EVALUATION OF GROUNDWATER QUALITY FOR DRINKING PURPOSE IN BASRAHGOVERNORATE BY USING APPLICATION OF WATER QUALITY INDEX

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Abstract:

This study aims to apply Water Quality Index(WQI) to evaluate quality of groundwater samples collected from Basrah governorate south of Iraq. The samples were collected from (29) wells located in different districts in Basrah governorate (Safwan, Zubair and Um-Qasr) during Summer season of 2015. The groundwater samples were analyzed forpH, electrical conductivity, total dissolved solids and other major ions. For calculating WQI, eleven parameters; pH, EC, TDS, Total hardness as $CaCO_3$, Calcium, Magnesium, Sulphate, Chloride, Nitrate, Sodium and Potassium have been considered. The suitability of groundwater in the study area for human drinking purpose was achieved by WQI depending on guideline values of World Health Organization (WHO2011) for chemical parameters. Then, the weight (Wi) were assigned to the parameters based on their influence in human health. The results showed that the (WQI) values for the groundwater of study area varied from poor to unsuitable for human drinking purpose.

Keyword: Evaluation, Groundwater, Water Quality Index

تقييم نوعية المياه الجوفية لأغراض الشرب في محافظة البصرة باستخدام تطبيق مؤشر جودة المياه

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الخلاصة

تهدف الدراسة الحالية الى تطبيق مؤشر جودة المياه (WQI) لتقييم عينات المياه الجوفية في محافظة البصرة.تم جمع العينات في موسم الصيف لعام 2015 من (29) بئرا من اقضية مختلفة (سفوان، الزبير و ام قصر) في محافظة البصرة . تم تحليل عينات المياه الجوفية كيميائياً من حيث درجة الحموضة ، التوصيل الكهربائي، المواد الصلبة الكلية والايونات الرئيسية . لحساب مؤشر نوعية المياه (WQI) ، تم اعتبار احد عشر عاملاً وهي درجة الحموضة (pH) ، المواد الصلبة الكلية (TDS) ، التوصيلية الكهربائية (EC)،العسره الكلية بدلالة كاربونات الكالسيوم $CaCO_3$ ، الكالسيوم، المغنيسيوم ، الصوديوم، البوتاسيوم ، الكبريتات ، الكلوريدات ، النترات لغرض النظر فيها . وقد تحققت ملائمة المياه الجوفية (WQI) في منطقة الدراسة لغرض الشرب البشري اعتمادا على القيم الارشادية لمنظمة الصحة العالمية (WHO) للمعاملات الكيميائية التي تم اعتمادها. و قد تم تعيين وزن (Wi) للمعاملات على اساس مدى تأثيرها الملحوظ على صحة الانسان الى حد كبير . اظهرت نتائج الدراسة ان (WQI) للمياه الجوفية لمنطقة الدراسة تتغير من رديئة الى غير مناسبةلأغراض شرب الانسان.

الكلمات المفتاحية : المياه الجوفية ، مؤشر جودة المياه ، تقييم

1. INTRODUCTION

Water in all type in important for life especially human's life. Groundwater is one of the most popular resources for human activities like drinking, domestic uses, industrial, construction and irrigation. Groundwater has many features make it better than surface water from numerous aspects. Generally, groundwater has a good quality and it is protected well from potential sources of pollution and less prone to seasonal variations. The development and increase of human's activities caused contamination of these water resources. Therefore, evaluation of groundwater resources quality is very important to ensure the safe use of water.WQI is defining as rating technique, which provides the composite influences of individual water quality parameter on the overall quality of water. It is used to reduce a large amount of water quality parameters to a single numerical value (Mahmood et al., 2013). Water quality and its suitability for drinking purposes can be examined and determine its quality index. The World Health Organization WHO (2011) standard for drinking purposes had been considered for calculation of WQI. In Iraq and other countries, many researchers had been studied the quality of groundwater for different purposes. Mahmood, et al.(2013) used water quality index to evaluate the groundwater at Basrah city for drinking and irrigation. Al-Mohammed and Mutasher (2013) appliedwater quality index to evaluate groundwater quality for drinking purpose in Kerbala city. Ahmed (2014) assessed the suitability of groundwater quality for drinking purpose for some villages around Darbandikhan district, Kurdistan region using water quality index. Ibrahiem (2015) applied WQI for selected area of dibdibba aquifer southern Iraq and represented the result as GIS maps to show the location of polluted areas.

