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# Water Quality of Groundwater and Diyala River in Jisr Diyala Area within Baghdad City- Iraq

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**Abstract**

Groundwater is very important for different uses in the present study area which represents Jisr Diyala, located in southeastern Baghdad and covered with quaternary deposits which include the shallow aquifer in the area. Groundwater and surface water were investigated to determine their suitable uses. The main ion concentrations of the wet period seemed to be lower than those in the dry period. According to TDS values, the water is classified as brackish to salty with a high degree of hardness. Most of water samples were of NaCl type due to pollution with sewage water and rock-water interaction. The results show that the water of the study area is suitable for livestock and irrigation purposes only.

**Keywords:** Physical parameters, Water quality, Piper diagram, Water suitability

# نوعية المياه الجوفية ومياه نهر ديالى في منطقة جسر ديالى ضمن مدينة بغداد/ العراق

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**الخلاصة**

تعد المياه الجوفية مهمة لاستعمالات عدة في منطقة الدراسة المتمثلة في منطقة جسر ديالى. تقع منطقة الدراسة جنوب شرقي بغداد وتغطي اراضيها بطبقات من ترسبات العصر الرباعي والتي تتضمن الخزان الجوفي في منقطة الدراسة. جرى دراسة المياه الجوفية والسطحية لتحديد استعمالاتها المناسبة. وجد ان تراكيز العناصر الرئيسية في الفترة الرطبة اعلى منها في الفترة الجافة. وطبقا لقيم الايونات الذائبة الكلية(TDS) صنفت المياه بانها مجة-مالحة مع عسرة عالية. معظم مياه منطقة الدراسة صنفت على انها ذات نوعية كلوريدية(NaCl-type) نتيجة تلوثها بمياه المجاري وعمليات التفاعل مع الصخورة الحاملة لها. كما بينت النتائج ان مياه المنطقة يمكن استعماله لاغراض الري ولشرب الحيوانات فقط.

## Introduction

Groundwater is very important because it fills the need in the case of surface water scarcity and due to the many dissolved salts it contains. The groundwater quality data are related with the type of rocks and sediment of the aquifer and reveal the history of water-rock interaction [1].

It is not easy to monitor the quality of water due to the complexity associated with the need to analyze large numbers of parameters and variables[2]. The hydrochemical analysis of water provides

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evidence on the rock-water interaction and artificial pollution and reveals the suitability of water for different uses. Groundwater often contains mainly eight major chemical elements, namely $Na^{1+}$, $K^{1+}$, $Ca^{2+}$, $Mg^{2+}$, $SO4^{2-}$, $Cl^{1-}$, $HCO3^{1-}$and $CO3^{1-}$ [1,2].

The study area, Jisr Diyala, is located in the southeastern of Baghdad at the confluence of Diyala River and Tigris River. In the study area, Diyala River represents a contamination source due to its highly contaminated water. The study area is about 17 $km^2$, within longitudes of 44˚ 47′ – 44˚ 55′ and latitudes of 31˚ 15′ – 31˚ 30′ (Figure-1).

The geology of the study area is represented by the quaternary deposits derived from Fatha, Injana and Mukdadiya Formations which fill the flood plain. The thickness of these deposits may exceed 250m in some locations [3]. The climate of Iraq is highly affected by the Mediterranean and Arabian Gulf conditions, characterized by semi-arid climate of hot summer and cold short winter [4].

