Electrical Conductivity ranged in the summer between (572–1078) Microsims/m.

The reason for the increase in the values of electrical conductivity during the summer season is due to the increase in the values of all ions, in addition to the decrease in water levels in general as a result of the decrease in river discharges, and thus the concentrations of total dissolved salts increase, As the relationship between total dissolved salts and electrical conductivity, as is well known, is a positive relationship[3]. The geological formation also plays an important role in the rise of the conductivity values, as the formation of Qolqulah consisting of stone (flint and cobblestones) prevails in the study area.

### 1.1.2 : dissolved solids : TDS

The values of total dissolved salts vary spatially and temporally at the locations of the samples of the study area, as the values of total dissolved salts for these models ranged between (301–423)ppm during the winter season, while the values of dissolved salts ranged between (356–646)ppm during the summer, The climatic factors have a significant impact on raising the values of dissolved salts, as the falling precipitation and the recharge

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coming from the high sides through the horizontal movement of water play an important role in the temporal and spatial distribution of groundwater salinity.

### 1.1.3 : PH value:

By noting Appendix (1), it is clear that there is no significant difference between the (PH) values in reality, as these values generally ranged between (6.9 − 7.6) during the winter season, while during the summer season, the (PH) values ranged between (7.5− 8.4), The reason for the discrepancy is mainly due to the fact that most of the wells have active dissolution processes over the limestone−calcareous−dolomatic rocks, as dissolving the calcareous materials in the water reduces the acidity of this water, Also, the presence of calcium and magnesium ions, which work to form some unbalanced salts, as well as the precipitation of some bicarbonate from its waters in the study area as a result of the increase in summer temperatures, which makes the value of (PH) tend towards alkaline, The ratio of carbonates to bicarbonates has a major role in the variation of PH values, as bicarbonates are removed upon evaporation which leads to an increase in carbonates, so the PH value rises, so the hot water is more alkaline than the cold water[4].

### 1.1.4 : total hardness T.H

The total hardness values of the study area sample sites ranged between (110−168.8) ppm during the winter season, while the total hardness values during the summer season ranged between (139.9−216.4) ppm.

This rise is due to the conversion of (calcium and magnesium bicarbonate) into precipitated carbonates in the water, by weathering and dissolution of limestone rocks as they pass and Reduction water, in addition, the high water temperatures increase the process of dissolving limestone rocks during the movement and contact of water with them.

## 1.2 : Groundwater chemical properties:

### 1.2.1 : Positive ions:

#### 1.2.1.1 : Calcium ion $Ca^{+2}$:

The potassium ion values for the winter season ranged between (21−33)ppm, while the values of the same element for the summer season ranged between (27−39)ppm.

The reason for this is attributed to the low concentrations of this ion in general in the study area due to the presence of a group of rocks (Qandil − Schlier metamorphic) that cover most of the eastern parts of the region, so the process of weathering and dissolution is reduced in this type of rock.

### 1.2.1.2 : Magnesium ion: $Mg^{+2}$

Through the results of laboratory analyzes of the samples, we can see that the percentage of calcium during the winter season ranged between (14−22) ppm in the study area, and the values of the same element during the summer season ranged between (17−35) ppm.

The limestone and dolomite rocks are the main source of magnesium ions in the region, as they appear in the formation of (Bakhmeh and Qamjuqa), when the dolomatic rocks are subjected to dissolution, the magnesium ion is released, and the relationship between magnesium and salinity is a positive relationship, that is, with an increase in salinity, the concentration of magnesium in the deposited minerals increases.

### 1.2.1.3 : Sodium ion : $Na^{+}$

The sodium ion values for the winter season ranged between (28−38) ppm, and the values of the same ion for the summer season ranged between (30−43) ppm.

The main source of sodium ion is the dissolution of minerals that make up salt rocks, especially halite (NaCl). Clay minerals are liberated by weathering a large amount of them as a result of ion exchange between water and rocks. Human activity also affects the concentration of sodium in groundwater through the use of salts in household needs, or reuse of irrigation waste water, which works to increase the concentration of sodium ion[(5)].

### 1.2.1.4 : potassium ion : $K^{+}$

It is evident from the analytical study of Appendix (1), that the values of potassium ion concentrations for the winter season in the study area ranged between (0.23−0.61) ppm, while the values of this ion for the summer season ranged between (0.55−0.91) ppm.

