

Environmental study of groundwater in southwest of Baghdad, Yusufiyah using GIS

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Abstract

Ground water hydrochemical study in Yusufiyah depends upon (25) wells where major cations and anions were obtained as well as trace elements. The hydrochemical properties include the study of (pH, EC, TDS, and TH). The groundwater of the study area is odorless and colorless except the wells (13 and 16) with a salty taste due to the elevated (TDS) concentration in it, where the wells depth ranges between 7-20 meters. Depth of water in these wells was about 25-35 meters above sea level. Groundwater generally flows from east to west and from north east to south west. The resource of groundwater depends upon surface water. Physical specifications are measured in the water samples included temperature, color, taste, odor, pH, electrical conductivity (EC) and total dissolved solids (TDS). The chemical specifications included major cations (Ca^{2+} , Mg^{2+} , Na^+ , and K^+) and major anions (NO_3^- , SO_4^{2-} , Cl^- , and HCO_3^-) in addition to the trace elements (Fe, Ni, Co, Cd, Cu, Zn, Pb, Mn). The groundwater in the study area is polluted with some heavy elements like (Fe, Ni, Cd and Pb) because their concentrations are higher than the permissible limits according to WHO (2007) and IQS (2009).

Key words

Ground water, hydrochemical properties, Environmental study

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دراسة بيئية للمياه الجوفية في جنوب غرب بغداد (اليوسفية) باستخدام GIS

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الخلاصة

الدراسة الهيدروكيميائية للمياه الجوفية في اليوسفية تعتمد على 25 بئراً حيث تم الحصول على الكاتيونات والأنيونات الرئيسية وكذلك العناصر النزرة. وتشمل الخصائص الهيدروكيميائية دراسة PH و EC و TDS و TH المياه الجوفية من منطقة الدراسة وجد ان مياه الابار عديمه الرائحة واللون باستثناء البئر (13 و16) واغلب مياه الابار في المنطقه تمتاز بطعم مالح بسبب ارتفاع في تركيز TDS. حيث مدى عمق الابار ما بين (7-20 m). كان عمق المياه في هذه الابار حوالي (25-35 m) فوق مستوى سطح البحر. المياه الجوفية تتدفق عادة من الغرب الى الشرق ومن الشمال الغربي إلى الجنوب الشرقي. الموارد من المياه الجوفية يعتمد على المياه السطحية. تم قياس المواصفات الفيزيائية لعينات المياه وشملت درجة الحرارة، واللون والطعم والرائحة، ودرجة الحموضة، التوصيله الكهربائيه (EC) والمواد الصلبة الذائبة (TDS). وتضمنت المواصفات الكيميائية الكاتيونات الرئيسيه (الكالسيوم والمغنيسيوم والبوتاسيوم والصوديوم). والانيونات (الكبريتات والهيدروكربونات والنترات والكلوريد). بالإضافة إلى العناصر النزرة (الحديد، النيكل، الكوبلت، الكادميوم، والنحاس، الزنك، والرصاص، المغنيز). معظم الابار في منطقة الدراسة نوع المياه فيها (Na_2SO_4)، وتتراوح الابار الأخرى بين النوعين ($MgCl_2$) و ($MgSO_4$). (الكالسيوم، الصوديوم، كبريتات، وكلوريد)، هي أيونات وفيرة في عينات المياه الجوفية. جميع عينات المياه الجوفية ليست مناسبة للشرب والأغراض الصناعية ومناسبة للمواشي واغراض الري. وتلوث المياه الجوفية في منطقة الدراسة مع بعض العناصر الثقيلة مثل (الحديد، النيكل، الكادميوم والرصاص) بسبب تركيزاتها أعلى من الحدود المسموح بها وفقاً لمنظمة الصحة العالمية (2007) و IQS (2009).

Introduction

The groundwater is important source for humans. Recently, deterioration of water quality due to pollution was noticed. Therefore it is important to study the ground water resources to maintain its optimum investment. The Yusufiyah area is located in the southwest of Baghdad, lies within the importance agriculturally and economically areas.

The study aims is to determine of hydrochemical characteristics of groundwater and the groundwater pollution in the area of Yusufiyah.

Yusufiyah

Al-Yusufiyah city is located at the southwest of Baghdad located between latitudes ($33^{\circ} 13' 58'' - 33^{\circ} 01' 15''$), and longitudes ($44^{\circ} 08' 52'' - 44^{\circ} 08' 28''$), and covers an area of about 435 km² as shown in Fig.1.

