GROUNDWATER QUALITY ASSESSMENT IN KIRKUK CITY IN IRAQ

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ABSTRACT

Due to insufficient water resources, groundwater is considered as the main water supply sources in some regions in Kirkuk city. A Golden Software (Surfer8) is used to show the elevation and the chemical characteristics of the groundwater that have been investigated and evaluated in order to examine the major suitability of the water for drinking and domestic uses. Water samples collected from 29 wells and analyzed for pH, electric conductivity (EC), total dissolved solids (TDS), Ca^{++}, Mg^{++}, Na^{+}, HCO_3^{-}, Cl^{-} ,$SO_4^{--}$and the total hardness. The mean value for the analyzed data was (7.9, 1287.9, 995.38, 111.7, 67.7, 73.662, 202.42, 32.88, 430, and 570.058) mg\l respectively.
The analysis result was compared with the WHO standards of drinking water quality parameters and show that the analysis is within the standards of WHO except the concentrations of the sulphate and the total hardness. A high concentration of sulphate is due to the gypsum nature of the soil in Kirkuk city. It is observed that the quality of water is not suitable for drinking and domestic purposes in most water samples.

Keywords: Groundwater, Water quality, Major Ions, WHO Standards, Kirkuk.

تقييم نوعية المياه الجوفيّةِ في مدينة كركوك في العراق

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الخلاصة

نظرا لقلة مصادرِ المياهِ السطحية، تعتبر المياه الجوفيّة المصدر الرئيسي لمياه الشرب في بَعْض مناطقِ مدينةِ كركوك. تم استخدام برامج (Surfer8) لعرض بيان الإرتفاعِ والخصائصِ الكيميائيةِ للمياه الجوفيّةِ الذي تم التحري عنه وتقُيّمه لغرض اختبار صلاحية هذه المياه لشرب والإستعمالاتِ المنزليةِتم جمع عينات الماءِ مِنْ ٢٩ بئرِ وحلّلتْ لكل من الرقم الهيدروجيني، التوصيل الكهربائي، مجموعَ المواد الصلبةَ الذائبة، ايونات الصوديوم، ايونات المغنيسيوم، ايونات الكالسيوم، البيكاربونات، الكلور، الكبريتات والعسرة. وكان متوسط القيم للعناصر المقاسة هي (٧.٩، ١٢٨٧.٩، ٩٩٥.٣٨، ١١١.٧، ٦٧.٧، ٧٣.٦٦٢، ٢٠٢.٤٢، ٣٢.٨٨، ٤٣٠، و٥٧٠.٠٥٨) ملغم/لتر على الترتيب. تم مقارنة النتائج مَع معاييرِ منظمة الصحة العالمية لمياه الشرب ودلت النتائج على ان جميع العناصر اعلاه تقع ضمن الحدود المسموحة بها فيما عدا الكبريتاتِ والعسرة. وترجع التراكيزالعالية للكبريتاتِ الى طبيعةِ التربة الجبسَية في مدينةِ كركوك. وطبقا لهذا النتائج يمكن اعتبار نوعيةَ الماءِ الجوفية غير مناسبةَ للشرب والأغراضِ المنزلية في معظم العيناتَ الماخوذة.

INTRODUCTION

Water sources available for drinking and other domestic purposes must possess high degree of purity, free from chemical contaminations and microorganisms. The increasing urbanization and the lack of order in the planning and use of the soil affect not only the availability but also the quality of the groundwater, which brings about significant environmental, social, political, and economic implications.

Water, because of its physicochemical nature, flows easily around us, and this phenomenon allows us to see it constantly; however, the availability of freshwater is extremely scarce, and without it, there are no possibilities of human life.

The limitations of the quality and quantity of water resources in the planet, and as groundwater is one of the main sources of freshwater, it is necessary to develop policies to preserve, protect and restore aquifers in order to preserve this vital resource of fundamental importance for the development of mankind.

Many naturally occurring major, minor and trace elements in drinking water can have a significant effect on human and animal health either through deficiency or toxicity due to excessive intake (Frengstad et al. 2001). Several authors have discussed in detail on the potential health impact due to water (Edmunds and Smedly 1996; Frengstad et al. 2000; Reimann and de Caritat 1998). This paper focuses on the urban area of the Kirkuk city.

