EVALUATION OF GROUNDWATER QUALITY USING WATER QUALITY INDEX (WQI) AND GIS TECHNIQUES

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ABSTRACT

Eighty-four water samples were collected to evaluate the groundwater quality in western part of Iraq using water quality index (WQI) with the help of Geographical Information System (GIS) technique. These samples were analyzed to define the chemical parameters including cations and aniona in addition to physical parameters including dissolved solids (TDS), pH and electrical conductivity (EC). The analytical data has been manipulating by Piper diagram to determine the type of groundwater in the studied area. Na^{+}- $SO_4^{-2}$and Na^{+}- Cl^{-} facies are a bulk groundwater type representing 51% and 31% respectively. All physiochemical data were transferred to the geographic information systems (GIS) platform to generate the database of water quality including spatial distributions map for each parameter. These parameters have been used to calculate the value of water quality Index (WQI) which is transfer also to the platform of GIS to produce the WQI map. This map represents the spatial distribution index of the potable water in the studied area. It shows only13% of the studied water samples located in the middle and western part of the study area can be used for drinking purpose and remaining samples unsuitable water for drinking purpose and need to be treated in the case of use.In terms of the irrigation, generally groundwater in the studied area becomes more suitable for irrigation purposes in the central part and towards the south-west.

Key words: Water Quality Index (WQI), GIS, Potable Water, Western Iraq

تقييم نوعية المياه الجوفية لاغراض الشرب باستخدام تقنيات مؤشر نوعية المياه ونظم المعلومات الجغرافية

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المستخلص

تم في هذه الدراسة جمع اربع وثمانون (84) عينة لتقييم نوعية المياه الجوفية في الجزء الغربي من العراق باستخدام تقنيات مؤشر جودة نوعية المياه (WQI) ونظم المعلومات الجغرافية(GIS). تم تحليل هذه العينات لتحديد الايونات الموجبه والسالبه بالإضافة إلى المحددات الفيزيائية بما في ذلك المواد الصلبة الذائبة (TDS) ودرجة الحموضة (pH)والتوصيلية الكهربائية (EC). وقد تم معالجة البيانات التحليلية بواسطة مخطط بايبر لتحديد نوع المياه الجوفية في المنطقة المدروسة. وتبين ان النوع السائد للمياه في منطقة الدراسة هو $Na^{+}- SO_4^{-2}$و$Na^{+}- Cl^{-}$ ويمثل 51٪ و 31٪ على التوالي. جميع البيانات الفيزيائية والكيميائية تم نقلها إلى بيئة نظم المعلومات الجغرافية (GIS) لإنشاء قاعدة بيانات لنوعية المياه بما في ذلك خريطة التوزيع المكاني لكل محدده. وقد استخدمت هذه المعلمات لحساب قيمة مؤشر نوعية المياه (WQI) والذي تم نقلها أيضا إلى منصة نظم المعلومات الجغرافية لإنتاج خريطةلمؤشر نوعية المياه لمنطقة الدراسة وتمثل هذه الخريطة مؤشر التوزيع المكاني للمياه الصالحة للشرب في المنطقة المدروسه. وقد أظهرت أن 13٪ فقط من عينات المياه المدروسة الواقعة في الجزء الأوسط والغربي من منطقة الدراسة يمكن استخدامها لأغراض الشرب وبقية العينات غير الصالحة لأغراض الشرب ويجب معالجتها في حالة الاستخدام. أما فيما يتعلقبالري، فإن المياه الجوفية عموما في منطقة الدراسة تصبح أكثر ملائمة لأغراض الري في الجزء الأوسط وفي اتجاه الجنوب الغربي.

الكلمات الدالة: مؤشر جودة المياه، نظم المعلومات الجغرافية، مياه الشرب، غرب العراق

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INTRODUCTION

The western region constitutes one-third of Iraq's area and most of them are uninhabited because of water scarcity and located far away from the Tigris and Euphrates Rivers which are the main sources of water in Iraq, so the Iraqi government has drilled several wells distributed along this area. In the current study 84 wells were selected to evaluate the water quality and determine its validity for drinking purposes using the water quality index (WQI) with the help of GIS technique. This method has been widely used successfully in recent years and is an excellent way to gives a comprehensive view of the state of the groundwater through the integration of composite data. A number of studies have been described the development of WQI method for groundwater such as (2) (17) (18) (12) (13) (4) (5) and (9). The main objectives of this study are to decide geological and hydrogeological properties of the investigation area, to determine the water quality in the western Iraq and to assess the its suitability for drinking and irrigation purposes depending on water quality index (WQI) map creating by using the ArcGIS Spatial Analyst tool.

Area of study

The study area is bounded by latitudes 30° 30' 00" to 35° 00' 00" North and longitude 38° 55' 00" to 44° 10' 00" East covering an area of approximately 138.500 square km (Fig.1). Historically, this part of Iraq was known as the "Brigade of Dulaimi" and currently called Alanbar Provence. The population of this area is about 1, 000,600 depending on the census of 2014 most of who live in the urban areas.