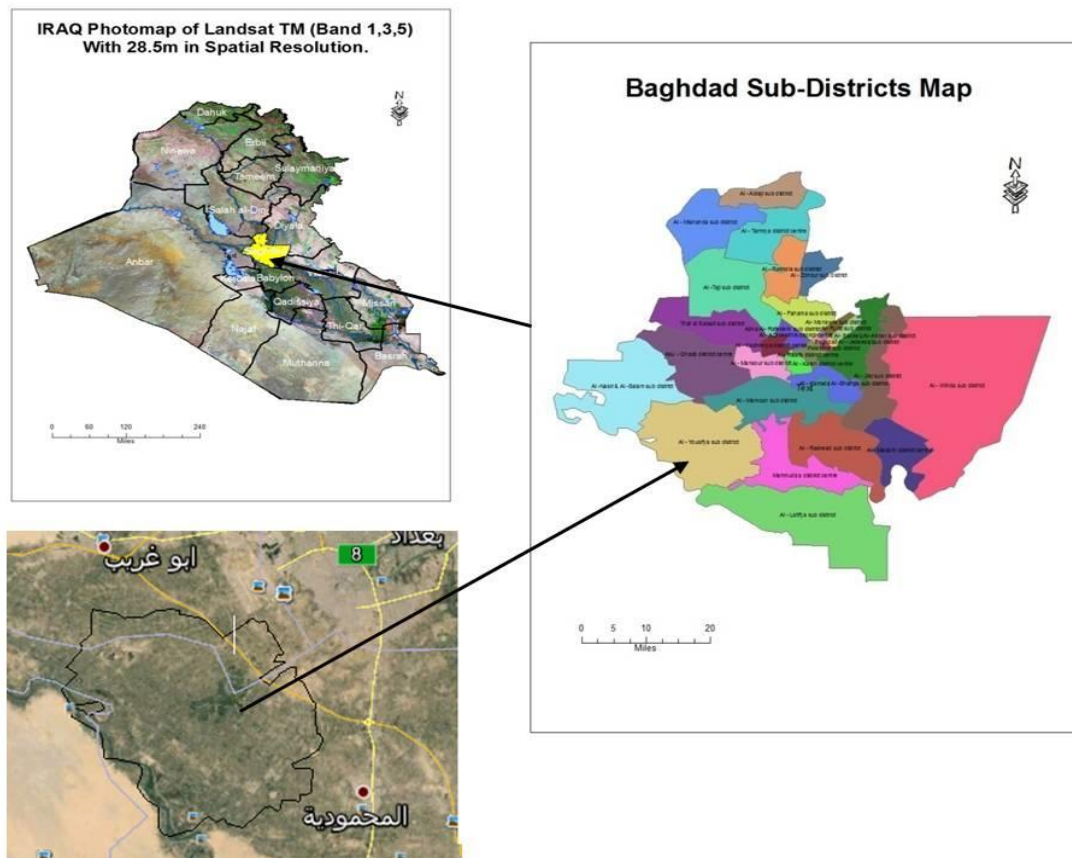


Fig.1: Location of Al-Yusufiyah.

Materials and method

Field work

The ground water samples were collected from 25 wells during Feb. (2014) which represent the wet period as shown in Fig. 2. The acidity (pH), electrical conductivity (EC), and total dissolved salt (TDS) of the water samples were measured in the Lab.

Except the T°C direct was measured in the field. The coordinates for each sample (Longitude, Latitude and Elevation) were accurately determined using a GPS (Global Positioning System) instrument (Type-etrex).

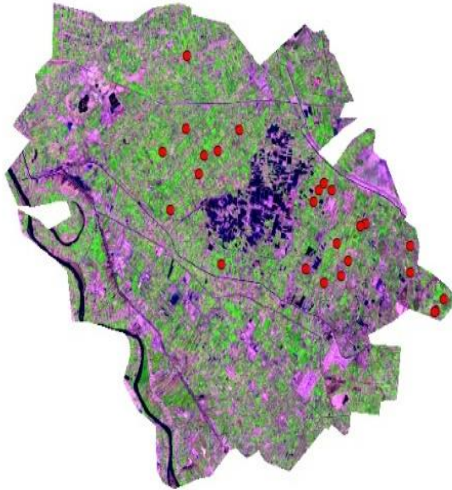


Fig.2: The location of the groundwater samples.

The study of the groundwater includes interpretation of physical, chemical and biological properties; physical properties include color, odor, temperature, chemical properties include determination of concentration of the major cations (Ca^{2+} , Mg^{2+} , Na^+ and K^+) major anions HCO_3^- , SO_4^{2-} and Cl^-), minor ions NO_3^- as well as the trace elements Fe, Co, Ni, Cu, Zn, Cd, Pb and Mn, acidity, The groundwater quality is nearly of equal importance to the quantity [1]. Therefore, it's necessary to make chemical, physical and bacterial analyses of groundwater to determine its suitability for different purposes (drinking, livestock, industrial, agriculture and irrigation) [2].

Inverse Distance Weighting (IDW) is a type of deterministic method for multivariate interpolation with a known scattered set of points. The assigned values to unknown points are calculated with a weighted average of the values available at the known points. The name given to this type of methods was motivated by the weighted average applied, since it resorts to the inverse of the distance to each known point ("amount of

proximity") when assigning weights [3].

Results and discussion

The results of the physical and chemical characteristics of the ground water reflect that the all water samples in the study area are colorless and odorless except the wells (13,16).

pH occur and values less than 7 are commonly encountered [4].

Electrical conductivity of water is an indirect measurement of salinity, and it is temperature dependent [5]. Fig.3 shows that the interpolation of EC in ppm. The distribution of the concentrations of EC in the study area, the range (2050-4793) and the average (3151).

Fig.3 the contour maps shows the distribution of the concentrations of electrical conductivity of the wells in the study area (Yusufiya). The total dissolved salts behave like the electrical conductivity [6], and the electrical conductivity increases due to the increased in the total dissolved salts [7].

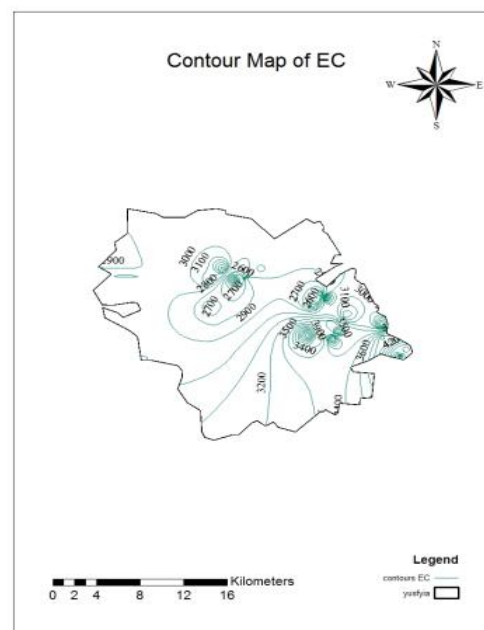


Fig.3: The interpolation and contour line of EC map in $\mu\text{S}/\text{cm}$.

Total dissolved solids (TDS)

Fig. 4 shows that the interpolation of TDS in ppm. Where the contour maps, shows the distribution of the concentrations of TDS in the study area, the range (1904-4680), the average (2859).

Fig. 4, which represents the inverse of the subsurface. Where the concentrations decreased in the Lakes region because the TDS decreased in the recharge area. An increase in the southeast of the study area. The contour maps showing the distribution of the concentrations of dissolved salts of the wells in the study area (Yusufiyah). The total dissolved salts TDS decreased in the (Recharge Area)[6]. The concentration of TDS decreased when increasing groundwater velocity as the high-velocity groundwater will be a few concentrations of dissolved salts because of (Residence Time)[8].