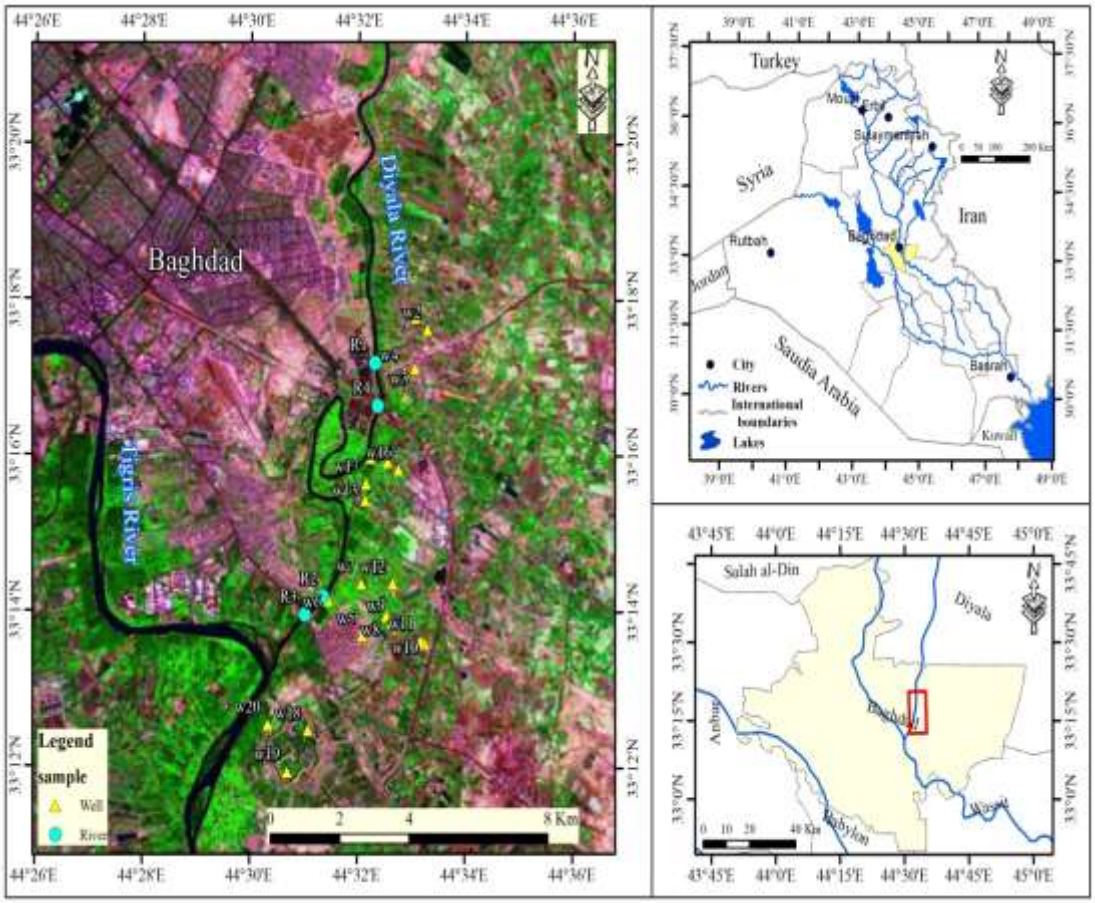


**Figure 1-** Location map of the study area

## Methodology

A total of 48 water samples were collected and analyzed for two periods, the first was in November 2017 (dry season) and the second was in May 2018 (wet season). 20 samples were collected for each period from wells (groundwater) in the study area, while 4 samples for each period were selected from Diyala River. Polythene containers were used in collecting samples for the hydro chemical analysis which included main actions, anions and some of trace elements, whereas the physical parameters consisted of pH., temperature, TDS, and others. The analyses were achieved in the laboratories of the Ministry of Science and Technology. The resulted data were used for the classification of water quality along with water suitability for human, irrigation, livestock and industrial purposes. The analyses were performed using the standard methods for the analysis of water.

## Results and discussion

The main results of field measurements, including locations, coordinates of the wells and river stations, and hydrochemical analyses are shown in Tables-(1 and 2).

**Tables 1, 2-**The range and average values of physical properties and main cations and anions of groundwater and surface water in the study area for the two periods.