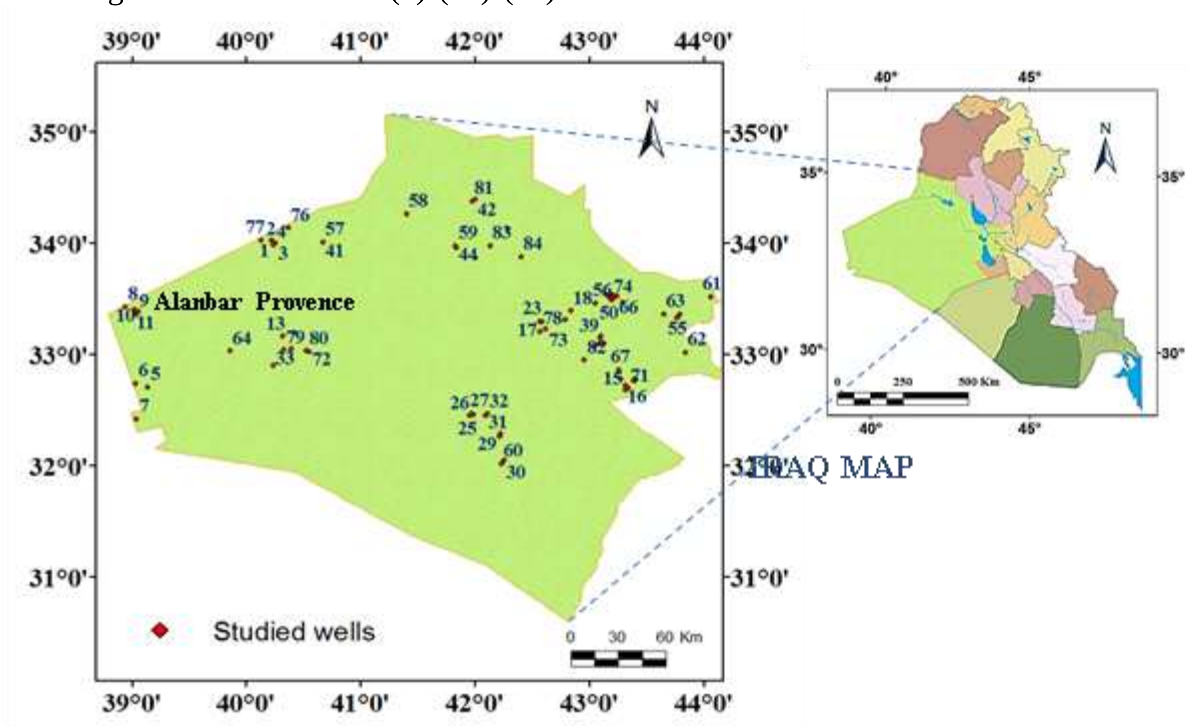

Fig.1. Location map of the study area and the selected wells

Geologically there are various formations in the study area extending from an early Pyramid era to the Holocene period as shown in Fig.2. Physiographically the study area is located within two main regions of Iraq (Western Desert and the Island). It consists of three types of aquifers, confined, unconfined and mixed aquifers namely Um Radhuma, Muhaiwir, Mulussa, Euphrates, Fatha, Gaara,Anah. The groundwater table elevation above Mean Sea Level (A.M.S.L) has been measured in the study area in 84 existing well and the spatial distribution map has been prepared as shown in Fig 3. It has noted that the maximum depth was recorded in the western part of the study area and it is gradually decreasing towards the east and northeast of the study area. This indicates that the east and northeast part of the study area acts as the discharge area.

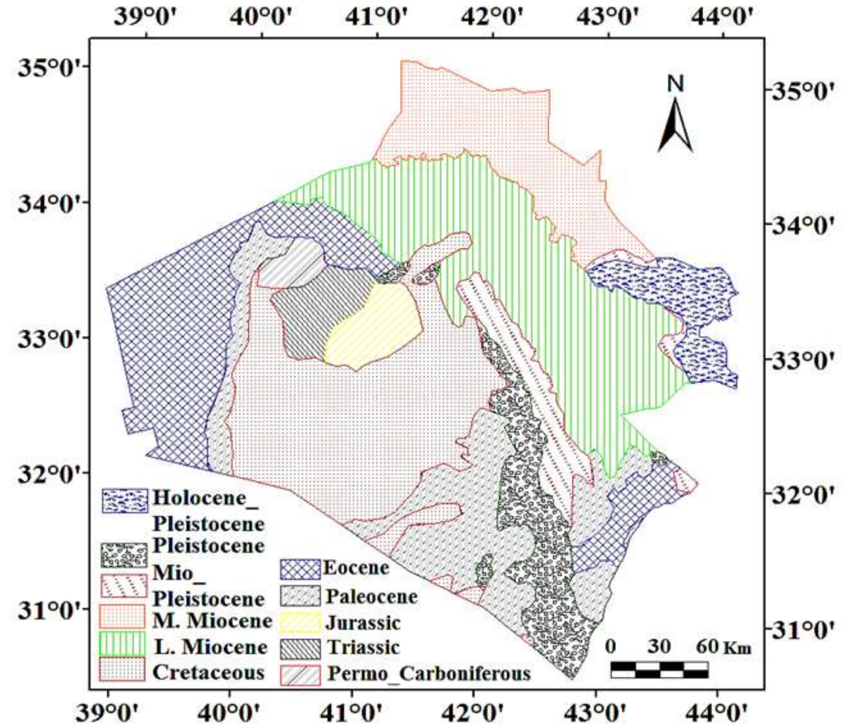

Fig.2. Geological map of the study area [After (3)]

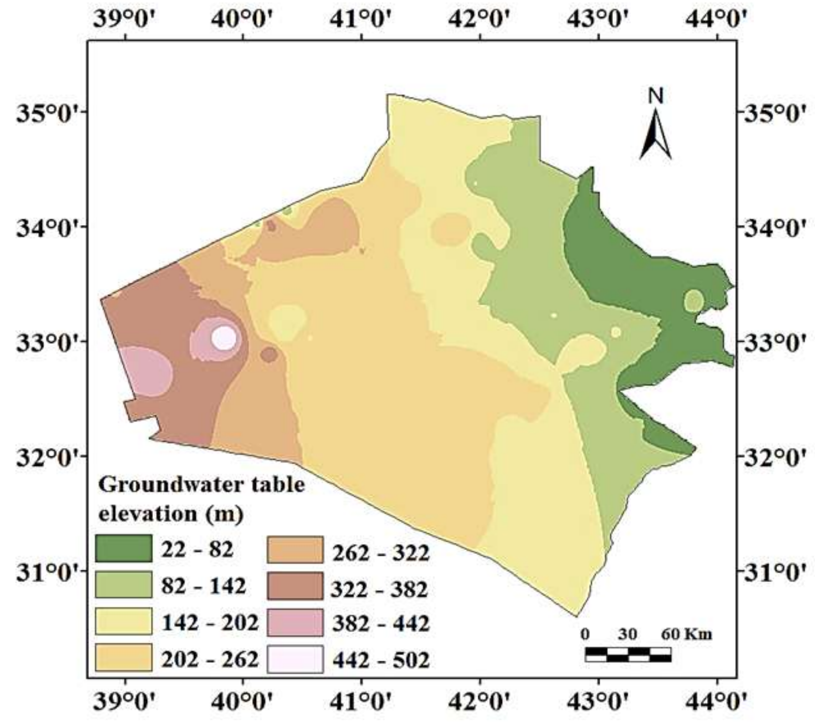

Fig.3. Groundwater table elevation (A.M.S.L) map

MATERIALS AND METHODS

Eighty four wells drilled in the study area by the General Directorate to drill water wells Al Anbar branch have been selected. Global Position System (GPS) system has been used to determine the wells locations and heights above sea level. These locations were dropped on aerial maps using geographic information systems program ARC GIS Software (Fig.1). Eight**y** four water samples were collected and analyzed in the laboratory of the General Company for Drilling Wells Al-anbar Branch during April, 2010. Cations and anions in addition to other physical parameters such as PH, Total Dissolve Soiled (TDS) and Electrical conductivity (EC) have been measured in all water samples collected. These samples were analyzed using the methods shown in the Table 2. Several methods were used in the current research to evaluate water for irrigation and drinking purposes. Water Quality Index (WQI) with the help of GIS technique has been applied to evaluate the water potability. Electrical conductivity (EC), Sodium percent (Na %), Sodium Adsorption Ratio (SAR) and Standard diagrams (Wilcox, 1955 and United State Salinity Laboratory (USSL), 1954) were used to assess the suitability of water for irrigation purposes in the studied area.