Major ions

More than 90% of the dissolved solids in groundwater can be attributed to eight ions:

(Ca²⁺, Mg²⁺, Na⁺ and K⁺), (NO₃⁻, HCO₃⁻, SO₄²⁻ and Cl⁻) [14].

Major cations

Calcium ion (Ca⁺²)

Fig. 5 shows that the interpolation of (Ca²⁺) in ppm, where the contour maps, shows the distribution of the concentrations of Ca²⁺ in ppm the study area. The range (12.5-390), the average (209.4).

Fig. 5, shows that contribute to human activities and some other operations to the launch of this ion and increase the concentrations [8]. Where the contour maps, shows the distribution of the concentrations of the Calcium (Ca⁺²) of the wells in the study area (Yusufiya).

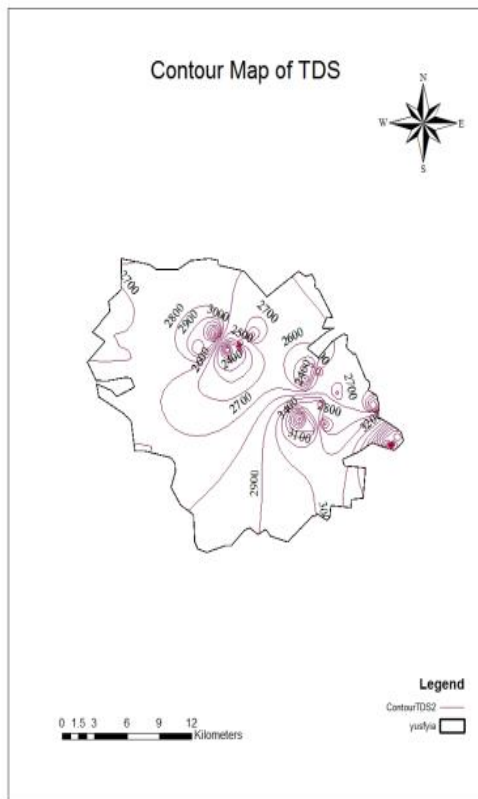


Fig.4: The interpolation and contour line of TDS map in ppm.

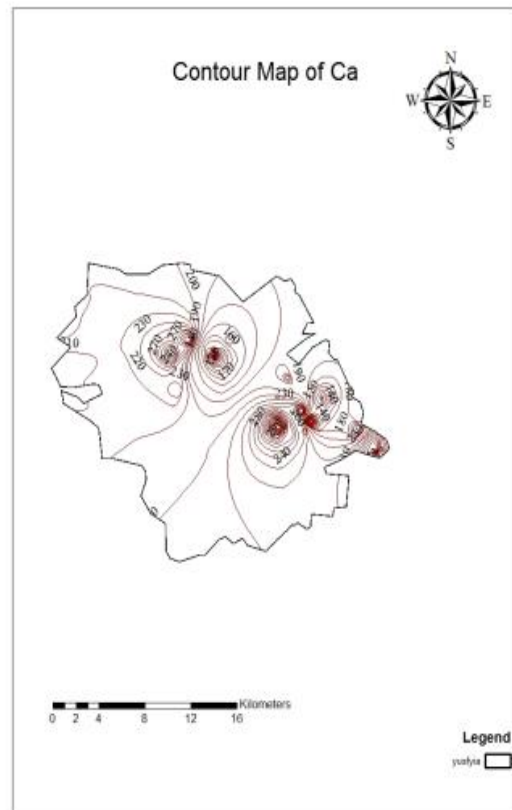


Fig.5: The interpolation and contour line of Ca map in ppm.

Magnesium ion (Mg^{2+})

The Fig.6 shows that the interpolation of (Mg^{2+}) in ppm. Where the contour maps, shows the distribution of the concentrations of (Mg^{2+}) in ppm the study area. The range (212-1162), the average (315.6).

In Fig. 6, shows that the Clay minerals that are found in sandstone heavy minerals is the source of this ions [9]. Where the contour maps, shows the distribution of the concentrations of the Magnesium Ion (Mg^{+2}) of the wells in the study area (Yusufiya).

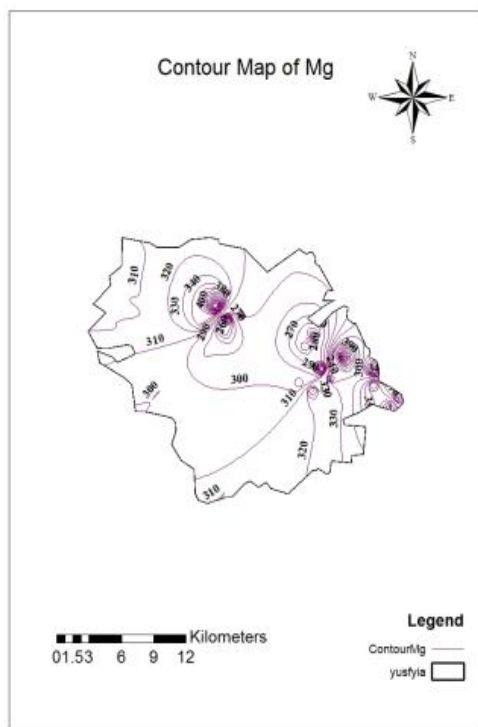


Fig.6: The interpolation and contour line of Mg map in ppm.

Sodium ion (Na^+)

Fig.7 shows that the interpolation of (Na^+) in ppm, where the contour maps, shows the distribution of the concentrations of Na in the study area are in the range 82.5-372, the average (191).

Fig.7, shows that the human activities effective and clear in the concentration of sodium in the water, such as the use of salts in the environmental needs, and re-use of wastewater for irrigation [10]. As well as in saline areas and

areas of water logging and soil left. Clearly, in the Lakes region, as well as consistent with the places concentrate barley plant and the lack of the presence of plants, the contour maps, shows the distribution of the concentrations of the Sodium Ion (Na^{+1}) of the wells in the study area (Yusufiya).