1-Groundwater Samples

| Parameters | Dry period | | Wet period | |
|---|---|---|---|---|
| | Range | Average | Range | Average |
| T °C | 27.8-29.8 | 28.4 | 22.9-23.9 | 23.5 |
| pH | 6.9-7.9 | 7.3 | 7.8-8.1 | 7.3 |
| Ec µs/cm | 2673-37300 | 8078.5 | 2646-5791.5 | 6107 |
| TDS | 2105-22000 | 5291.3 | 1960-15700 | 4523.7 |
| T.H | 958.5-2254.4 | 1586 | 1024.2-2332.1 | 1652 |
| $Na^+$ | 214-854 | 565.9 | 920-234 | 556.3 |
| $K^+$ | 0.7-5.3 | 2.6 | 1.2-5.8 | 3.37 |
| $Ca^+$ | 210-449 | 344.5 | 222.512 | 355.8 |
| $Mg^+$ | 100-256 | 176.3 | 110-263 | 185.5 |
| $So_4^{2-}$ | 478-1523 | 956.9 | 488-1578 | 980.5 |
| $HCO_3^-$ | 276-545 | 426.8 | 244-554 | 429.9 |
| $Cl^-$ | 345-1386 | 1034.4 | 430-1317 | 1044.7 |
| $CO_3$ | 0-49 | 9.5 | 0-7.7 | 4.6 |
| $NO_3$ | 0-256 | 40.03 | 1.6-55 | 17.7 |
| pb | * | * | 0.01-0.07 | 0.03 |
| Fe | 0.01-0.06 | 0.03 | 0.01-0.04 | 0.02 |
| Cd | * | * | 0.01-0.04 | 0.02 |
| Zn | 0.01-0.07 | 0.03 | 0.01-0.08 | 0.02 |

**2-Surface Water Samples**

| Parameters | Dry period | | Wet period | |
|---|---|---|---|---|
| | Range | Average | Range | Average |
| T °C | 22.5-24.3 | 23.2 | 20.6-23.4 | 22 |
| pH | 7.1-7.7 | 7.3 | 7.4-7.5 | 7.4 |
| Ec µs/cm | 1566-2268 | 4207.8 | 1755-2430 | 1954.1 |
| TDS | 1160-1680 | 3116.9 | 1213-1763.6 | 1447.5 |
| T.H | 611.9 | 985.3 | 666.3-1063 | 840 |
| $Na^+$ | 127-178 | 141.2 | 133-194 | 154.7 |
| $K^+$ | 2.2.3 | 2.3 | 2.5-3 | 2.9 |
| $Ca^+$ | 143-210 | 161.5 | 135-223 | 167.5 |
| $Mg^+$ | 84-112 | 88.7 | 80-112 | 102.5 |
| $So_4^{2-}$ | 367-475 | 421.7 | 362-520 | 439.2 |
| $HCO_3^-$ | 250-298 | 205.7 | 255-320 | 281.2 |
| $Cl^-$ | 226-401 | 266.5 | 231-414 | 284 |
| $CO_3$ | 0 | 0 | 0 | 0 |
| $NO_3$ | | | 3-6.8 | 4.8 |
| pb | * | * | * | * |
| Fe | 0.01-0.07 | 0.03 | 0.01-0.02 | 0.01 |
| Cd | * | | * | * |
| Zn | 0.01-0.07 | 0.04 | 0.01-0.03 | 0.02 |

*Below detection limit of the instruments

**Physiochemical properties of groundwater**

The groundwater of the study area is characterized by the following properties; the pH average value was 7.3 for both the dry and wet periods. The average water temperature was about 28.4° during the dry period and 23.5º during the wet period. The slight difference in temperature was due to the difference in air temperature during sampling times.

The Electric Conductivity (Ec) average of water samples was about 8078.5 μs for the dry period and about 6107 μs for the wet period. The Ec values in the dry period were slightly higher than the wet period due to the rainfall attenuation. According to Detay [5] who showed the relationship between Ec and mineralization degree of water, the type of water in the study area is extremely mineralized in both periods due to the high salinity.

Total dissolved solid (TDS) average values were 5291 and 4523.7 ppm for the dry and wet periods, respectively.

Hardness average values were about 1586 and 1652 ppm for the dry and wet periods, respectively. When comparing the T.H values with the classifications of water hardness reported by Todd [6], the groundwater in the study area is classified as very hard (T.H > 180 ppm) in both periods. High hardness of water in the study area may be caused by the high concentration of calcium and magnesium ions released to the groundwater from rock-water interactions.

**Physiochemical properties of surface water**

The surface water of the study area is characterized by the following properties; pH average value of the dry period was about 7.3, while it was about 7.4 for the wet period. The average of water temperature as about 23.2° during the dry period and 22º during the wet period. The slight difference in temperature is due to the difference in the air temperature during sampling times.

Ec average values of water samples was about 4207.8 μs for the dry period and about 1954.1 μs, for the wet period. The Ec values in the dry period were slightly higher than the wet period due to the rainfall attenuation. According to Detay [5] who demonstrated the relationship between Ec and mineralization degree of water, the type of water in the study area is extremely mineralized for the two periods due to the high salinity.