Table 1.A summary of the methods used for the analysis of water samples

Serial No	Parameters	Methods
1	pH, TDS and conductivity	Electrolytic
2	Na^+ and K^+	Flame photometer
3	Ca^{2+}, Mg^{2+},	EDTA titration
4	HCO^{3-},	H_2SO_4 titration
5	Cl^-	$AgNO_3$ titration
6	SO_4^{2-}	Spectrophotometers

RESULT AND DISCUSSION

Different division of India and different parts of the world like (6) and (11) have been reported the statistical analysis of chemical parameters of water. Liner correlation analysis of water quality data have also been studied by (15) for water potability of Al-Mukalla city. Statistical analysis was carried out in the present study using the SPSS version 22 which is a statistical package for social sciences. To identify the physiochemical parameters that deviate from Iraqi standard for drinking water the basic statistical test mean, standard deviation and spearman's correlation matrix (assuming $p < 0.01$) have been applied. Table 2 shows the values of the minimum, maximum, mean and standard deviation of all the chemical parameters.

Table 2.Descriptive statistics for all studied wells

	pH	EC (μS/cm)	TDS (ppm)	Ca^{+2} (mg/l)	Mg^{+2} (mg/l)	Na^+ (mg/l)	K^+ (mg/l)	HCO_3^- (mg/l)	SO_4^{-2} (mg/l)	CL^- (mg/l)	NO_3^- (mg/l)
Minimum	7.08	668	473	30	10	32	0.1	15	73	60	0.1
Maximum	7.91	6650	4706	348	186	620	98.0	511	1531	1314	16
Mean	7.32	2964	2156	182	93	293	11.7	217	657	448	3.5
Std. Deviation	0.23	1341	948	84	48	138.8	16.8	134	309	219	3.0

It has observed that the chemical parameters like pH, Ca^{2+}, Mg^{+2}, K^+ Cl^- and NO_3^-within the limits of Iraqi standard whereas the remaining parameters are higher than the limits. The standard deviation for all parameters are within the limits of Iraqi standard for potable water except the potassium element (K^+) is more than the limits of Iraqi standard for drinking water. The correlation coefficient matrix between WQI and chemical parameters and between themselves in the present study has been measured by simple correlation coefficient (r) and it is presented in Table 3. The correlation of the analysis measures convergence in the relationship between the selected chemical variables. If the correlation coefficient is closer to +1 or -1, it represents the optimal linear relationship between the two chemical variables. The analysis of this method attempts to prepare the nature of the relationship between potable water chemical parameters determinants with each other's and with water quality index (WQI). It has been observed that the relationship is highly significant between EC and all chemical parameters except Na^+ (r= 0.44) and NO_3^- (r= 0.18). In some sites the relationship between Mg^{2+} and Cl^- is highly significant indicates that the hardness of the water is permanent in nature. Also show the good relationship between calculated WQI with the concentration of all parameters except NO_3^- (r=0.16)

Table 3.Correlation coefficient for studied well water sample and WQI

	pH	EC	TDS	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	HCO_3^-	SO_4^-	CL^-	NO_3^-	WQI
pH	1											
EC	0.14	1										
TDS	0.15	0.99	1									
Ca^{+2}	0.12	0.87	0.88	1								
Mg^{+2}	0.22	0.85	0.86	0.91	1							
Na^{+}	0.30	0.85	0.86	0.70	0.64	1						
K^{+}	0.11	0.44	0.44	0.42	0.38	0.44	1					
HCO_3^-	0.05	0.77	0.75	0.58	0.51	0.75	0.52	1				
SO_4^-	0.21	0.85	0.87	0.87	0.86	0.80	0.48	0.61	1			
Cl^-	0.26	0.81	0.82	0.86	0.83	0.78	0.33	0.51	0.71	1		
NO_3^-	0.47	0.18	0.16	-0.01	0.19	0.19	-0.03	0.26	0.14	0.02	1	
WQI	0.24	0.95	0.96	0.87	0.84	0.93	0.57	0.78	0.92	0.84	0.16	1

Hydrochemical classification

For the purpose of hydrochemical classification many graphical methods, have been used. All the methods designed to understand and identify the quality of water and its composition in different classes based on the dominance of certain cations and anions in solutions (24). The Piper diagram is the best of these methods due to many water analyzes data can be drawn on the same diagram and it can also be used to determine mixing of type's water and classification. In current study piper diagram prepared by AqQA software has been used to recognize the hydrochemical facies of groundwater in western part of Iraq. Back and Hanshaw (1965) have been suggested subdivisions of the tri-linear diagram to understand and identify the water composition in different classes based on the domain in which water type occur on the diagram segments Fig.4. The interpretation of distinct facies from the 0 to 10% and 90 to 100% domains on the diamond shaped cation to anion graph is more helpful than using equal 25% increments. It has been noted that 84% of water sample falls in zone of no dominant cation type, 14 % of water samples falls in zone of sodium-potassium type and 2% of water samples falls in zone of calcium type. Alkalis type of water ($Na^+ + K^+$) exceed the alkaline earth type of water ($Ca^{2+} + Mg^{2+}$) where as in anion strong acids ($Cl^- + SO_4^{2-}$) exceed the weak acids (HCO_3^-) which show non-carbonate hardness in all samples. Na^+-SO_4^{-2} and, Na^+- Cl^- facies, is a bulk groundwater type in the study area representing 51% and 31% from the total water samples respectively. Dominance Na^+-SO_4^{-2} facies reflects the presence of the evaporate minerals, which are the main source of these ions and it is evidence that represent recharge areas. Na^+- Cl^- water type reflecting the effect of geological formations on the quality of studied groundwater which comprises halite. At few locations, the groundwater belongs to mixed Mg^{2+}- Ca^{2+}-SO_4^{-2} and mixed Mg^{2+}-Ca^{2+}- Cl. Mixed water types (Ca^{2+} Mg^{2+} Cl^-) suggest the dissolution carbonate-bearing minerals and ion exchange process.

Evaluation of groundwater quality

In the study area, evaluation of groundwater quality was carried out to identify its potability and irrigation purposes. Chemistry of groundwater has been used as a tool for predicting water quality for drinking and irrigation purposes (7).

Water potability

Water Quality Index with the help of GIS technique has been applying in the present study to assess suitability of groundwater quality for drinking purposes. For the calculating water quality index (WQI) eighty four (84) groundwater samples were collected along the 138.500 square km of the study area. These samples were analyzed using the methods shown in the Table 2. The Iraqi Drinking Water Standars (1992) was taken into consideration for the calculating WQI. The first step to calculate the water quality index is to set specific weights for chemical parameters and their relative importance in drinking water, as shown in Table 4. The highest weight was given to nitrite parameter (NO_3^-) due to the importance of the role played in water quality than others [12]. Lesser weightage is assigned to sodium Na^+, magnesium Mg^{2+} and calcium Ca^{2+} because it is being harmless to drinking groundwater quality. The relative weight ***(Wi)*** is calculated in the second step using the equation number one given below:

$$Wi = wi / \sum_{i=1}^{n} wi \quad (1)$$

Where, ***Wi*** relative weight, ***wi*** the weight of each parameter and ***n*** is the number of parameters. The quality rating scale ***(qi)*** was calculated in the third step by dividing each chemical parameter concentration ***(Ci)*** by its respective Iraqi standards for drinking ***(Si)*** as shown in Table 4 and the result multiplied by 100 using the following equation.

$$qi = (Ci / Si) * 100 \quad (2)$$

In the fourth step ***SIi*** is calculated for each chemical parameter using the following relationship

$$SIi = Wi \,.\, qi \quad (3)$$

Finally, Water Quality Index (WQI) was calculated using the following equation:

Table 4.Shows the calculated relative weight *(Wi)* values of each parameter.