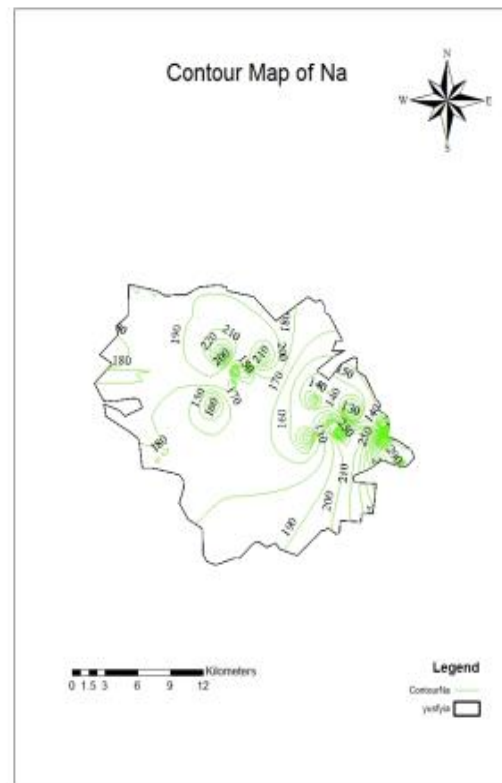


Fig.7: The interpolation and contour line of Na map in ppm.

Potassium ion (K^+)

Fig.8 (the contour maps) shows the distribution of the concentrations of K^+ in the study area, and shows that the interpolation of K^+ in ppm is in the range 2.2-22.9, the average (6).

Fig.8, shows that the chemical fertilizers increase the potassium concentration in groundwater [11]. The fertilizers were used in abundance in the increase of water season. The contour maps show the distribution of the potassium ion concentrations (K^{+1}) of the wells in the studied area (Yusufiya).

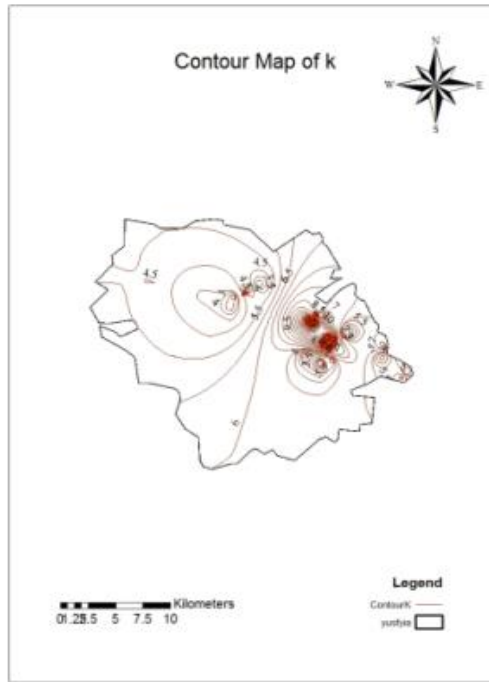


Fig.8: The interpolation and contour line of K map in ppm.

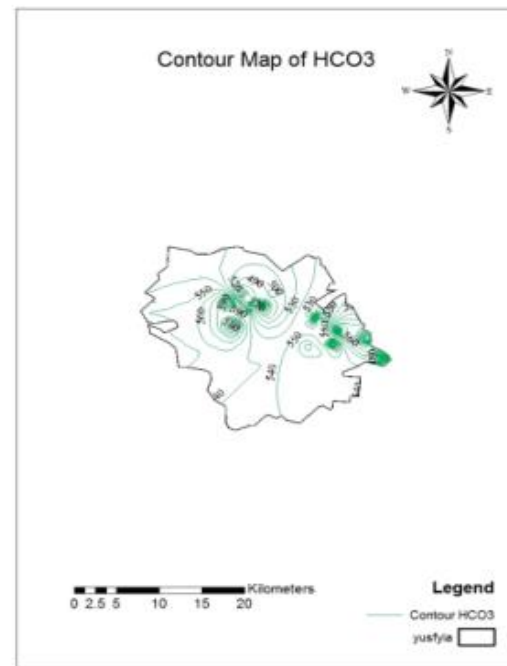


Fig.9: The interpolation and contour line of HCO₃ map in ppm.

Major anions

Bicarbonate ion (HCO₃⁻)

Fig.9 (the contour maps) shows the distribution of the concentrations of HCO₃ in the study area. And shows the interpolation of HCO₃ in ppm is in the range 305-686, the average 536.56.

Fig. 9 shows that the concentration of bicarbonate ion was high in areas that were in the presence of wheat fields. The bicarbonates ion concentration is high in an excess aqueous season where (recharge area) because of CO₂ in the atmosphere, which dissolves in water is one of the most important sources of bicarbonates [11].where the contour maps showing the distribution of the concentrations of bicarbonate Ion (HCO₃⁻) of the wells in the study area (Yusufiya).

Sulfate ion (SO₄²⁻)

In the Figs. 10 are the contour maps, shows the distribution of the concentrations of SO₄²⁻ in the study area. The range (502-1808), the average (920.32) of SO₄²⁻ in ppm.

Fig.10 shows that the concentration of (Sulfate Ion) was high in an area does not have plants [6]. High concentration of sulfate ion in the area means increased concentration of anaerobic bacteria. Where the contour maps showing the distribution of the concentrations of (Sulfate Ion SO₄²⁻) of the wells in the study area (Yusufiyah).

Chloride ion (Cl⁻)

The contour maps in the Figs. 11, shows the distribution of the concentrations of Cl⁻ in the study area. The range (221-1162) and the average (487.19) of Cl⁻ in ppm.

Fig. 11, shows that the increasing of the concentration of chlorine due to the use of organic fertilizers and human activities in the study area. The water treatment by chlorine leads to increased chlorine ion concentration in ground water. We note in the north-east region an Increase in the barley fields, and a few plants. Where the contour maps, shows the distribution of the concentrations of Chloride Ion Cl of the wells in the study area (Yusufiya).