A Golden software (Surfer 8) is used to draw the head elevations of the groundwater and the concentrations of chemical elements, then the concentrations of these chemical elements has been discussed.

The objective of present study was to assess chemical groundwater compositions and its suitability for domestic and drinking purposes due to unavailable surface water and lack in rainfall quantities.

STUDY AREA

Kirkuk city is located at 35.47°N, 44.41°E, in the Iraqi governorate of Kirkuk, 250 kilometres (156 miles) north of the capital, Baghdad. The Kirkuk region lies among the Pir Magrun (Gudrun) to the northeast, the Zab River and the Tigris River to the west, the Hamrin Mountains to the south, and the Sirwan (Diyala) River to the southeast. The annual rainfall is 380 mm, mainly during December to April. Khasa River, the ephemeral water source for irrigation in Kirkuk city, divides the city into two parts running from north to south**. Fig. 1** shows the plan of Kirkuk city.

SAMPLING AND ANALYTICAL PROCEDDURE

In order to study the quality variation of groundwater in the study area groundwater samples have been collected by the general institute of groundwater in Kirkuk city. A total of 29 samples of groundwater in the study area were collected from 29 pumping wells. The collected samples were analyzed for major ions such as Ca^{++}, Mg^{++}, Na^{+}, HCO_3^{-}, Cl^{-} and SO_4^{--}. Unstable parameters such as pH and electrical conductivity (EC) were measured in the field. Other parameters were analyzed in the laboratory. When water passes through or over deposits such as limestone, the levels of Ca^{++}, Mg^{++}, and HCO_3^{-} ions present in the water can greatly increase and cause the water to be classified as hard water. This term results from the fact that calcium and magnesium ions in water combine with soap molecules, making it hard to get suds. Total hardness was calculated using Aq.QA v.1.1. Software. Total permanent water hardness is calculated with the following formula:

Total permanent hardness = Calcium hardness + Magnesium hardness

The calcium and magnesium hardness is the concentration of calcium and magnesium ions expressed as equivalent of calcium carbonate. The molar mass of $CaCO_3$, Ca^{++} and Mg^{++} are respectively 100.1 g/mol, 40.1 g/mol and 24.3 g/mol. The ratios of the molar masses are:

$$\frac{M_{CaCO_3}}{M_{Ca}} = \frac{100.1}{40.1} = 2.5$$
$$\frac{M_{CaCO_3}}{M_{Mg}} = \frac{100.1}{24.3} = 4.1$$

So, total permanent water hardness expressed as equivalent of $CaCO_3$ can be calculated with the following formula:

$$[CaCO_3] = 2.5\,[Ca^{++}] + 4.1\,[Mg^{++}]$$

The analytical precision for the measured major ions was within ±5%. In order to study the quality of water, the obtained chemical data was evaluated in terms of its suitability for domestic and drinking purposes. The analytical data not only can be used for the classification of water for utilitarian purposes but also for ascertaining various factors on which the chemical characteristics of water depend (Sadashivaiah et al., 2008).

GROUNWATER CHEMISTRY

Among major cations, Calcium Ca^{++} was generally dominant representing on average 43.3% of all the cations. Sodium Na^{+} and Magnesium Mg^{++} ions were of secondary importance, representing on average 29.6% and 27.2% of all cations, respectively.
Among the major anions, the concentrations of, Sulphate SO_4^{--}, Bicarbonate HCO_3^{-} and Chloride Cl^{-} ions lie in between (23 and 975), (25 and 357)and (5 and 94) mg l^{-1} with a mean of (430, 202.42 and 32.88) mg l^{-1}, respectively. The order of their abundance is $SO_4^{--} > HCO_3^{-} > Cl^{-}$, contributing on average (mg l^{-1}), (64.6, 30.4 and 4.9)% of the total anions, respectively.