Chemical parameters	Sl	Weight(wi)	Relative weight (Wi)
TDS	**500**	**4**	**0.129**
pH	**6.5**	**2**	**0.065**
Ca^{2+}	**75**	**2**	**0.065**
Mg^{2+}	**30**	**2**	**0.065**
Na^+	**20**	**2**	**0.065**
K^+	**10**	**3**	**0.097**
Cl^-	**200**	**3**	**0.097**
SO_4^{2-}	**200**	**4**	**0.129**
HCO_3^-	**200**	**4**	**0.129**
NO_3^-	**40**	**5**	**0.161**
		∑ wi= 31	**∑ Wi= 1**

$$WQI = \sum SIi \quad (4)$$

According to (12) the water quality index values were classified into five types as shown in the Table 5. When comparing the results of the calculated water quality index with the Ramakrishnalah, *et al.* (2009) classification it shows that 13% of the water samples fall in the second category (II), which represents the quality of good water and 9% of the water available well falls under the third category (III), representing of poor water quality. Twenty-eight (28%) percent of the water sample falls in category IV which indicates that the water quality is very poor. Fifty (50%) percent of water samples fall in category V indicating unsuitable water for drinking purposes.

Table 5.Percentage of studied water sample based on WQI value

WQI value	Class	Water quality	Well Number	Percentage of studied sample
<50	**I**	**Excellent**	**Nil**	**Nil**
50-100	**II**	**Good**	**1,2,3,4,24,30,41,72,79,80,82**	**13%**
100-200	**III**	**Poor**	**5,28,29,31,32,33,54,57**	**9%**
200-300	**IV**	**Very poor**	**6,17,19,25,27,51,55,60,63,64,65,69,83**	**28%**
>300	**V**	**Unsuitable**	**8,20,21,22,23,26,34,35,36,37,39,40,42, 43,44,45,46,47,48,49,50,52,53,56,59,61,62,66,67,68,70,71,73,74,75,76,77,78, 81,84**	**50%**

GIS data base generation for water quality

Generally, soluble ions and salts are the main components of groundwater. Calcium, magnesium, sodium, bicarbonate, sulphate and chloride are major ions in drinking water. Potassium, carbonate, nitrate and iron are found in low concentrations. These ions are beneficial, but, it may cause severe problems for humans when if increased. The results of chemical analysis of water samples were transferred to the GIS environment to create a water quality data base in the study area, and the spatial distribution map of each parameter has been generated using the Arc GIS 9.3 software, Spatial Analyst extension, and inverse distance weight (IDW) interpolation methods as shown in the following Fig. 5 to 15. The EC values of the groundwater vary within a range 625-6654 μS/cm (Fig. 5). It is clear that the electrical conductivity values increase to the northeastern direction and 80% from the water samples exceed the Iraqi standard for drinking water. Total dissolved solids (TDS) indicate that the concentrations of dissolved ions in water and the general nature of water salinity. The TDS values ranged from 780 to 10790 mg/l (Fig. 6) and all water samples exceed the Iraqi drinking water standards except few site located in the middle part of the study area.

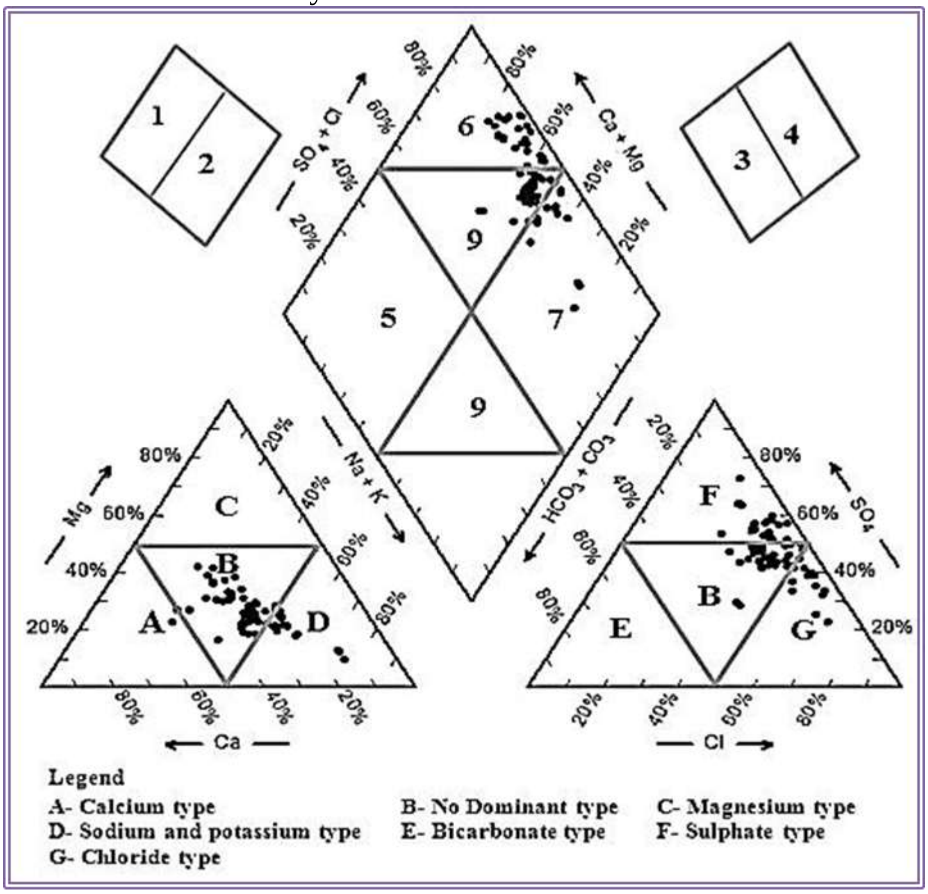

Fig.4. Piper diagram showing the chemical composition of groundwater in the study area