TDS average values were 3116.9 and 1447.5 ppm for the dry and wet periods, respectively.

Hardness average values were about 985.3 and 840 ppm for the dry and wet periods, respectively. When comparing the T.H values with the classifications of water hardness published by Todd [6], the groundwater in the study area is classified as very hard water (T.H > 180 ppm) for the two periods. High hardness of water in the study area may be caused by the high concentration of calcium and magnesium ions released to the groundwater from rock-water interactions.

The heterogeneity of the dissolved ions in water is mainly influenced by the climate, the type of mother rocks and human activities [7].

The highest concentrations of ions were recorded for sodium and chloride ions, as the study area is located within quaternary deposits which consist of clay stone, siltstone and sandstone (Geological Survey, 2014) [7]. However, there was a systematic variation in the groundwater chemistry because of domestic and industrial uses. Sulphate ions were also of high concentrations due to the dissolution of sulphate rocks of the Fatha Formation [7].

Water quality was determined by using hydrochemical formula and the hydrogeological facies were determined. The water type of most of the samples in the study area was sodium-chloride. The concept of hydrochemical facies was developed in order to understand and identify the water composition in different classes. Also water type was determined using Piper diagram (Figures- 2 and 3). Water points falling in the upper half of the rhombic represented water secondary salinity, while the others represented sodium chlorite; primary salinity (carbonate alkalinity of more than 50%). Surface water samples (red triangles) fell within and/or nearby the samples of groundwater (black dotes), indicating the interconnection between Diyala River and groundwater, especially those wells located near the river.