2. Study Area Location

Basrah governorate is located in the southeastern part of Iraq overlooking the Gulf Arab head in the south-eastern part. It is located between the brackets along the 47°40' and 48°30' east and latitudes in 29° 50' and 31° 20'in the north. The estimated area of 19070 km^2which is equivalent to 762800 acres as shown in figure (1). The study area located within semi-arid zone. The prevailing climate in the study area is hot in summer with little rainfall in Winter. Study area located within earth formation named "Dibdibba formation ", which has a large extension over a large area in the southern part of Iraq plus some area in the middle west of Iraq. Dibdibba formation age is upper Miocene- Pliocene, and it is consisting of sand, gravel with pebbles of igneous rocks and white quarts somewhere cemented into a hard grit (Jassim and Coff. 2006). It Dibdibba formation characterized by unconfined to semi-confined condition, the average of its saturated thickness is about (14m) (Al-Basrawi, 2006).The depth of selected wells varied from (15-25)m and chose according to it availability in area.

3. Methodology

3.1 Groundwater Samples Collection

Water samples were collected from (29) wells distributed over different districts in governorate (Safwan, , Zubair and Un-Qasr) during two periods; the first period during the end of August (2015) through which sampling was from the wells belong to the General Authority for groundwater - Basrah branch, which is encoded by (W) while the second period was during the beginning of September (2015) through which sampling from the wells that its ownership belongs to Basrah environment directorate, which is encoded by (E). Figure (2) show the location of wells in the study area. The analyses of samples were done in the laboratories of Basrah environment directorate - division of environmental analysis. The groundwater samples are collected after (10) minutes of pumping to avoid unpredictable change in characteristics of groundwater according to standard procedures (APHA, 1995), the time of sampling was in the morning by using polyethylene bottles of one litter volume (Rainwater and Thatcher, 1960) and samples transported to the laboratory within the same day of collection. pH ,electrical conductivity (EC), total dissolved solid (TDS) and temperature (T°) were measured immediately by using portable electronic instrument model SD300. Sodium and potassium were measured by flame photometer; Calcium, Magnesium and total hardness measured by Titration with EDTA (Ethylene DiamineTetrscitic Acid); chloride measured by titration with $AgNO_3$ as well as sulphate measured by turbidity metric method. Bicarbonate measured by technicon in volumetric.

While the phosphate measured by Ascorbic acid method. Table (1) shows the maximum, minimum, average values of the chemical parameters for the groundwater of study area.