Potassium is more stable than the sodium ion because of its high resistance to chemical weathering, so its concentration in groundwater is much lower than the sodium ion, and the most important sources of potassium ion are (sulfite, mica) within the formations (shale and clay rocks), the low concentrations of this ion are due In general, to the geological nature of the region in which its sources are less widespread within the rock formations of the district.

## 1.2.2 : Negative ions:

### 1.2.2.1 : The sulfate ion : $So4^{-2}$

The sulphate ion values during the winter season ranged between (47−71)ppm, while the sulphate ion values ranged between (54−81)ppm during the summer season.

The reason for the decrease in the sulfate ion concentration during the winter season is due to the low temperatures and the low amounts of evaporation as well as the increase in the amounts of river discharges due to the heavy rain factor that works to reduce the concentrations of these ions in the groundwater.

### 1.2.2.2 : nitrate ion: $No3^{-}$

The nitrate ion comes from sedimentary rocks, and nitrates are among the dangerous pollutants in the water, which cause hypoxia in the blood (cyanosis), and they are also among the substances that cause stomach cancer. And it was determined by the World Health Organization as a maximum limit in groundwater (10) mg / liter(6), and The nitrate ion concentrations during the winter season (wet period) ranged between (0.10−1.21) ppm, while the nitrate ion values in the summer (dry period) ranged between (0.20−2.54) ppm.

The reason for the decrease in the concentration of this ion, especially during the rainy period (winter season), which leads to a decrease in the values and concentrations of the nitrate ion, while the rise in its values during the summer season in the groundwater of the study area is due to the rise in temperature with the increase in evaporation amounts.

### 1.2.2.3 : Clorid − ion: $Cl^{-}$

The chloride ion concentrations ranged between (52−76) ppm during the winter season (wet period), while the values of the same ion in summer (dry period) ranged between (66−98) ppm.

The decrease in its concentrations during the winter season is due to the mitigation processes resulting from rainwater and recharge coming from the high areas, as well as the effect of the rocky nature of the region represented by (evaporite rocks such as halite), which has a major role in enriching the concentration of this ion(7).

### 1.2.2.4 : bicarbonate ion : $Hco3^{-}$

The concentrations of the bicarbonate ion ranged between (24−38)ppm during the winter season (the wet period), while the concentrations of this same ion in the summer (the dry period) ranged between (31−56)ppm.

The reason for this increase in the summer (the dry period) is due to the high temperatures and evaporation, which helps the precipitation of the bicarbonate ion and the retention of carbonates in the water, so that its concentrations increase by a certain percentage, and carbon dioxide gas dissolved in rainwater or surface water is based on the formation of carbonic acid ($H_2CO_3$). ) which works to dissolve the dolomite limestone rocks, which is the main source of the bicarbonate ion, and filter it to the groundwater in the study area, which leads to an increase in its concentration

## 2 : Suitability of water for drinking purposes :

### 2.1 : Groundwater suitability for drinking purposes:

By observing Appendix (1) and comparing its results with Table (1), it was found that all sites fell within the limits and international and Iraqi standard specifications for human drinking and for both seasons (winter season and summer season) and for all physical and chemical ions, except for the value of the ion ($HCO_3$), where all wells occurred Outside the permissible limits as the lowest permissible limit according to international standards.

### 2.2 : The suitability of water for agricultural and irrigation purposes:

Salinity concentration (TDS), electrical conductivity (EC), sodium adsorption ratio (SAR) and sodium ion percentage (Na%), as well as the US− Salinity Lab standard based on (TDS, EC) value are among the most important The criteria used in determining the suitability of water for agricultural purposes, as the evaluation of irrigation water and determining its suitability depends on the nature of the characteristics of the water used, as well as the nature and specifications of the soil that is irrigated with this water.

#### 2.2.1 : Sodium Absorption Ratio (SAR):

The value of (SAR) expresses the relationship between the ratio of sodium salts to calcium and magnesium salts, As increasing its value in irrigation water works to increase the value (PH) of the soil, Thus, it works to break down the soil structure and disperse its colloidal particles, turning it into alkaline soil, which requires constantly monitoring this percentage in the irrigation water[8].