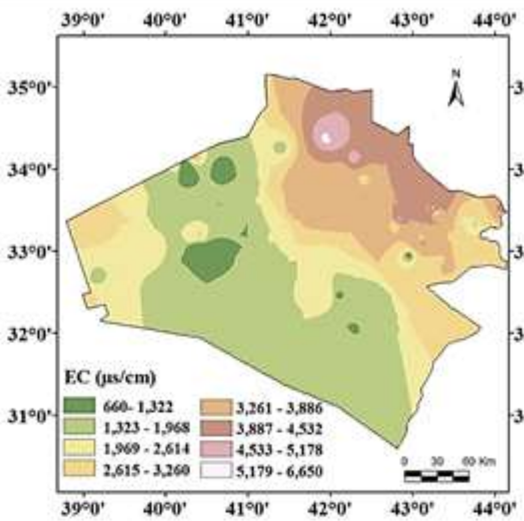

Fig.5. Spatial distribution map of EC

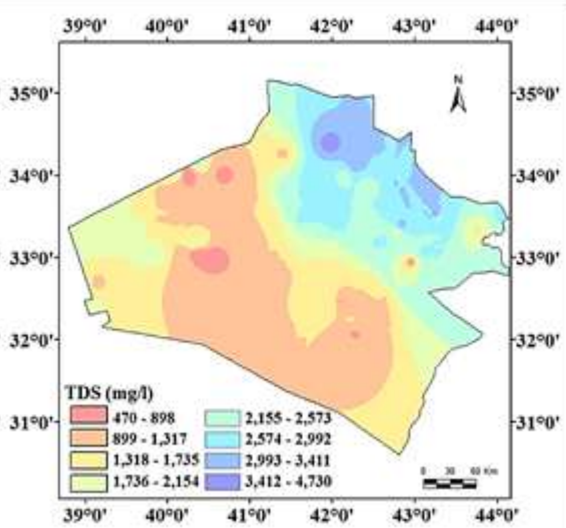

Fig.6.Spatial distribution map of TDS

pH parameter is one of the important factors in groundwater assessment and is an estimate of the amount of chemical components that can be dissolved in water. The pH of the groundwater samples in the study area ranged from 7.1 to 8.2 (Fig.7) indicating alkaline nature of groundwater. Calcium (Ca^{2+}) concentrations of groundwater were determined as 30 to 348 mg/l. Spatial distribution map of Ca^{2+} ions has been prepared as shown in (Fig.8). It has been observed that only 17% within permissible limit of Iraqi drinking water standards whereas all of the other samples exceeding the limits. Magnesium (Mg^{2+}) concentrations of groundwater samples varied from 10 to 186 mg/l (Fig. 9). Calcium (Ca^{2+}) can be derived from dissolution of carbonate minerals (e.g., calcite, dolomite, and aragonite) as well as carbonate cement within formations. The primary source of Mg^{2+} in natural water is ferromagnesian minerals (olivine, diopside, biotite, hornblend) within igneous and metamorphic rocks and magnesium carbonate (dolomite) in sedimentary rock (16). Potassium (K^+) concentrations of groundwater are found within the permissible limits of Iraqi drinking water (Fig.10).

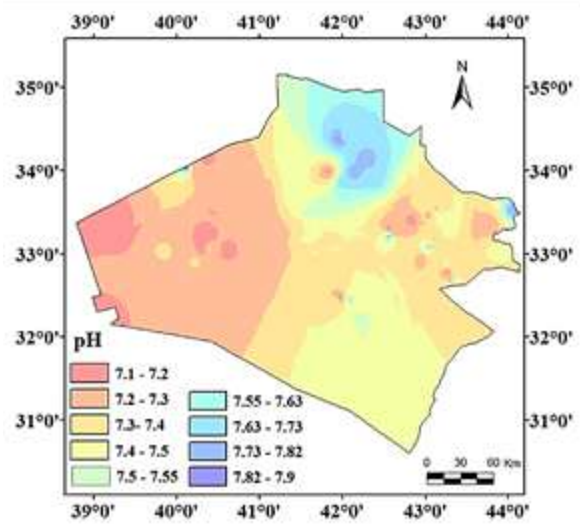

Fig.7.Spatial distribution map of pH

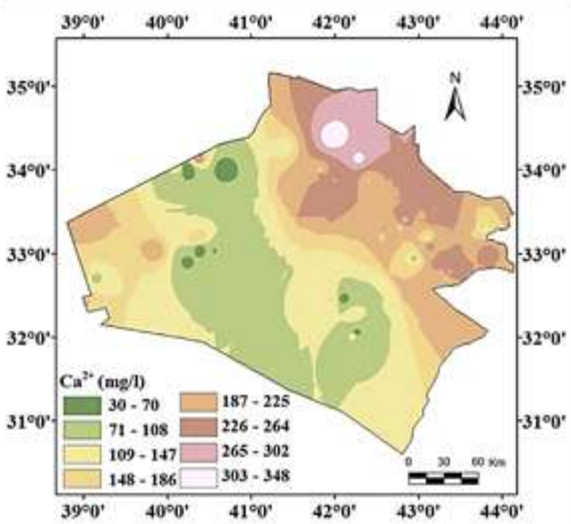

Fig.8.Spatial distribution map of Ca^{2+}

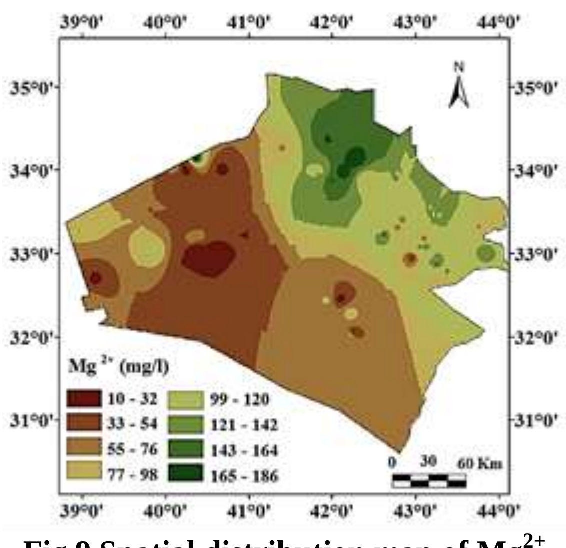

Fig.9.Spatial distribution map of Mg^{2+}

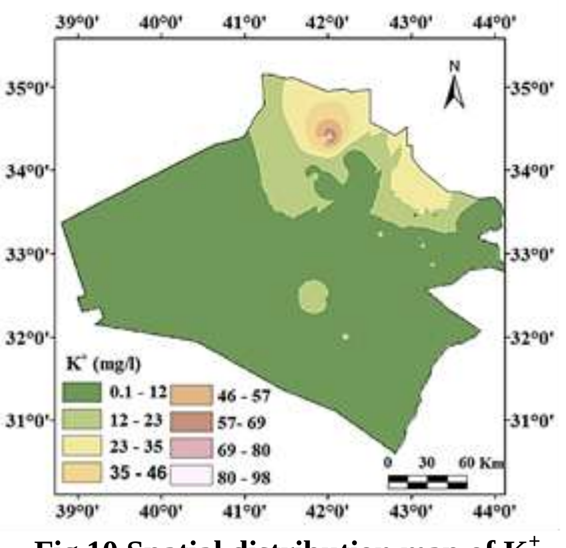

Fig.10.Spatial distribution map of K^+

Sodium ion (Na^+) is usually found in high quantities in the groundwater samples because of most soils and rocks contain and easy to dissolve it. The maximum permissible limits for sodium ion according to Iraqi standards are 200 mg/l. Hence 80% of the water samples are within the Iraqi drinking water standards (Fig. 11). Bicarbonate (HCO_3^-) values in groundwater samples range from 15 to 511 mg\l as shown in Fig. 12. Accordingly, 56% of the total samples are exceeding the limits of Iraqi drinking water standards. Chloride (Cl^-)

component is distributed in various forms widely in each type of rock in different forms. Thus, it is commonly high in groundwater, wherever the high temperature and less rainfall (12). The chloride contents were very high in the study area, only 17% are within the permissible limits (Fig.13). Sulphate (SO_4^{-2}) contents of groundwater samples ranged from 37 to 1531 mg\l (Fig.14). Consequently, most of the groundwater samples exceed the permissible limits of Iraqi drinking water standards