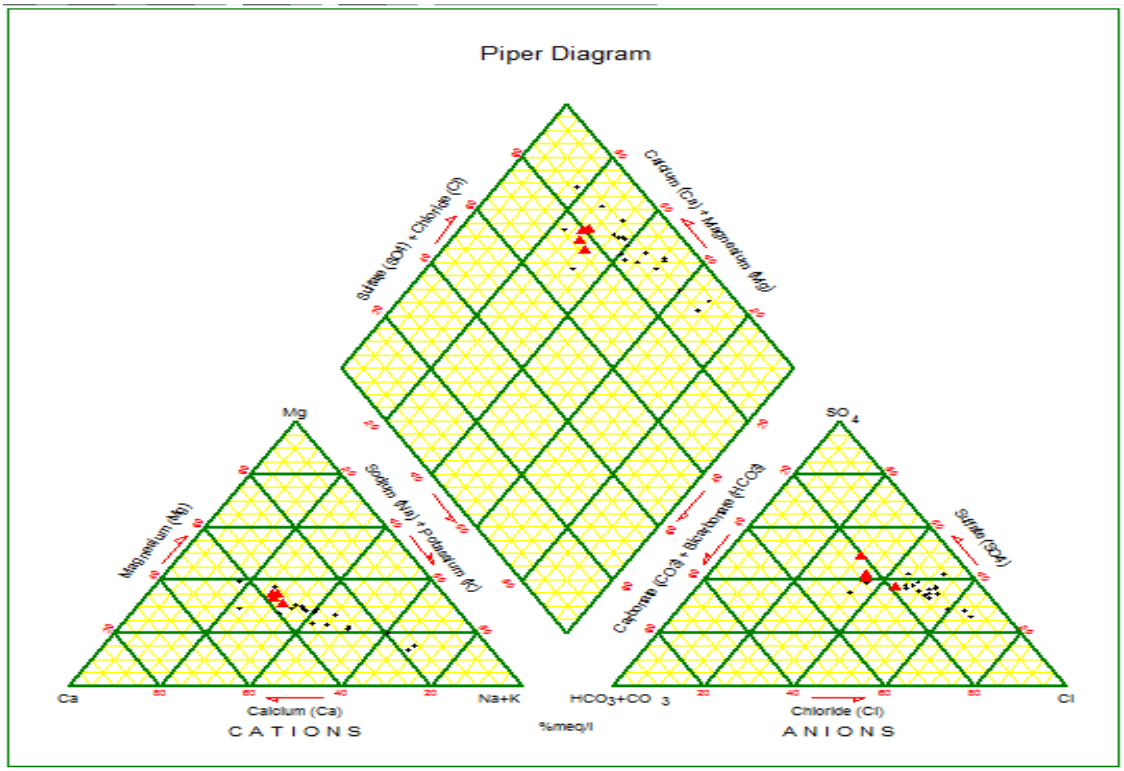


**Figure 2-**Piper diagram of the water samples in the dry period.

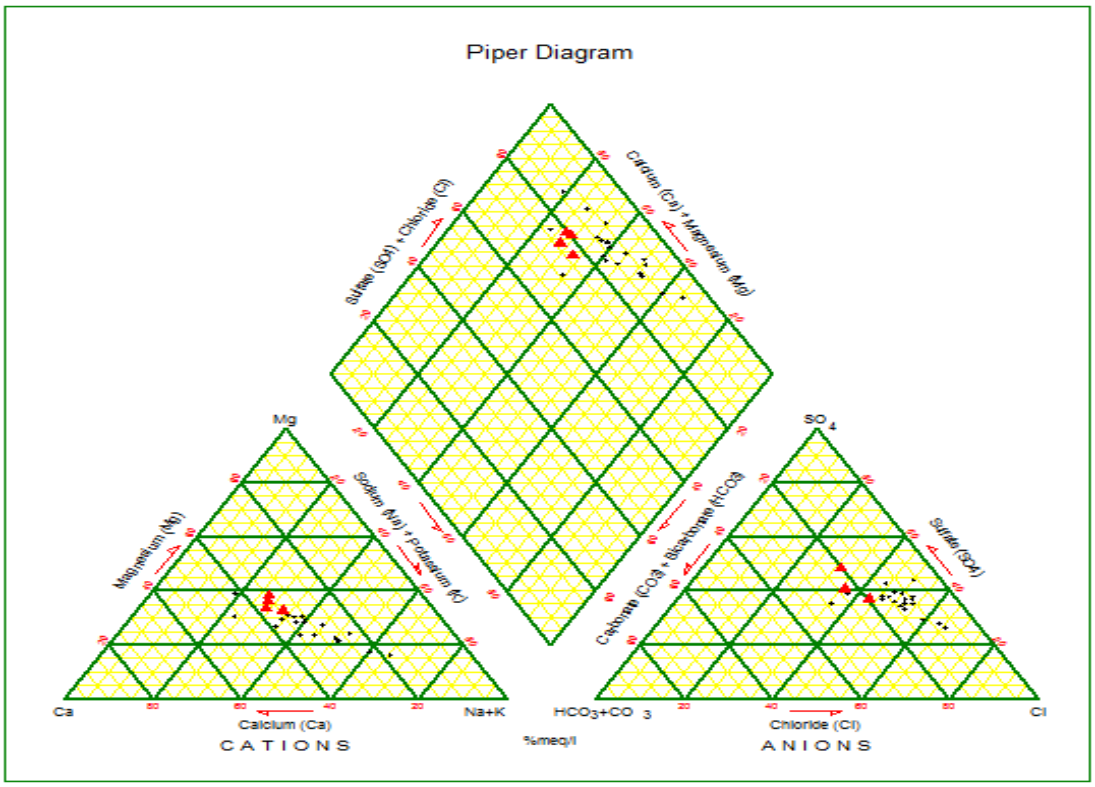


**Figure 3-**Piper diagram of the water samples in the wet period.

**Groundwater and surface water suitability**

**Groundwater and surface water suitability for human drinking**

To decide that water is suitable for human consumption, it must be free from any substances which could cause health affects; substances like organisms and chemical pollutants [8]. The hydrochemical ions and parameters of groundwater and surface water of the studied area were compared with the

standard specification of the WHO issued in 2011[9] and the Iraq standard for drinking water of 2009 [10] (Table-3). The results for the two periods showed that surface and groundwater in the study area are unsuitable for human consumption.