Sodium adsorption ratio (SAR) can be extracted by applying the following equation to the values of ions measured in the unit (epm), and then the

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degree of validity of irrigation water is determined according to the extracted results[9].

$$SAR = \frac{Na}{\frac{\sqrt{Ca + Mg}}{2}}$$

**Table (1) Iraqi and international standard specifications for the suitability of drinking water for humans**

| No | element ions | Iraqi specifications | International specifications (WHO) | |
|---|---|---|---|---|
| | | | minimum | maximum |
| 1 | Na | 200 | - | 200 |
| 2 | Mg | 50 | - | 125 |
| 3 | Ca | 50 | - | 75 |
| 4 | CL | 250 | - | 250 |
| 5 | SO4 | 250 | - | 250 |
| 6 | NO3 | 50 | - | 50 |
| 7 | HCO3 | 200 | 125 | 350 |
| 8 | K | - | - | 12 |
| 9 | Ph | 8.5 | 6.5 | 8.5 |
| 10 | T.H | 500 | - | 500 |
| 11 | EC | 1500 | - | 1530 |
| 12 | **TDS** | 1000 | - | 1000 |

1- W.H.O. International Standard for Drinking Water - Geneva, Switzerland, edition, 2010, p489-496.

2- Iraqi Standard Specifications, Draft Update Standard Specifications No. (424), (2009), p.22.

After applying the (SAR) value equation to the results of chemical analyzes of the ion values extracted in unit (epm) for groundwater samples taken from the wells of the study area and after matching their values from Appendix (2) with the standard specified by the American Salinity Laboratory (Us-Salinity) in Table (3), It was found that the concentration of sodium adsorption percentage for all well samples for both seasons (winter and summer) falls within the classification (S1 low sodium), whose water is suitable for irrigating most crops and for almost all soil types except for crops that are very sensitive to sodium, as it is considered excellent water suitable for watering all crops. Which are less dangerous because the sodium adsorption rate (SAR) is less than (epm10).

**Table (2) The suitability of groundwater for agricultural irrigation according to the SAR value of the wells of the study area**

| Sample | SAR for the winter season | SAR for the summer season |
|---|---|---|
| G1 | 1.44 | 1.68 |
| G2 | 1.53 | 1.68 |
| G3 | 1.63 | 1.79 |
| G4 | 1.61 | 1.78 |
| G5 | 1.74 | 1.74 |
| G6 | 1.72 | 1.83 |
| G7 | 1.98 | 2.15 |
| G8 | 1.66 | 1.60 |
| G9 | 1.89 | 1.92 |
| G10 | 1.55 | 1.44 |
| G11 | 1.82 | 1.64 |

**Source: SAR equation application and Appendix data (2).**

**Table (3) Classification of (US–Salinity) laboratory for irrigation water according to (SAR) value**

| class water | SAR | The suitability of water for irrigation |
|---|---|---|
| S1- Low Sodium | 10 -Zero | The water is suitable for irrigation of most crops and almost all types of soil, except for crops that are very sensitive to sodium. |
| S2- Medium Sodium | 18-10 | The water is suitable for coarse-textured soils with good permeability, and is not suitable for fine-textured soils, especially when leaching is insufficient and there is a small amount of gypsum in the soil. |
| S3- High Sodium | 26-18 | Water is harmful to most soils and requires good tapping and rinsing with the use of gypsum. |
| S4- Very high in sodium | over 26 | The water is usually unsuitable for irrigation purposes. |

**Source: Ahmed Haider Al–Zubaidi, Soil Salinity, Dar Al–Hikma Press, Baghdad, 1992, pg. 241.**

### 2.2.2 : : Sodium Percentage (Na%) :

The concentration of sodium ion is important in the classification of irrigation water, because the sodium ion interacts with the soil, reducing the permeability of the soil and increasing its validity, As a result of the ion exchange that takes place between positive ions (calcium and magnesium) with sodium in clay minerals[10]. Therefore, the concentration of sodium ion is one of the indicators to detect the suitability of water for agricultural irrigation, and the percentage of sodium is extracted from the following equation[11].

$$Na\% = \frac{Na + K}{ca + mg + Na + k} \times 100$$

And when matching the results of the percentage of sodium (Na%) for the groundwater samples of the wells of the study area in Table (4) with the categories of Table (5), we find that all site samples taken from the study area for both seasons (winter and summer) fell within the category (20−40). %) and thus it is considered in the (good) category for agricultural irrigation.