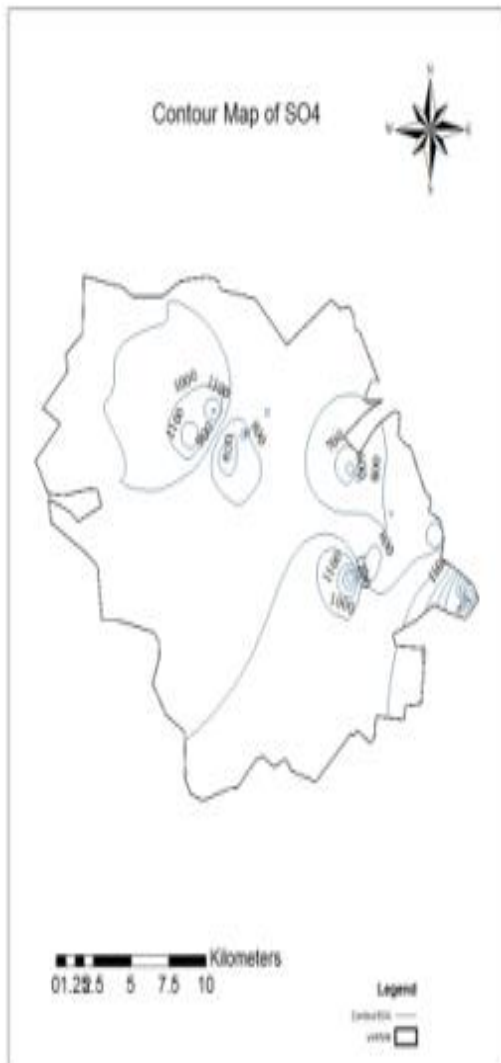


Fig.10: The interpolation and contour line of SO₄ map in ppm.

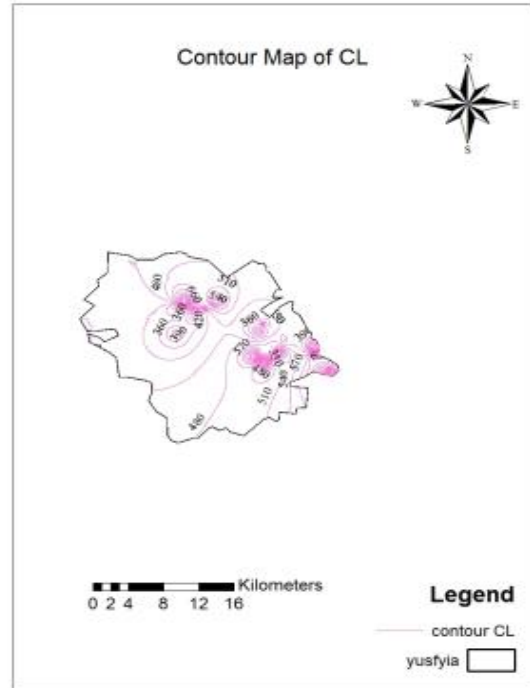


Fig.11: The interpolation and contour line of Cl map in ppm.

Nitrate ion (NO₃⁻)

In the Figs. 12 are the contour maps, shows the distribution of the concentrations of (NO₃⁻) in the study area. The range (0.3-64) and the average (11.86) of NO₃⁻ in ppm.

Fig.12 shows that the concentration of (nitrate Ion) was high in an area does not have plants. The ratio of nitrate in shallow reservoir is more than the deep reservoir. The most important sources of nitrate in groundwater are sewage (Septic system), organic fertilizer and chemical fertilizers, which represents the main source of this ion [10], [6] and [12]. Where the contour maps, shows the distribution of the concentrations of nitrate **Ion** (NO₃⁻¹) of the wells in the study area (Yusufiyah).

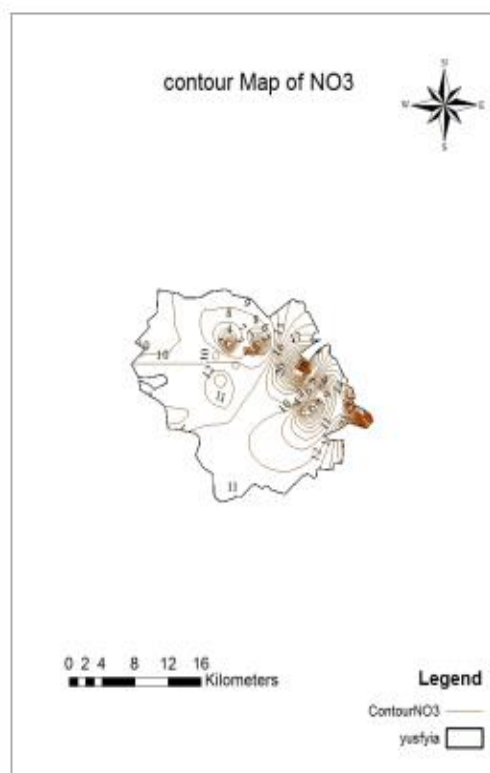


Fig.12: The interpolation and contour line of NO₃ map in ppm.

Total hardness (TH)

Hardness is an important criteria for determining the usability of water for domestic, drinking and many industrial uses [2]. The range (325-1850), the average (1025.6).

Heavy metals (Trace elements)

Iron (Fe)

Iron concentration of water samples of the studied area range between (4.82 - 0.24 ppm) with an average of (5.456 ppm). In the Fig.13 are the contour maps, shows the distribution of the concentrations of Fe in the study area. Fig.13 shows that the Increasing of the concentration of Iron ion due to increases in areas of high human activity [6]. the contour maps, shows the distribution of the iron ion concentrations of the wells in the studied area (Yusufiyya).