All ions concentration increases toward south along the flow path. This indicates the increasing distance from the recharge sources. The electric conductivity (EC) varies from 382 to 5260 µmhos cm^{-1} indicating that there are probably fresh water (<500 µmhos cm^{-1}), marginal water (500-1500 µmhos cm^{-1}) and brackish water types (>1500µmhos cm^{-1}) in the area. Total dissolved solids ranges from 288 to 2033 with an average of 995.83 mg l^{-1}. The pH value of the aquifer is high indicating an alkaline nature with an average of 7.9 while the maximum value recorded was 8.2 and minimum was 7.7. Total hardness has been calculated and it varies from (152 to 996) mg\l as $CaCO_3$ with a mean value 570.058 mg\l as $CaCO_3$.

WATER QUALITY ASSESSMENT

The classical use of water analyses in groundwater hydrology is to produce information concerning the water quality. The water quality may yield information about the environments through which the water has circulated (Janardhana, 2007).The main objective following the hydrogeochemical assessment is to determine groundwater suitability to different uses based on different chemical indices. In this paper, assessment of the suitability for drinking and domestic consumption was evaluated by comparing the hydrochemical parameters of groundwater in the study area with the prescribed specification of World Health Organization (WHO, 2004) (**Table 1**).
The pH values of the groundwater vary between 7.7 and 8.2, indicating slightly alkaline to alkaline nature of groundwater. According to the WHO, the range of desirable pH values of water prescribed for drinking purposes is 6.5 – 9.2 (WHO, 2004). There are no water samples with pH values outside

of the desirable ranges. **Fig. 2** shows that the distribution of pH is increase tower south and the maximum value was 8.2 in the well with coordinate (44°23'00", 35°25'15") in Kirkuk city.

Figures (3-8) show the distribution of Ca^{++}, Mg^{++}, Na^{+}, Cl^{-}, HCO_3^{-}, SO_4^{--} respectively in the study area, most of the parameters do not exceed the maximum permissible limits of WHO (2004) as shown in table 1 except the SO_4^{--} which occur naturally in numerous minerals, including barite (BaSO4), epsomite (MgSO4·7H2O) and gypsum (CaSO4·2H2O). These dissolved minerals contribute to the mineral content of many drinking-waters. The concentration of the sulphate exceeds the allowable limit in 72.41% of the samples in the study area. The rest 27.59% are within the allowable limits of WHO but they have high concentrations of total hardness due to the gypsum nature of Kirkuk city soil.

Figures (9 and 10) show the distribution of the EC and the TDS in the study area it can be recognized that the concentrations exceed toward the south and shows high values in the centre of the city. The EC and concentration of TDS is less than the maximum permissible limits of 1500 μmhos cm^{-1} and 1000 mg l^{-1}, respectively, in 68.97% and 58.62% of the total groundwater samples. In Kirkuk aquifer the total hardness varies from 152 to 996 mg l^{-1}. According to Sawyer and McCartly's (1967) classification for hardness, (96.6 and 3.4) % of total groundwater samples are very hard and hard respectively. Water hardness has no known adverse effects; however, hard water is unsuitable for domestic use. Depending on factors such as pH and alkalinity, a hardness of more than about 200 mg l^{-1} will lead to scale deposits in the piping system (Van der Aa, 2003).

The recommended limit for sodium concentration in drinking water is 200 mg l^{-1}. A higher sodium intake may cause hypertension, congenial heart diseases and kidney problems (Singh, 2008). Concentrations of sodium are within the prescribed limit of 200 mg l^{-1} in 46% of the analyzed groundwater samples.

Fig.11 shows the observed head in the study area. The head is decrease toward the south of the study area.

CONCLUSION

The importance of the groundwater resources for water supply is unquestionable; its use will increase in the next few years in order to meet the needs imposed not only by population concentration but also by the economic development, and its relative advantages over surface water. Therefore, this resource needs to be protected. But first it is necessary to know it, study it, and assess its chemical characteristics and its drainage direction. In this way, this study has allowed having a wider and deeper knowledge of the groundwater of the city of Kirkuk, and has served as a management tool not only for the global analysis that the anthropic actions can cause on it, but also for the development of management and protective measures for the groundwater resource of the city of Kirkuk in order to improve the quality of life of its inhabitants.