**Table (4) Suitability of groundwater for agricultural irrigation according to the value of Na%**

| Samples | Na% for the winter season | description | Na% for the summer season | description |
|---|---|---|---|---|
| G1 | 28.73 | Good | 31.16 | Good |
| G2 | 31.23 | Good | 31.79 | Good |
| G3 | 34.74 | Good | 36.27 | Good |
| G4 | 32.53 | Good | 33.59 | Good |
| G5 | 32.75 | Good | 31.15 | Good |
| G6 | 32.22 | Good | 32.19 | Good |
| G7 | 37.33 | Good | 38.44 | Good |
| G8 | 36.31 | Good | 33.37 | Good |
| G9 | 36.54 | Good | 34.82 | Good |
| G10 | 31.80 | Good | 26.19 | Good |
| G11 | 36.83 | Good | 29.70 | Good |

**From the work of the researcher based Na% equation application and Appendix data (2).**

**Table (5) Suggested limits for the percentage of sodium, Na%**

| Na% | Item |
|---|---|
| Less than 20% | Excellent |
| %40-20 | Good |
| %60-40 | Allowed |
| %80-60 | Doubtful |
| More than 80% | not good |

**Sours: David Keith Todd, Ground water Hydrology, John wiley and Sons, U.S.A.,1980,p.335.**

**2.3 : Groundwater suitability for industrial purposes:**

According to the limits and standard specifications proposed in Table (6), we find that most of the samples taken from the wells of the study area for both seasons (winter and summer) are compatible with the standard specifications for the canning industry, the cement industry, and the chemical industries, in addition to the oil industry. All well samples were compatible with the requirements of these industries. As for the paper industry, all the well samples taken showed that they did not conform to the specifications required for the paper industry according to the specified standard, The reason for the lack of conformity is due to the high percentage of calcium and magnesium concentrations from the specifications determined by the standard for this industry.

**Table (6) Standard specifications for suitability of water for industrial purposes according to (Salvato) classification**

| Industry | PH | TH (ppm) | $Cl^-$ (epm) | $So4^{-2}$ (epm) | $Ca^{+2}$ (epm) | $Mg^{+2}$ (epm) | المواقع | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | شتاء | صيف |
| Canning | 8.5-6.5 | 310 | 8.462 | 5.205 | 5.988 | 8.226 | جميعها | جميعها |
| Chemical | 9-6 | 1000 | 14.103 | 17.697 | 9.980 | - | جميعها | جميعها |
| Cement | 8.5-6.5 | - | 7.052 | 5.205 | - | - | جميعها | جميعها |
| petroleum | 9-6 | 900 | 45.130 | 11.867 | 10.978 | 6.992 | جميعها | جميعها |
| Paper | 9-6 | 475 | 5.641 | - | 0.998 | 0.987 | لا يوجد | لا يوجد |

**From the researcher's work based on: 1- Table (6), Appendix (2).**

**2.4 : Groundwater suitability for animal consumption:**

When matching the results of table (7) of the groundwater samples of the wells of the study area with the values of (TDS), we find that all site samples taken from the study area for both seasons (winter and summer) fell within the category (good) for animal consumption for watering poultry, horses and cows of all kinds (milk and meat), and sheep, according to (Crist and Lowry) criterion for water classification.

**Table (7) The validity of water for drinking animals according to (Crist and Lowry) specifications**

| (TDS)ppm | Quality | animal species |
|---|---|---|
| أقل من 1000 | Good | poultry to 2860 |
| 3000-1000 | Acceptable | |
| 5000-3000 | Weak | Horses to 6435 |
| 7000-5000 | Very weak | |
| أكثر من 7000 | Unacceptable | Milk cows to 7150 Meat cows to 10000 Sheep to 12900 |

Source: Hajar Tahseen Ali Hussein Al-Jubouri, Groundwater Systems in the Euphrates Basin between Hit and Haditha, Master Thesis, University of Baghdad, College of Education, Ibn Rushd, 2013, p. 194.

### 2.5 : Groundwater validity for building and construction purposes

After comparing the sampling results from Appendix (1) with the criterion specified in Table (8), we find that all sampling sites for both seasons (winter and summer) are valid for building and construction purposes according to the ALtoviski classification.