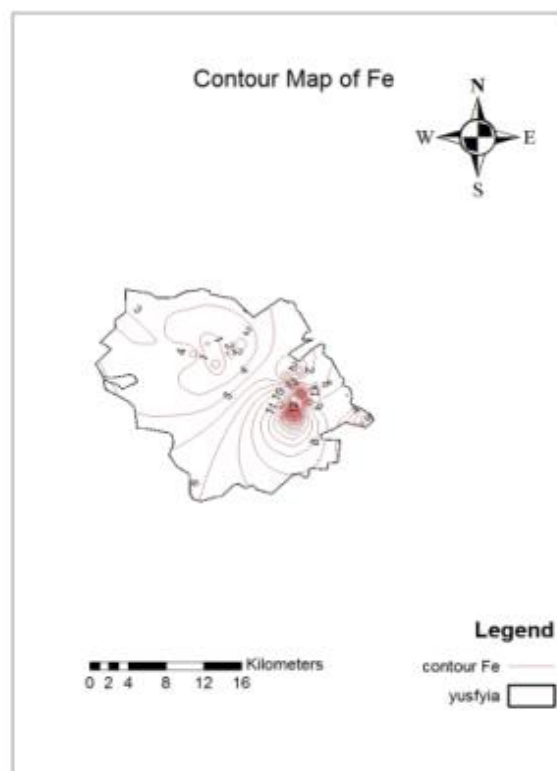


Fig.13: The interpolation and contour line of Fe map in ppm.

Cobalt (Co)

Cobalt concentrations of water samples of the study area range between (0.001 -0.142 ppm) with an average of 0.018ppm.

Fig.14 shows that the concentration of cobalt ions (Co) where the values of this ions did not exceed the limit, and that there is no pollution of, resulting from human activities for this ion. This is because the ion source is geological configurations in the region. The contour maps, shows the distribution of the cobalt ions concentrations of the wells in the studied area (Yusufiyah).

Nickel (Ni)

Nickel concentration in water samples of the studied area range between (0.004 - 0.284 ppm) with an average of 0.145 ppm, it becomes apparent that all wells of the study area are polluted with nickel ion because its concentration exceed the permissible limit except the wells No. (4,19). And this may be attributed to dissolution

processes of soils and agricultural activities (fertilizers uses) in the studied area.

Fig.15 shows that the nickel ion concentration is increase over the limit because of the use of fertilizers and human activities [13]. It is noted that the relationship between the (SO₄, Ni) are inverse. The reason of the appearance of this ion pollution in the studied area is using the fertilizers as well as the human activities in the regions. The contour maps, shows the distribution of the Nickel ion concentrations of the wells in the studied area (Yusufiya).

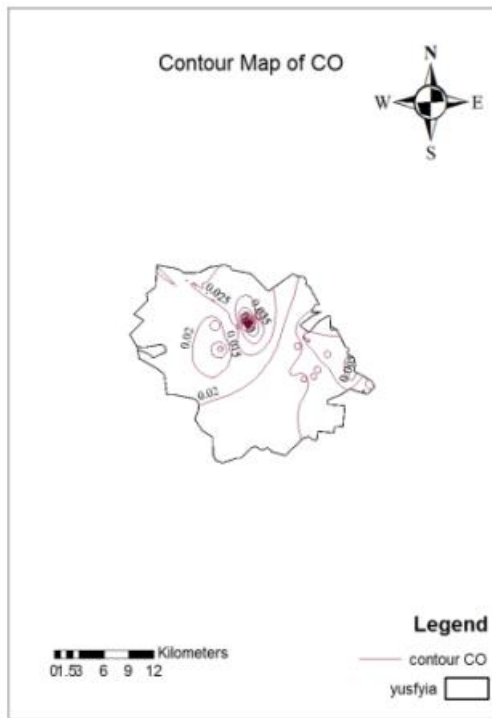


Fig.14: The interpolation and contour line of Co map in ppm.

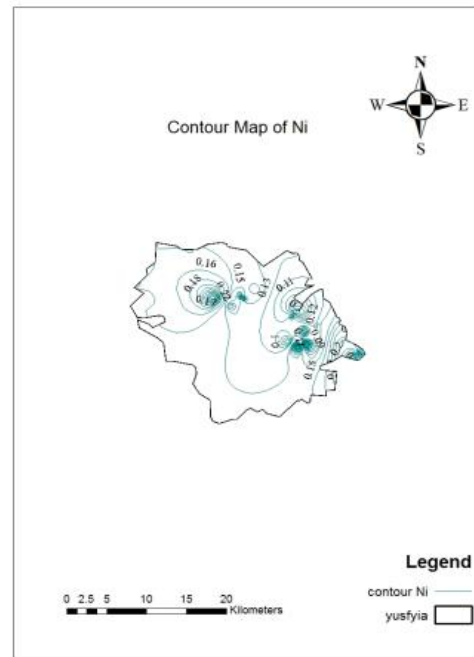


Fig.15: The interpolation and contour line of Ni map in ppm.

Copper (Cu)

Copper concentration of water samples of the studied area range between (0.001 - 0.970 ppm) with an average of 0.249 ppm. It is clear that the copper concentration in the area water is less than the permissible limits, no copper pollution in the groundwater of the studied area.

Fig.16 shows that the concentration of copper ion where the values of these ions did not exceed the limit, and that there is no pollution of resulting from human activities for this ion. But the increase is may be because the source is geological configurations in the region. The contour maps, shows the distribution of the copper ion concentrations of the wells in the studied area (Yusufiyah).

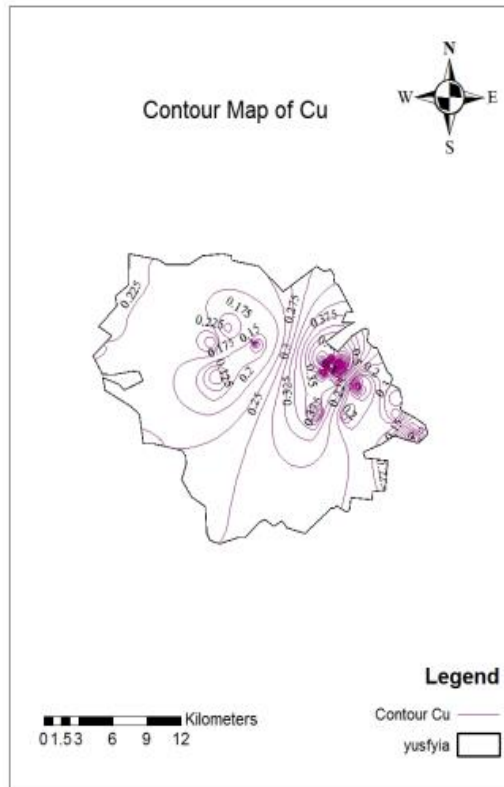


Fig.16: The interpolation and contour line of Cu map in ppm.