The groundwater sources in the Kirkuk city have been evaluated for their chemical composition and suitability for domestic and drinking uses. The investigation indicates that among major cations, Ca^{++} is generally dominant representing on average 43.3% of all the cations. The order of anions abundance is $SO4^{--}$> $HCO3^{-}$ > Cl^{-}, the analysis of the samples shows high concentrations of $SO4^{--}$. Sulphate has a laxative effect at concentrations of 1000–1200 mg/l, but no increase in diarrhoea, dehydration or weight loss. The presence of sulphate in drinking-water can also result in a noticeable taste; it may also contribute to the corrosion of distribution systems. Based on TDS, 58.62% of water samples are suitable for drinking purpose. Total hardness calculated show high level of hardness ranging from hard to very hard water that make the groundwater not suitable for domestic use.

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Table1: Water Chemistry Analysis of Groundwater Samples in the Study Area (n = 29)

parameter	unit	minimum	maximum	mean	WHO International Standards, 2004
Na^{+}	mg/l	17	289	73.6621	200
Mg^{++}	mg/l	14	143	67.7	150
Ca^{++}	mg/l	36	292	111.7	200
So_4^{--}	mg/l	23	975	430	250
Cl^{-}	mg/l	5	94	32.88	250
HCO_3^{-}	mg/l	25	357	202.42	240
pH	-	7.7	8.2	7.9	6.5-9.2
TDS*	mg/l	288	2033	995.38	1000
EC	µmhos cm^{-1}	382	5260	1287.9	1500
TH*	mg/l as $CaCO_3$	152	996	570.058	500