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**Schedule (8)**

**The proposed limits for the use of water for building and construction purposes according to the ALtoviski classification**

| HCO3 | SO4 | Cl | Mg | Ca | Na | ion concentration (mg/L) |
|---|---|---|---|---|---|---|
| 350 | 1460 | 2187 | 271 | 437 | 1160 | permissible limit |

**Source: M.E, ALtoviski, Hand book of Hydrology, Gosgeolitzdat, Moscow, 1962, p.614.**

## Appendix (PPM) (1)

| simple | EC | | TDS | | PH | | T.H | | Ca | | Mg | | Na | | K | | SO4 | | NO3 | | CL | | HCO3 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | W | S | W | S | W | S | W | S | W | S | W | S | W | S | W | S | W | S | W | S | W | S | W | S |
| G1 | 470 | 574 | 301 | 356 | 6.9 | 7.8 | 167 | 187 | 29 | 32 | 23 | 26 | 30 | 36 | 0.6 | 0.8 | 48 | 54 | 0.9 | 2.6 | 70 | 75 | 36 | 45 |
| G2 | 656 | 1060 | 420 | 636 | 7.2 | 8.4 | 147 | 178 | 26 | 30 | 20 | 25 | 30 | 35 | 0.3 | 0.6 | 52 | 64 | 0.1 | 0.2 | 61 | 67 | 30 | 41 |
| G3 | 644 | 1078 | 412 | 646 | 7.1 | 7.9 | 122 | 140 | 24 | 28 | 15 | 17 | 29 | 33 | 0.4 | 0.8 | 48 | 54 | 0.2 | 0.4 | 55 | 66 | 24 | 39 |
| G4 | 484 | 572 | 310 | 385 | 7.4 | 7.5 | 143 | 177 | 26 | 33 | 19 | 23 | 31 | 36 | 0.2 | 0.5 | 54 | 63 | 1.2 | 2.5 | 64 | 72 | 32 | 41 |
| G5 | 650 | 1046 | 416 | 629 | 7.3 | 8.4 | 165 | 212 | 30 | 36 | 22 | 29 | 36 | 39 | 0.6 | 0.8 | 69 | 79 | 0.1 | 0.2 | 69 | 92 | 38 | 56 |
| G6 | 661 | 1050 | 423 | 633 | 7.6 | 7.7 | 169 | 204 | 33 | 39 | 21 | 27 | 36 | 41 | 0.5 | 0.7 | 63 | 71 | 0.1 | 0.2 | 71 | 87 | 35 | 48 |
| G7 | 625 | 1050 | 400 | 630 | 7.6 | 7.5 | 142 | 167 | 32 | 38 | 15 | 18 | 38 | 43 | 0.4 | 0.6 | 53 | 76 | 0.2 | 0.3 | 73 | 88 | 26 | 31 |
| G8 | 622 | 1075 | 398 | 643 | 7.5 | 7.7 | 110 | 150 | 21 | 27 | 14 | 20 | 28 | 30 | 0.6 | 0.9 | 47 | 61 | 0.1 | 0.2 | 52 | 67 | 24 | 33 |
| G9 | 594 | 1030 | 380 | 590 | 7.3 | 7.6 | 139 | 183 | 31 | 37 | 15 | 22 | 36 | 40 | 0.5 | 0.8 | 66 | 80 | 0.2 | 0.2 | 68 | 98 | 29 | 42 |
| G10 | 589 | 1039 | 377 | 599 | 7.4 | 7.6 | 143 | 216 | 26 | 29 | 19 | 35 | 30 | 34 | 0.4 | 0.9 | 71 | 81 | 0.1 | 0.2 | 76 | 93 | 27 | 39 |
| G11 | 623 | 1056 | 399 | 634 | 7.1 | 7.8 | 126 | 198 | 24 | 28 | 16 | 31 | 33 | 37 | 0.4 | 0.8 | 64 | 68 | 0.1 | 0.2 | 68 | 88 | 31 | 47 |

Source: Results of laboratory analysis of water sites in Karbala Health Laboratory and Ministry of Science and Technology – Laboratories Department.

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## Appendix (epm) (2)