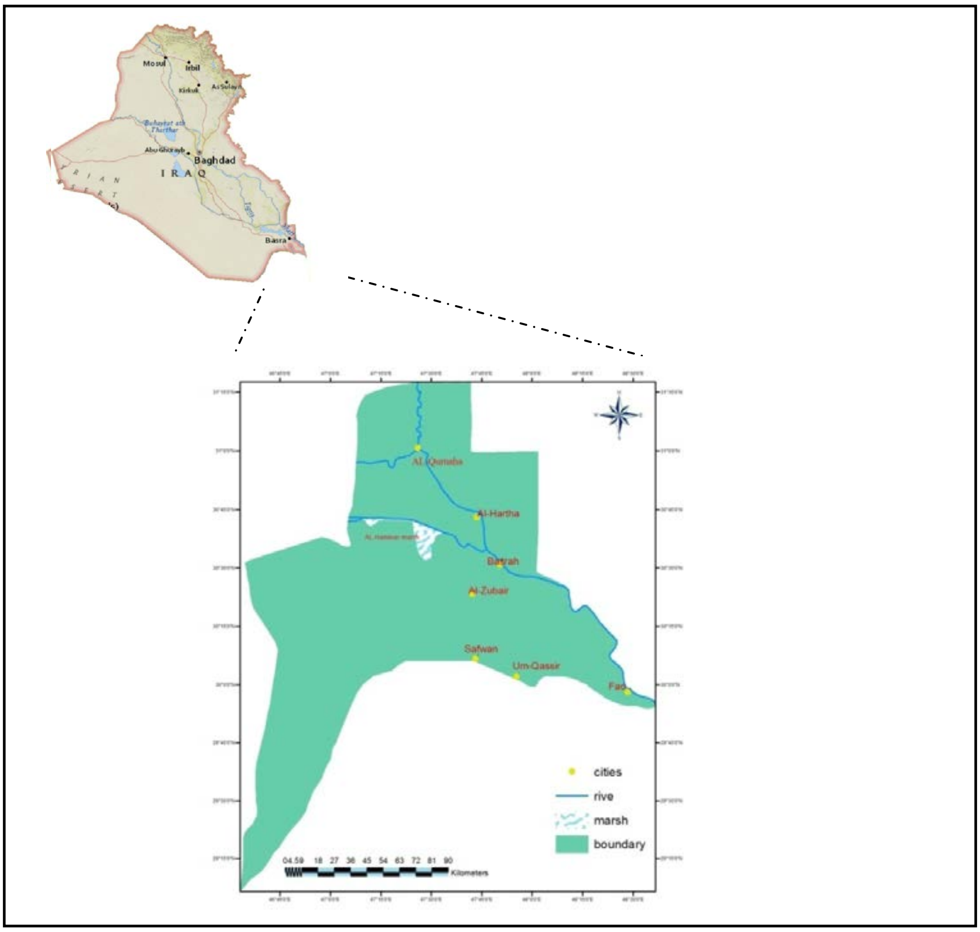

Fig.1. Location of Basrah Governorate

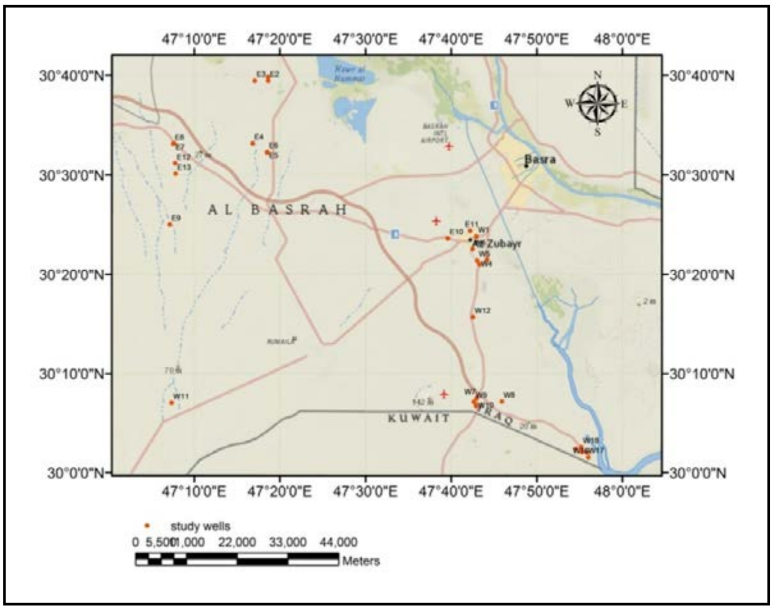

Fig.2.Location of Groundwater Wells of the study area

Table1.Minimum, Maximum and average value of physical and chemical parameters of groundwater samples

Parameters	Minimum	Maximum	Mean value
pH	6.6	7.7	7.2
EC	4365.00	15750	8328
TDS	2182	13000	5167.5
TH(as CaCO3)	1360.6	5535.4	2259.1
Cl	380	4750	2185.4
HCO3	1215	4792	2163.2
SO4	700	4500	1317.2
NO3	8.75	53.79	27.5
Ca	359	1280	576.5
Mg	75	579	200.2
Na	320	4500	1814.8
K	22	66	36.1
PO4	0.08	2.68	0.36

3.2 Drinking water parameters

Eleven water parameters were determined and compared with the Iraqi standard (2009) and WHO (2011) as shown in thetable (2).