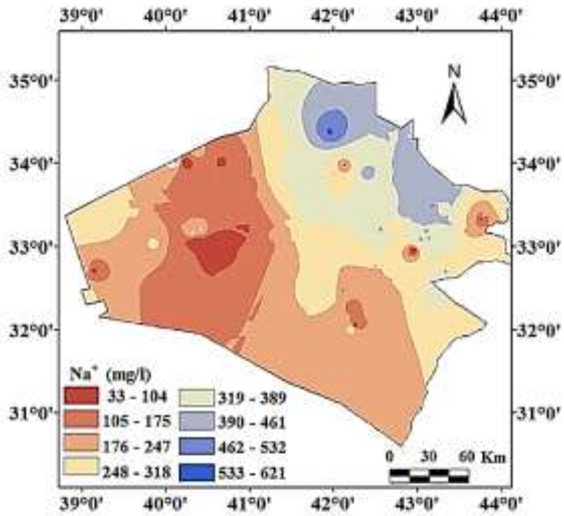

Fig.11.Spatial distribution map of Na^+

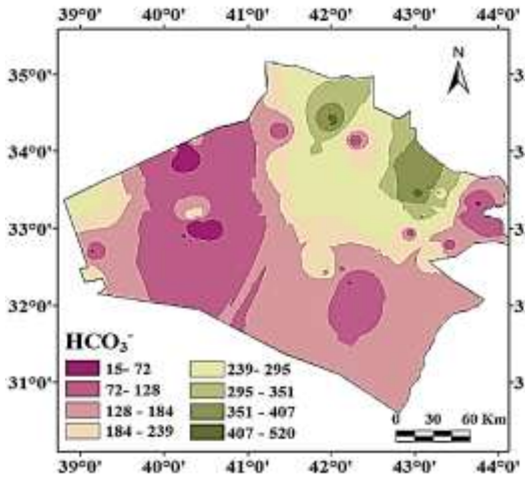

Fig.12.Spatial distribution map of HCO_3^-

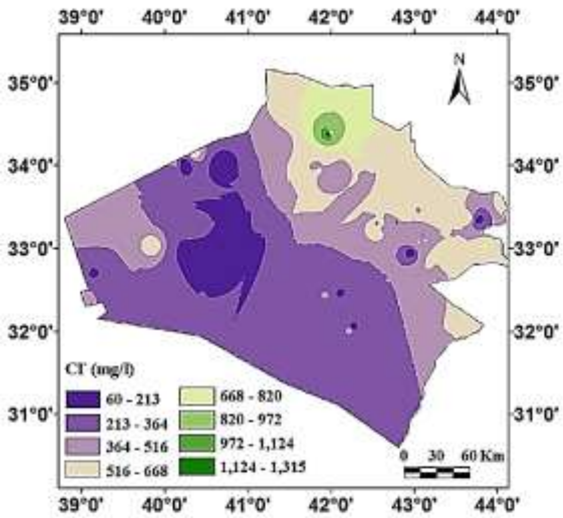

Fig.13.Spatial distribution map of Cl^-

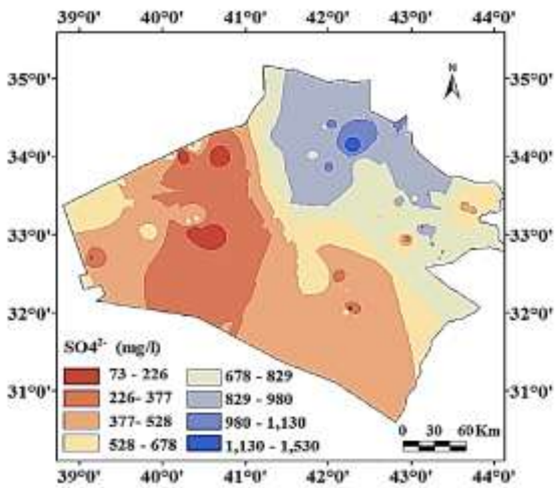

Fig.14.Spatial distribution map of SO_4^{-2}

The values of Nitrate (NO_3^-) vary from 0.1 to 16 mg/l in groundwater samples as shown in Fig.15. According to (8), the main source of nitrate in the groundwater is either excessive use of fertilizers sewage or decomposition of organic substances or waste.

Generation of Water Quality Index (WQI) map

According to calculated WQI values, the spatial distribution of water quality index map has been produced using reverse interpolation technique (IDW). It can be considered as a general suited map for providing information and observation data visually about irrigation water in the study area represented by the spatial distribution of the index of the water quality for irrigation. This map enabled decision makers to evaluate water for drinking purposes easily and for large areas because it is show the spatial distribution of groundwater quality as an index value. In current study all calculated WQI values have been transferred to GIS environment to create spatial distribution map of WQI. Fig.16 shows the spatial distribution map which has been observed that 17% of the studied water samples fall in the second category (II), which represents the quality of good water. The water in the study area is getting worse toward the north-east and it became unsuitable water for drinking purposes as shown in Fig. 16.