**Table 3**- Specifications of water for human drinking purposes [9, 10]

| Elements& Parameters | WHO (2011) in ppm | IQS (2009) in ppm | Sample values average of dry period | Samples values average of wet period |
|---|---|---|---|---|
| $Na^{+}$ (ppm) | 200 | 200 | 495.1 | 489.3 |
| $Ca^{2+}$ (ppm) | 75 | 150 | 314 | 324.4 |
| $Mg^{2+}$(ppm) | 50 | 100 | 161.7 | 171.6 |
| $Cl^{-}$ (ppm) | 250 | 400 | 906.4 | 917.9 |
| $SO_4^{=}$ (ppm) | 250 | 350 | 867.7 | 890.3 |
| TDS (ppm) | 1000 | 1000 | 3116.9 | 4011.0 |
| T.H (ppm) | — | 500 | 1449.7 | 1516.7 |

**Groundwater and surface water uses for livestock**

The limits of water use for drinking for animals differ from those of humans. The acceptable limits for human drinking are lower than those for animal drinking, because animals can drink water with much higher dissolved solids than humans can. Based on the criteria of Altoviski [11], the water samples of the study area are all very good for animal consumption (Table-4).

**Table 4**-Specifications of water for livestock consumption purposes [11]

| Elements& Parameters | Very good Water | Good Water | Acceptable Water for use | Can be used | High limits | Sample values average of dry period | Samples values average of wet period |
|---|---|---|---|---|---|---|---|
| $Na^{+}$ (ppm) | 800 | 1500 | 2000 | 2500 | 4000 | 495.1 | 489.3 |
| $Ca^{2+}$ (ppm) | 350 | 700 | 800 | 900 | 1000 | 314 | 324.4 |
| $Mg^{2+}$(ppm) | 150 | 350 | 500 | 600 | 700 | 161.7 | 171.6 |
| $Cl^{-}$ (ppm) | 900 | 2000 | 3000 | 4000 | 6000 | 906.4 | 917.9 |
| $SO_4^{=}$ (ppm) | 1000 | 2500 | 3000 | 4000 | 6000 | 867.7 | 890.3 |
| TDS (ppm) | 3000 | 5000 | 7000 | 10000 | 15000 | 3116.9 | 4011.0 |
| T.H (ppm) | 1500 | 3200 | 4000 | 4700 | 54000 | 1449.7 | 1516.7 |

**Groundwater and surface water suitability for irrigation purposes**

Assessment of water for irrigation depends upon many criteria [12-13] such as Sodium Adsorption Ratio (SAR) which is used to evaluate the sodium hazard in relation to calcium and magnesium concentrations [14], and calculated as follows:

$$SAR = \frac{rNa}{\sqrt{r(Ca+Mg)/2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$rNa^{+}$, $rCa^{+2}$, and $rMg^{+2}$: Concentration of ions in epm units.

Electrical conductivity (EC) and sodium concentration percentage (Na%) :

$$Na\ \% = \frac{rNa+rK}{rCa+rMg+rNa+rK} * 100 \quad \ldots\ldots\ldots (2)$$

All ionic concentrations are expressed in milli equivalents per litter (epm).

The results of these parameters are shown in Table-5. According to these values the water of study area is acceptable for irrigation.

**Table 5-**Classified groundwater for irrigation purposes based on pH, Ec, TDS, SAR, and Na%

| Water Quality | EC µs\cm | TDS ppm | SAR | Na% | pH |
|---|---|---|---|---|---|
| **Excellent** | 250 | 175 | 3 | 20 | 6.5 |
| **Good** | 250−750 | 175-525 | 3-5 | 20-40 | 6.5-6.8 |
| **Permissible** | 750−2000 | 525-1400 | 5-10 | 40-60 | 6.8-7.0 |
| **Doubtful** | 2000−3000 | 1400-2100 | 10-15 | 60-80 | 7- 8 |
| **Unsuitable** | >3000 | >2100 | >15 | >80 | >8 |
| **Sample water average of dry period** | 4207.8 | 3116.9 | 5.6 | 0.3 | 7.3 |
| **Sample water average of wet period** | 5414.9 | 4011.0 | 5.4 | 0.3 | 7.3 |

## Conclusions

**1-** Water of the study area was affected by domestic and industrial uses discharged directly into the river

**2-** Non-carbonic acidity is increased in the wells' water due to the effect of the evaporated rocks of Injana formation.

**3-** Chemical ions are increased in the well water near Diyala River because the contamination area is close by.

**4-** After comparing the water of wells with the international standards, it was found to be suitable for irrigation and drinking for animals but not suitable for human drinking.

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