Table2. Water Quality Standards

Parameters	Iraqi standards (IQS) 2009	WHO Standards (WHO)2011
pH	6.5-8.5	6.5-8.5
EC (µS/cm)	1500	1500
TDS (mg/l)	1000	1000
T.H as $CaCO_3$ (mg/l)	500	500
Ca^{+2} (mg/l)	50-150	75-200
Mg^{+2} (mg/l)	50-100	30-150
Na^{+} (mg/l)	200	200-400
K^{+} (mg/l)	-	12
SO_4 (mg/l)	250-400	200-400
Cl^{-} (mg/l)	250-350	200-600
NO_3^{-} (mg/l)	50	10-45
PO_4^{-} (mg/l)	-	5

3.3Water Quality Index

Water Quality Index (WQI) considered the most effective tool to convey the water quality information in the simplest form to the public(Babaei et. al., 2011). WQI transforms large and complex information of raw water quality data into a simplified and logical form with different categories of water quality that reflects the overall water quality status. Water quality index was calculated depending on eleven parameters. The WQI had been calculating by using the drinking water quality standard recommended by World Health Organization (WHO, 2011).

To calculate WQI, the following steps were used:

1. First step : Each of 11 parameters (EC, PH, TDS, Cl, HCO_3, SO_4, NO_3, Ca, Mg, Na and K) had been given an assigned weight (wi) according to its relative importance in the overall quality of

water for drinking purposes as shown in table (2) ranging from (1) to (5). A maximum weight of (5) is given to the parameters SO_4, NO_3, Cl and TDS for their importance in water quality assessment, while a minimum weight value of (1) is given to the parameter K that plays an insignificant role in the water quality assessment(Channo, 2012)

2. Second step: finding the relative weight depending on the following equation (Rokbani et. al. 2011):

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

Where :
Wi = relative weight
wi= weight of each parameter
n= number of parameters

3. Third step : calculating the quality rating Qi using the equation:

$$Qi = \left(\frac{ci}{si}\right) * 100 \quad ....(2)$$

Where:
ci= concentration of each parameter
si= standard value of each parameters

4. The last step : is computing WQI using the following equations(Channo,2012)

$$WQI = \sum_{i=1}^{n} (Wi * Qi) \quad ....(3)$$

Where:
WQI= water quality index
Qi= rating based on the concentration of i^{th} parameter
Wi = relative weight of i^{th} parameter.

In the end of the last step, WQI is computed for each sample (each well).The water quality ratings on the basis of an index value for this WQI are summarized in table (4). Figure (3) shows the spatial distribution of water quality index in the study area

Table3. Water quality standards (WHO, 2011), assigned and relative weight value needed to calculate water quality index (WQI)

Parameters	Drinking Standard WHO 2011	Assigned Weight wi	Relative Weight Wi
PH	8.5	2	0.054
EC (mmohs/cm)	1500	3	0.081
TDS (mg/l)	500-1000	5	0.135
T.H as $CaCO_3$ (mg/l)	500	1	0.027
Ca^{+2} (mg/l)	75-200	3	0.081
Mg^{+2} (mg/l)	30-150	3	0.081
Na^{+} (mg/l)	200-400	4	0.108
K^{+} (mg/l)	12	1	0.027
SO_4 (mg/l)	200-400	5	0.135
Cl^{-} (mg/l)	200-600	5	0.135
NO_3^{-} (mg/l)	10-45	5	0.135
		$\sum 37$	$0.999 \approx 1$

Table4. WQI range and Type of Water Classification

Range	Type of water
< 50	Excellent water
50-100	Good water
100.1-200	Poor water
200.1-300	Very poor water
>300	Water unsuitable for drinking purposes