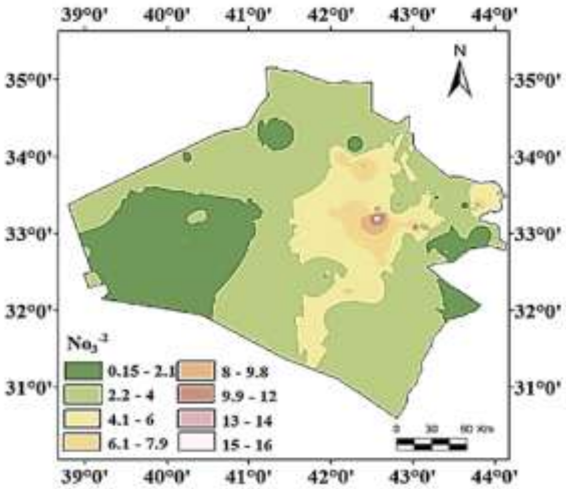

Fig. 15.Spatial distribution map of NO_3^{2-}

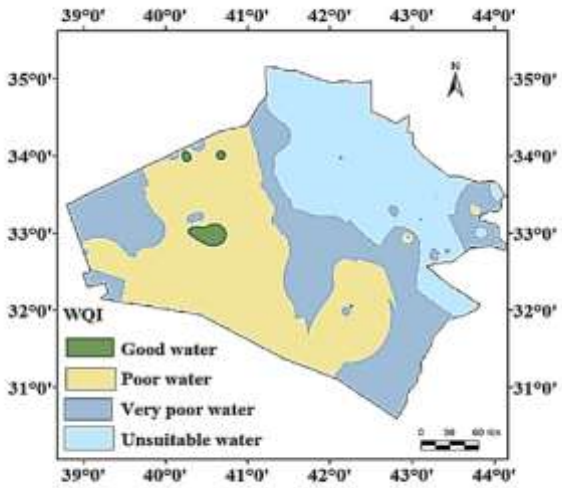

Fig.16.Spatial distribution map of WQI

Water Quality for Irrigation Purposes

Parameters such as electrical conductivity (EC), Sodium percent (Na %), Sodium Adsorption Ratio (SAR) and Standard diagrams (Wilcox, 1948 and USSL, 1954) were used in the present study to assess the suitability of water for irrigation purposes in the study area.

Electric Conductivity

is a good measure of the salinity hazard on agricultural crops because it reflects the amount of total dissolved salts in the groundwater. As indicated in Fig.5 the values of Electrical Conductivity (EC) in the studied wells vary between 660µS/cm to 6650 µS/cm. According to (25) classification as indicated in Table (6) that 72.6 % of groundwater samples are very high salinity and it is unsuitable for irrigation.

Percent of sodium (Na %) is a common parameter in all natural waters to assess its suitability for agricultural purposes and to its impact on some soil physical and chemical properties (25). A high proportion of sodium in irrigation water will raise the exchange of magnesium and calcium with sodium and therefore it causes permeability and impairment of the filth of soils (8) (20) & (26). This makes it difficult to plow the soil and is not valid for the emergence of seeds (21) & (10). The reason for this is that the presence of sodium in the soil in an exchangeable form replaces calcium and magnesium causing the dispersion of soil particles. This dispersion leads to breakdown of soil aggregates and becomes difficult and compact when dry (23). Also, when sodium is present in water with carbonate, it can lead to the formation of alkaline soil, whereas if present with chloride forms it can lead to saline formation. Both soils do not help plant growth (10).

Table 6.EC (µS/cm) Classification of Groundwater according to (28)

Conductivity Range	Quality	Well Number	Percentage of sample In the study area
< 1000	Safe	1,2,3,4,30,41,72,79,80,82	11.9
1000 – 1500	Tolerable	31,32,33,57	4.8
1500 – 2000	Tolerable to some extent	5,28,29, 54,58,60	7.1
2000 – 2500	Intolerable	63,26,25	3.6
> 2500	Health Hazard	6,7,8,9,10,11,12,13,14,15,16, 17,18,19,20,21,22,23,27,34, 35,36,37,38,39,40,42,53,55, 57,61,62,63,64,65,66,67,68, 69,70,71,73,74,75,76,77,78, 81,83,84	72.6

The sodium ratio is calculated using equation (5) given below.

$$Na\% = \left(Na^{+} + K^{+}\right)*100 / Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}$$

In the study area the percentage of sodium ranges from 21% in well number 83 to 76.98 % in well number 31. The calculated sodium percent were transferred to the geographic information systems (GIS) platform and spatial distribution map have been created (Fig.17). Sample points are plotted against specific conductance in Wilcox diagram (Fig. 18). It shows that the groundwater of the study area has bad condition and it is unsuitable quality in 50% of the water sample, excellent quality in 4%, good to permissible quality in 20%, doubtful to unsuitable quality in 25% and 1% excellent quality (Table 7). It is noted that 17% of the water sample was out of the limit of diagram because of the high value of the EC.Sodium Adsorption Ratio (SAR) also needs to be considered for evaluation of groundwater suitability for irrigation. The SAR recommended by the salinity laboratory of the US Department of Agriculture is calculated using the following Equation:

$$SAR = Na^{+} / \sqrt{(Ca^{2+} + Mg^{2+}) / 2)}$$

SAR values greater than 18 indicate groundwater is unsuitable for irrigation purposes (14). The calculated values of SAR in the study area varied from 0.9 to 10.3 meq /l which have been transferred to GIS and spatial distribution map has been generated as shown in Fig. 19. The data has been plotted on the US salinity diagram which is taken electrical conductivity (EC) as salinity hazard and sodium adsorption ratio (SAR) as alkalinity hazard as shown in Fig. 20 and summarized in Table 8.

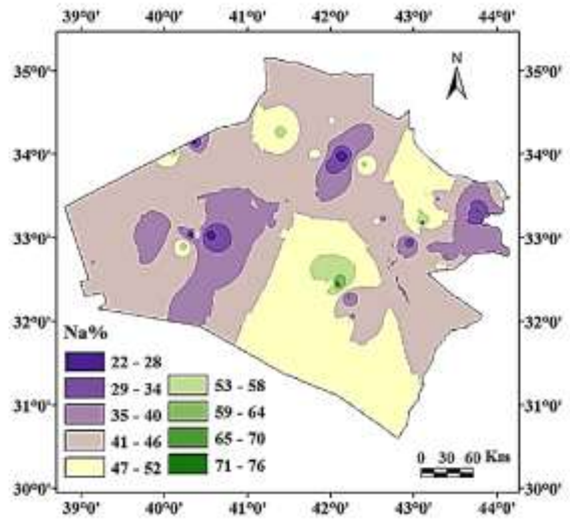

Fig.17. Spatial distribution map of Na%

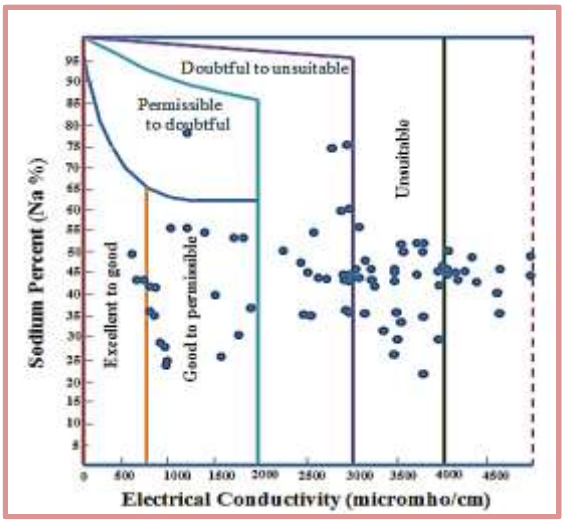

Fig.18.Diagram for irrigation water quality classification (Wilcox, 1948)