| Simple | Ca | | Mg | | Na | | K | | SO4 | | NO3 | | CL | | HCO3 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | W | S | W | S | W | S | W | S | W | S | W | S | W | S | W | S |
| G1 | 1.450 | 1.449 | 1.825 | 2.063 | 1.304 | 1.570 | 0.016 | 0.020 | 0.999 | 1.124 | 0.015 | 0.040 | 1.600 | 1.449 | 1.200 | 1.500 |
| G2 | 1.300 | 1.299 | 1.587 | 1.984 | 1.304 | 1.520 | 0.007 | 0.010 | 1.082 | 1.332 | 0.002 | 0.003 | 1.500 | 1.299 | 1.000 | 1.400 |
| G3 | 1.200 | 1.199 | 1.190 | 1.349 | 1.261 | 1.430 | 0.011 | 0.020 | 0.999 | 1.124 | 0.003 | 0.005 | 1.400 | 1.199 | 0.800 | 1.300 |
| G4 | 1.300 | 1.299 | 1.508 | 1.825 | 1.348 | 1.570 | 0.006 | 0.010 | 1.124 | 1.311 | 0.020 | 0.040 | 1.650 | 1.299 | 1.067 | 1.400 |
| G5 | 1.500 | 1.499 | 1.746 | 2.302 | 1.565 | 1.700 | 0.016 | 0.020 | 1.436 | 1.644 | 0.002 | 0.003 | 1.800 | 1.499 | 1.267 | 1.900 |
| G6 | 1.650 | 1.648 | 1.667 | 2.143 | 1.565 | 1.780 | 0.012 | 0.020 | 1.311 | 1.477 | 0.002 | 0.002 | 1.950 | 1.648 | 1.167 | 1.600 |
| G7 | 1.600 | 1.598 | 1.190 | 1.429 | 1.652 | 1.870 | 0.010 | 0.020 | 1.103 | 1.582 | 0.003 | 0.004 | 1.900 | 1.598 | 0.867 | 1.000 |
| G8 | 1.050 | 1.049 | 1.111 | 1.587 | 1.217 | 1.300 | 0.015 | 0.020 | 0.978 | 1.269 | 0.002 | 0.003 | 1.350 | 1.049 | 0.800 | 1.100 |
| G9 | 1.550 | 1.548 | 1.190 | 1.746 | 1.565 | 1.740 | 0.013 | 0.020 | 1.374 | 1.665 | 0.003 | 0.003 | 1.850 | 1.548 | 0.967 | 1.400 |
| G10 | 1.300 | 1.449 | 1.510 | 2.778 | 1.300 | 1.480 | 0.010 | 0.020 | 1.480 | 1.686 | 0.002 | 0.003 | 2.140 | 2.622 | 0.900 | 1.300 |
| G11 | 1.200 | 1.399 | 1.270 | 2.460 | 1.430 | 1.610 | 0.010 | 0.020 | 1.330 | 1.415 | 0.002 | 0.003 | 1.920 | 2.481 | 1.030 | 1.200 |

Source: From the researcher's work based on Appendix No. (1)

**Conclusions:**

1- The concentration of chemical elements varies from one season to another, where the concentration of these elements increases in the summer and decreases in the winter due to rainfall and low evaporation rates that increase the concentration of the elements in the groundwater of the study area.

2- The hydrochemical specifications change from one place to another depending on the proximity of the sources of nutrition and the distance traveled by the groundwater to the drainage areas and the rockiness of the reservoir, and that the groundwater of good quality prevails in all locations of the study area.

3- The electrical conductivity values during the winter season ranged between (470 - 661) microsiemens/m. While the summer conductivity values ranged between (572-1078) microsiemens/m.

4- The values of total dissolved salts for these models for the winter season ranged between (301-423)ppm, while the summertime values of dissolved salts ranged between (356-646)ppm.

5- The groundwater in the study area is suitable for human, animal, agricultural and industrial consumption (except for the paper industry). It is also suitable for irrigation because of its low concentrations, and it has suitable values of (SAR, Na%), and it is suitable for growing crops that tolerate low water salinity.

**Recommendations:**

1- Establishing hydroclimatic stations to measure the characteristics of rainfall and the volume of discharge in the study area for the purpose of providing the data needed by the researcher for hydrological studies.

2- Applying the concept of managing water basins and harvesting rainwater and benefiting from it in feeding the underground reservoir, and increasing the natural vegetation cover in the region through the construction of dams on the main streams of the basins located within the borders of the region and preserving the soil from erosion.

3- The researcher recommends conducting a bacteriological examination of all sites to ensure their safety from biological contamination before using them for consumption.

4- Doing a geochemical analysis of the soils and formations within the stratigraphy of the region to investigate groundwater contamination with chemical elements and identify their sources, in order to develop a well-studied drilling plan that takes into account the appropriate locations and depths for drilling wells with clean and unpolluted water.

5 - Activate the studies prepared on the construction of dams in the region for the purpose of storing rainwater to benefit from it for drinking and agricultural purposes and to replenish groundwater storage.

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