Zinc (Zn)

Zn is an essential element in plant and animal, but excessive amounts will be harmful to human life. Zinc concentration of water samples of the studied area range between (0.001-0.083 ppm) with an average of 0.013 ppm.

Fig.17 shows that Zinc ion concentration increases due to the use of chemical fertilizers and organic. But the ion concentration is within the allowable in the study area. The contour maps, shows the distribution of the zinc ion concentrations of the wells in the studied area (Yusufiyah).

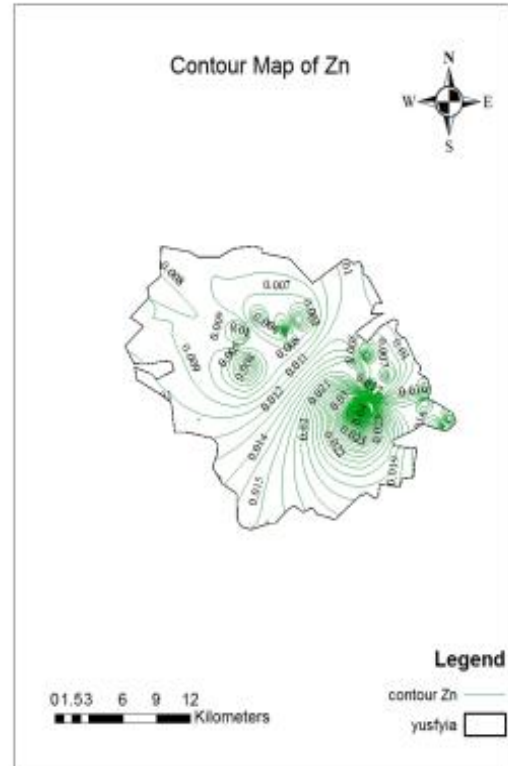


Fig.17: The interpolation and contour line of Zn map in ppm.

Cadmium (Cd)

Cadmium concentration of water samples of the studied area range between (0.031-1.066 ppm) with an average of 0.498 ppm. It is clear that all wells in the study area are polluted with cadmium ion. This may be attributed to agricultural activities (fertilizer uses) in the recharge areas in the studied area.

Fig.18 shows that the increasing of the cadmium ions concentration in the areas due to use the fertilizers and human activities. The contour maps, shows the distribution of the cadmium ion concentrations of the wells in the studied area (Yusufiya).

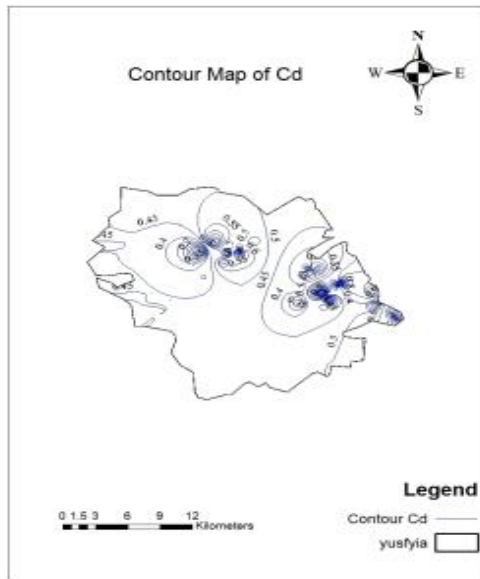


Fig.18: *The interpolation and contour line of Cd map in ppm.*

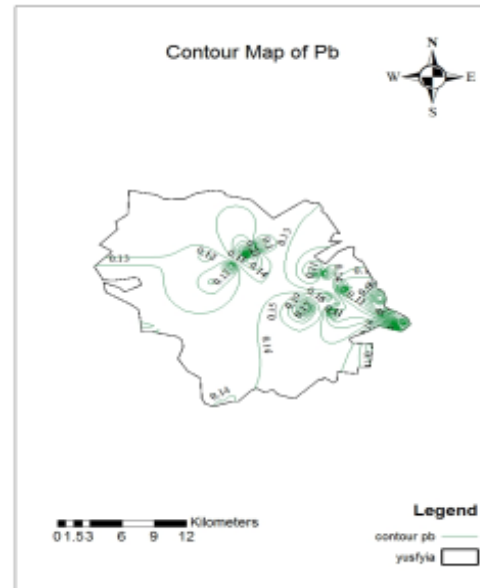


Fig.19: *The interpolation and contour line of Pb map in ppm.*

Lead (Pb)

Lead concentration of water samples of the studied area range between (0.000 - 0.362 ppm) with an average of 0.139 ppm. It is clear that all wells in the study area are polluted with lead ion. Except the well No.(19, 24).

Fig.19 shows that the lead ion concentration is increase over the limit because of the use of fertilizers and human activities [13]. Lead ion conduct similar behavior to calcium. The pollution in the study area of this ion because of using the fertilizers as well as the regions human activities. The contour maps, shows the distribution of the lead ion concentrations of the wells in the studied area (Yusufiyah).

Manganese (Mn)

The manganese concentration of water samples of the studied area range between (0.000 - 0.533ppm) with an average of 0.084 ppm. Manganese concentration in the area water is less than the permissible limit. Except the well No.(15,18). This means no Manganese pollution in the groundwater of the study area.

Fig. 20 shows that the Manganese concentration increases because using the fertilizers and human activities. However the ion concentration is within the allowable in the study area. The contour maps, shows the distribution of the manganese ion concentrations of the studied wells in the area. Manganese ion associated with the iron ion and the manganese concentration is less than half of the iron concentration.