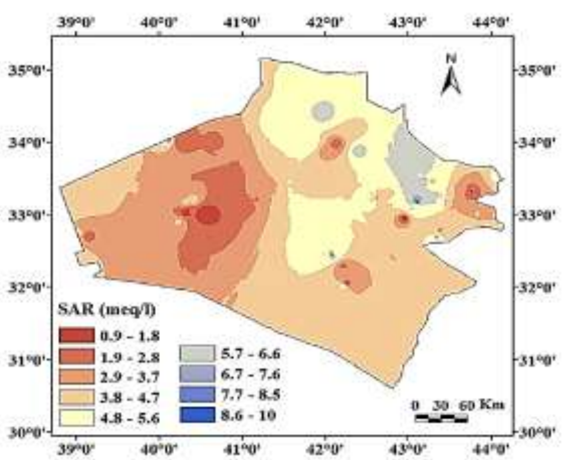

Fig.19.Spatial distribution map of SAR

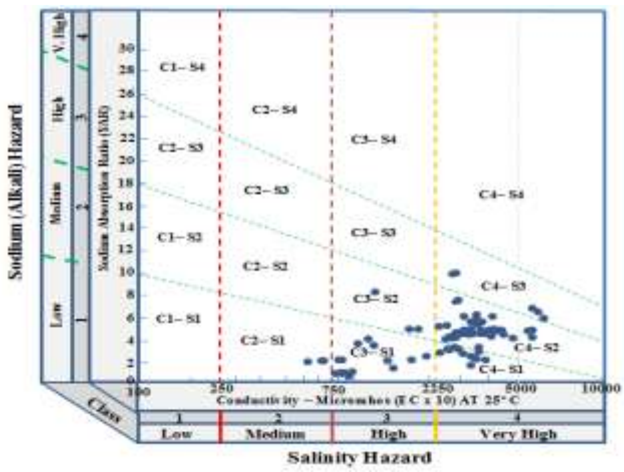

Fig.20.Diagram for irrigation water quality classification (USSL, 1954)

It shows that 26 % of samples fall in C3-S1, C3-S2 and C2-S1 fields, indicating medium- to high-salinity and low-alkalinity water; this can be used for irrigation, where moderate amount of leaching occurs and moderate permeability with leaching soil. Furthermore 75 % of the water sample fall in C4-S1, C4-S2 C4-S3 field, indicating very high salinity and low to medium sodium hazard and it is not suitable for irrigation under

Table 7.Classification of groundwater in the study area

Wilcox, 1948	Well No	% of sample	USLL, 1954	Well No	% of sample
Excellent	2,3,24	3.6	C3-S1	1,4,5	19.0
Good to permissible	1,4,5,28,29,30, 32,33,41,54,57, 58,60,72,79, 80,82	20.2	C2-S1	2,3,24	3.6
Doubtful to unsuitable	6,7,8,10,12,13, 14,16,19,25,26, 27,28,51,62,63, 64,65,67,71,77,	25.0	C4-S2	6-23,25,26,27, 34,36,37,39,40,42 ,44-50,52, 56,59,61,66,69,70 ,71,75,77,78,84	54.8
Permissible to Doubtful	31	1.2	C4-S1	35,43,55,62-65, 67,68,73,76,83	14.3
Unsuitable	9,11,15,17,18,20, 21,22,23,34,35,36, 37,39,40,42,43,44, 45,46,47,48,49,50, 52,53,55,56,59,61, 66,68,69,70,73,74, 75,76,78,81,83,84	50.0	C3-S2	31,58,60	3.6
			C4-S3	38,51,53,74,81,	6.0

normal condition and further action for salinity control is required in remediation such problem. Groundwater samples fall in the high salinity hazard class (C3) may detrimental effects on sensitive crops and adverse effects on many plants. Such areas require careful management practices. Based on the classification scheme of USSL and Wilcox spatial distribution map of irrigation water quality of the study area has been generated as shown in Fig. 21 and Fig. 22 respectively. Generally, it has been observed that the water wells located in the northeast of the study area cannot be used for irrigation purposes while in the center and western part of the study area the water wells can be used in irrigation purposes where high topography ground level and deep groundwater.

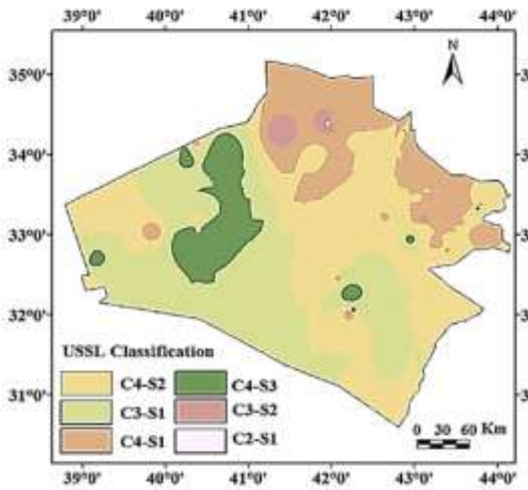

Fig.21.Spatial distribution map of USSL, 1954 classification

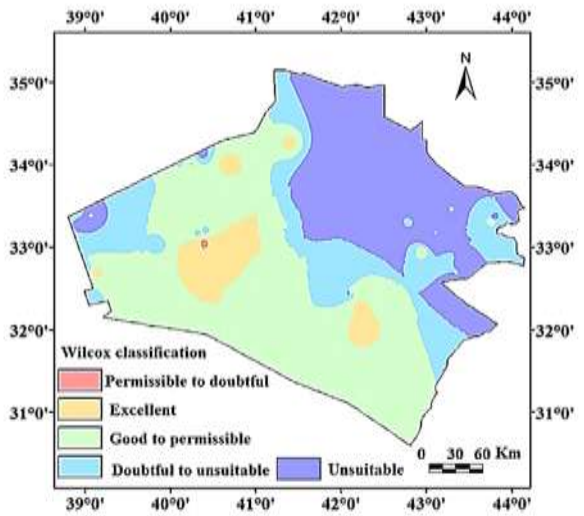

Fig.22.Spatial distribution map of Wilcox, 1948 classification

CONCLUSION

The spatial distribution of water quality index (WQI) mapping was carried out in the present study using the Arc GIS 9.3 software, Spatial Analyst extension, and inverse distance weight (IDW) interpolation method. This map shows the spatial distribution of groundwater quality as index value. Hence it is provides a comprehensive view and gives the result that describes the state of the groundwater and contribute to support the decision-makers to identify the ideal sites for good groundwater to meet future needs in the study area. An analysis of the results of the WQI maps confirms that the groundwater in the study area becomes suitable for drinking purposes in the central part and towards the south-west where high tobography ground level and deep groundwater table. Irrigational suitability of groundwater in the study area was evaluated also by EC, SAR, Na %, USSL classification and Wilcox classification. It was found that the water in the studied area is suitable for irrigation purposes in the central part and its quality become unsuitable for irrigation purposes in the northeastern direction where low tobographyground level and shallow groundwater table.

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