*TDS is the Total Dissolved Solids and TH is the Total Hardness

Fig.1: Plan of Kirkuk City, Iraq

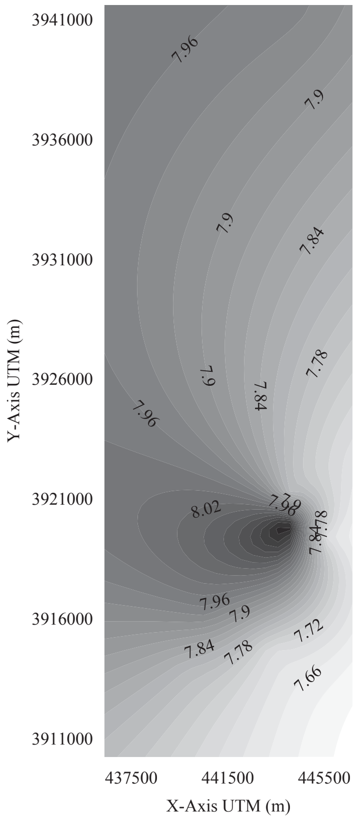

Fig.2 pH

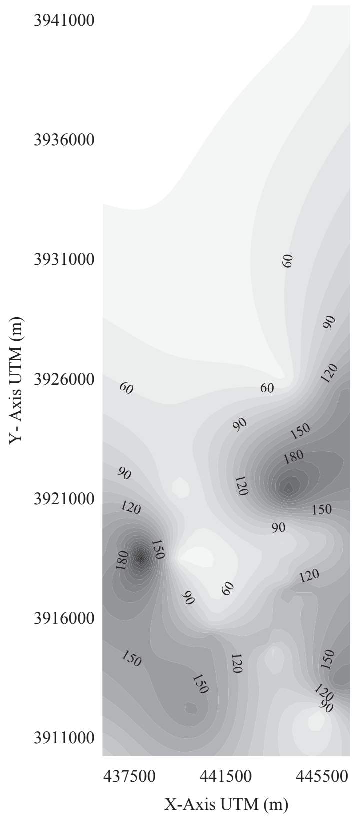

Fig.3 Ca^{++} Concentration mg/l

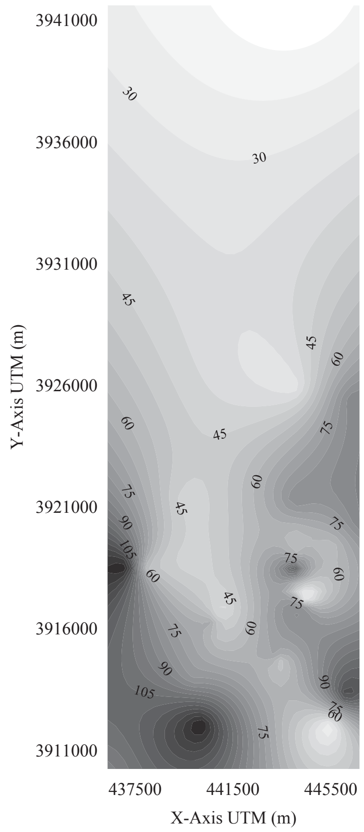

Fig.4 Mg^{++} Concentration mg/l

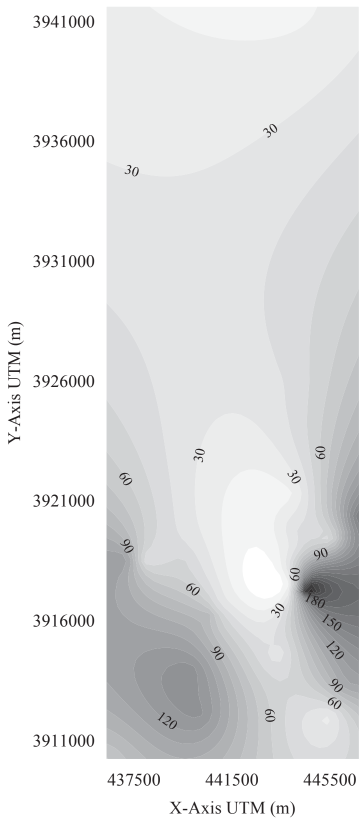

Fig.5 Na^{+} Concentration mg/l

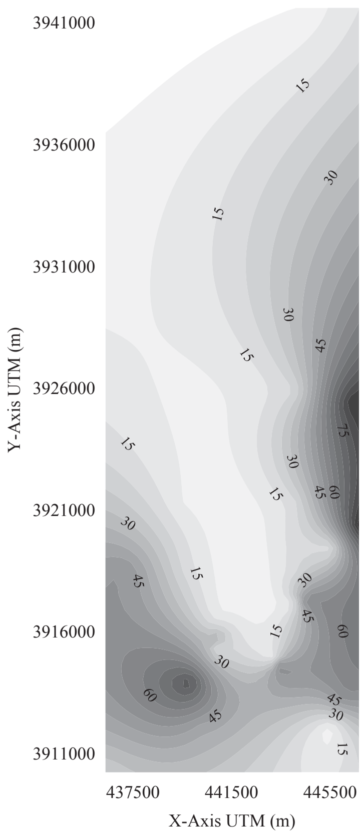