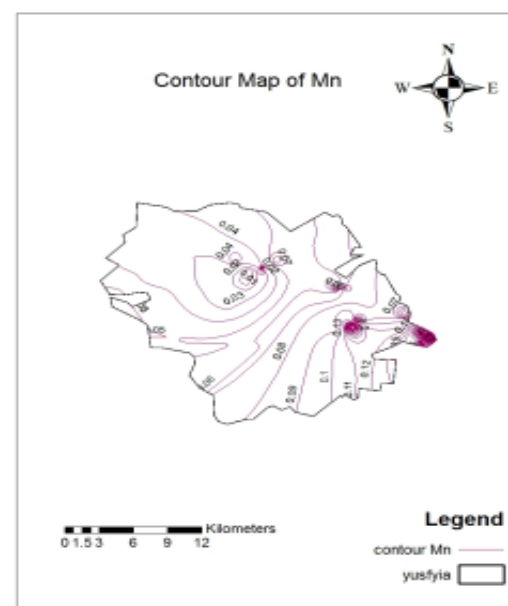


Fig.20: *The interpolation and contour line of Mn map in ppm.*

Accuracy and precision

The accuracy of the results of the water samples analyses can be estimated from the results of reaction error test (U) or relative difference (R.D), by calculation, the absolute difference between the total of cations and anions concentration of total for these concentrations in epm units as percentage [14].

U values range between 1.36- 10.83% for the wet period. Therefore the results of the analysis can be used in the hydrochemical interpretation in the study area. When the above method was applied to the water samples of the study area, it is found that the results are within an acceptable limit except the results of samples W-5, W-7, W-8, W-13, W-16, W-18 and W-20 for wet season are within an acceptable limit with risk.

Hydrochemical formula and water type

The types of groundwater in the study area is determined according to Kurolov formula. According to This formula [15]. The hydrochemical classification of the waters depends on the epm% of the major cations and anions that arranged in decreasing order. The cations located at the base and the anions above, and the TDS in gm/l and PH values are added to them. The type of water will be known from the cations and anions (epm %).

The results of the high water season show prevailing of the Ca^{+2} , Na^+ and Mg^{+2} cations and SO_4^{-2} , Cl^- and HCO_3^- anions in the groundwater of the study area, the hydrochemical Kurolov formulas for water quality in the study area.

The predominant salts in water samples are (MgSO_4), (MgCl_2) and (Na_2SO_4) for wet period.

Classification of Groundwater

The classification of ground water depends on the main cations and

anions concentrations by unit equivalent weight of ion (epm) or milliequivalent per liter (mg/l).

Sholler Classification (1972)

The Sholler (1972) classified groundwater, according to the relation among the major cations and anions in epm, and he used the decreasing order of the ionic concentration of cations and anions and he arrived to 6×6 Ionic order.

These (6×6) orders of ionic concentration lead to 36 combinations of water type Sholler (1972), indicated that the best way to present these (36) water types is to use the graph with the following ionic order, as shown in Fig.21.

Ca^{++} , Mg^{++} , ($\text{Na}^+ + \text{K}^+$), Cl^- , SO_4^{-} , HCO_3^-

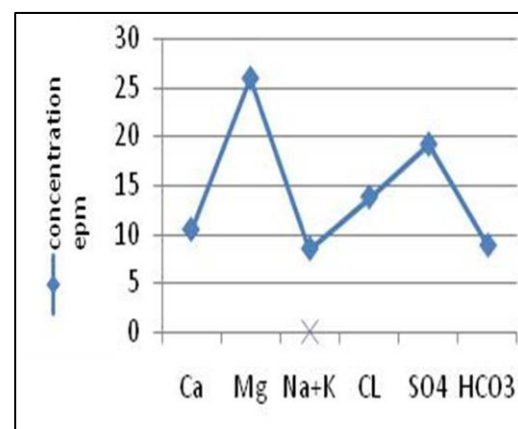


Fig.21: Sholler classification for mean concentrations of ions for High water season in the study area.

According to Sheller's classification, the water samples of Al-Yusifiyah area include (five) sub groups or water types. The mean concentrations of ions are shown

($\text{Ca}=10.41$, $\text{Mg}=25.87$, $\text{Na}+\text{K}=8.46$, $\text{Cl}=13.74$, $\text{SO}_4=19.13$, $\text{HCO}_3=8.79$)

Water assessment

The study area is an agricultural area where population works in agriculture and animal husbandry. So this study is an attempt to determine the suitability

of groundwater for human drinking, livestock and irrigation purposes.

The ground water uses for multiple purposes

Iraqi standard [16] and World Health Organization standard [17] were used to determine its suitability as drinking water in the study area. As a result the groundwater in the study area is unsuitable for human drinking purposes, where in the case of suitable ones element, the other element is not suitable. The groundwater of study areas had been evaluated for livestock uses depending on the classification proposed by [18]. On the basis of Altoviski classification all the samples are (very good) for livestock uses for high water season. There are many classifications to know the suitability of water for irrigation purposes. The plant's tolerance for total dissolved solids and electrical conductivity in water, which is used in irrigation are different depends on the quality of plants [9]. According to the classification proposed by [1]. All water samples of the study area are suitable for growing most types of crops.

Based on this classification, the groundwater samples from all wells are of class (Moderately Saline) type of wet season.

Conclusions

1- The results of chemical analysis of groundwater samples show that the results can be used in hydrochemical interpretations.

2- The groundwater in the study area is generally of low alkalinity with (pH) average (7.3).

3- The results of the analysis of major elements (cations and anions) and nitrate in the groundwater of the study area showed that the prevailing ion in the cations is (Mg) ion and anions are (SO₄) ion. No nitrate pollution in the

groundwater of the study area. According to Total Hardness (TH) the groundwater in the study area is classified as a very hard water.

4- The results of the analysis of heavy elements in the groundwater of the study area confirm that groundwater is polluted with some elements like (Fe, Ni, Cd and Pb).

5- The results of the hydrochemical formula show that most wells of the study area have water type of, MgSO₄ and the other wells range between MgCl₂ and NaSO₄, water type of the wet period. Generally the salts distribution in area of water is attributed to the lithology of recharge areas and the study area as a result of the agricultural and human activities.

6- The groundwater in the study area is unsuitable for human drinking purposes, but it's suitable for all kinds of animals both domestic and livestock animals.

7- Based on the Classification of irrigation water the groundwater samples from all wells are of class (Moderately Saline) type.

8- The groundwater in the study area is not suitable for industrial purposes.

9- According to the classification proposed shown all water samples of the study area are suitable for growing most types of crops.

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