Fig.6 Cl^{-} Concentration mg/l

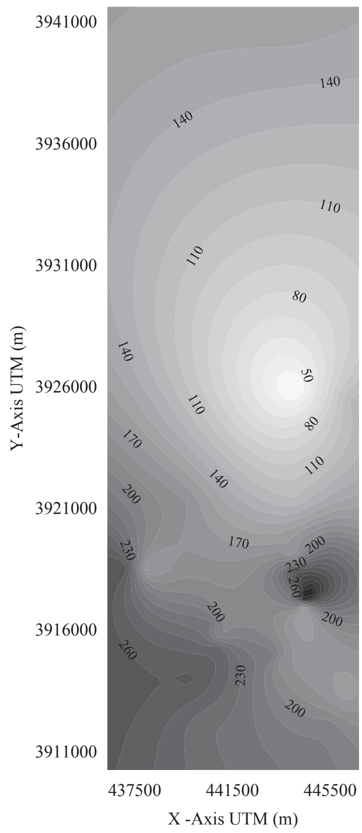

Fig.7 HCO_3^{-} Concentration mg/l

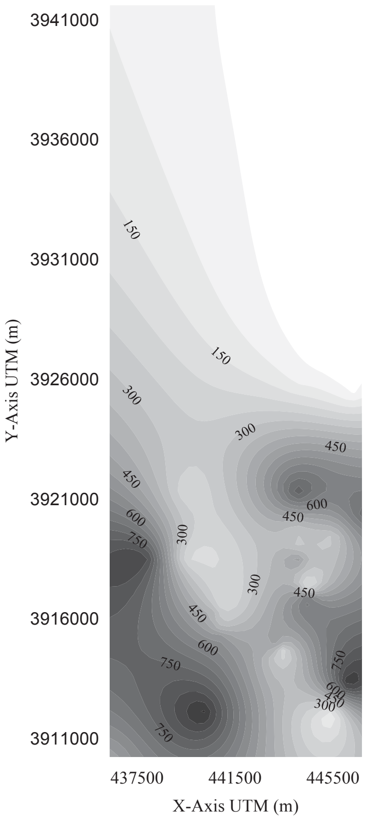

Fig.8
SO_4^{2-} Concentration mg/l

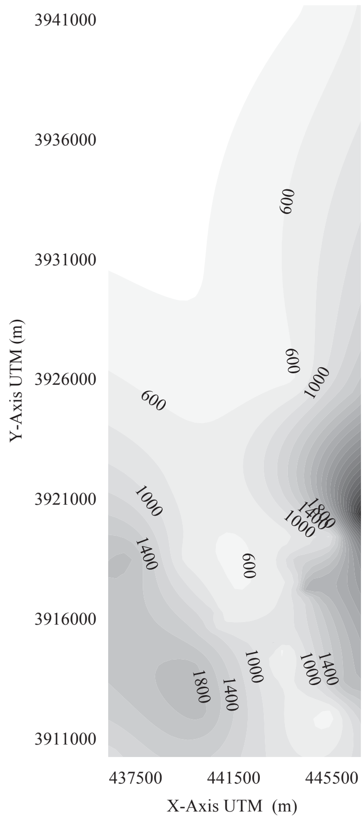

Fig.9
E.C μmhos cm^{-1}

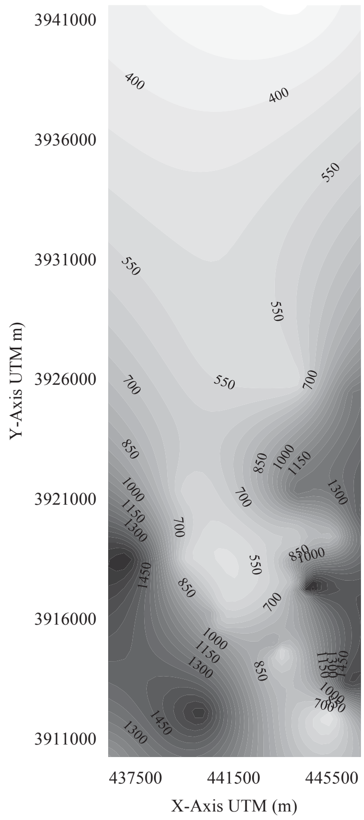

Fig.10
TDS Concentration mg/l

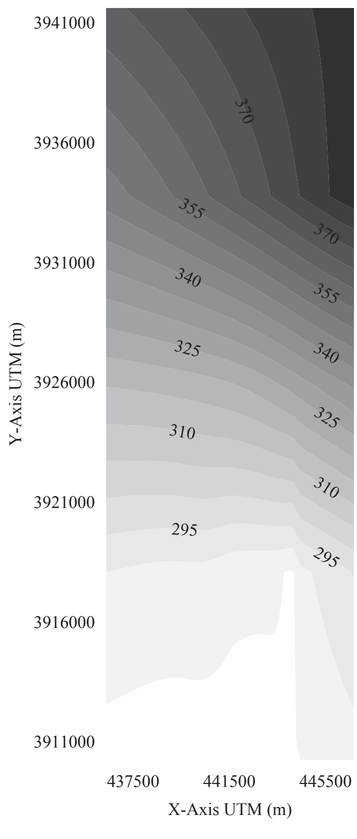

Fig.11 Observed Head (m) AMSL