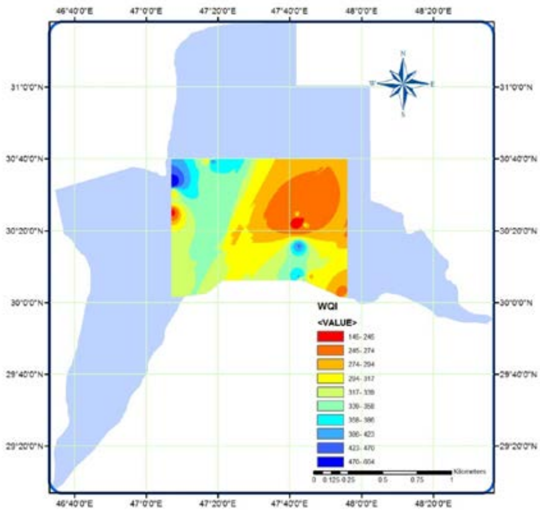

Fig.3. Spatial Distribution of Water Quality Index in study area

4.RESULT AND DISCUSSION

4.1. pH

pH is one of the most important water quality parameters. The maximum permissible limit for pH in drinking water as given by WHO is 8.5 while its minimum is 6.5. The pH values of the samples vary from 6.6 to 7.7 with a mean value of 7.7 (table1).This shows that the quality of groundwater of the study area is within the desirable limit. The variations in pH values in most due to the chemical composition of the Dibbdiba aquifers in the study area. Figure (4) shows the spatial distribution of pH in the study area.

4.2. Total dissolved solid (TDS)

The concentration of dissolved solids in groundwater is important to decide its suitability for drinking, irrigation or industrial purposes. Groundwater containing more than 1000 mg/l of total dissolved solids is generally referred as brackish water. The TDS concentration of the samples in the study area ranged from 2182 to 13000 ppm with a mean value of (5167.5) ppm. All water samples in the study area are fall under higher solids content. Figure (5) shows the spatial distribution of TDS in the study area.

4.3. Electrical conductivity (EC)

Electrical conductivity is an indirect measurement of salinity, and it is temperature dependent, where an increase in water temperature of one degree Celsius cause an increase in electrical conductivity by (2%) (Hem, 1985). The values of EC concentration of the samples in the study area were ranged between (4365-15750) µS/cm with a mean value of (8328) µS/cm. All water samples in the study area are lies above the maximum permissible limit for drinking water purposes. Figure (6) shows the spatial distribution of EC in the study area.

4.4. Sodium (Na^+)

The major source of sodium content in the groundwater is due to thepresence of salts. Desirable limit of sodium content in groundwater is (200- 400)mg/l. The maximum concentration of sodium in the samples of the study area was (4500) ppm and the minimum was (320) ppm with a mean value of (1814.8) ppm. Concentration excess of (200)ppm of sodium considered as unacceptable (salty) taste (Schmoll et al., 2006). Figure (7) shows the spatial distribution of Na in the study area.

4.5.Calcium (Ca^{2+})

The concentration of calcium ion in the study area was ranged between (359-1280) ppm with a mean value of (576.5) ppm. Permissible limit of calcium is (75-200) mg/l. the increase in calcium concentration due to the type of water carrying strata which have calcite, dolomite, gypsum and anhydrate minerals which have the direct effect in enriching the groundwater in the study area with calcium ions (Al-Mansory, 2000). Figure (8) shows the spatial distribution of Ca in the study area.

4.6. Magnesium (Mg^{2+})

Magnesium occurs in water mainly due to the presence of Olivine, Biotite, Augite and Talc minerals. The results showed that the magnesium of groundwater in the study area was ranged from (579) ppm to (75) ppm with a mean value of (200.2) ppm. Permissible limit of magnesium is (30-150) mg/l. The presence of Dolomite rocks in Dibdibaa quifer, which is the local sources of Magnesium result high values of magnesium ion concentration in the study area(Haddad, 1977). Figure (9) shows the spatial distribution of Mg in the study area.

4.7. Potassium(K^+)

Potassium is an essential for plants and animals. Potassium salt in most rock was not easily dissolved in groundwater (Stumm and Morgan, 1996). The maximum concentration of potassium in the samples of the study area was (66) ppm and the minimum concentration was (22) ppm with a mean value of (36.1) ppm. Figure (10) shows the spatial distribution of K in the study area.

4.8. Chloride (Cl)

Chloride is present in all natural waters at greatly varying concentration depending on the geochemical. The maximum value of Cl in the samples of the study area was (4750) ppm and the minimum value was (380) ppm with a mean value of (2185.4) ppm. When chloride concentration exceeding 600 mg/l gives water detectable or salty taste, which is objectable to many people (WHO, 2011). Figure (11) shows the spatial distribution of Cl in the study area.

4.9. Sulfate (SO_4^{2-})

Sulphates occur in natural waters at a concentration up to 50 mg/l. The presence of high concentration sulfate in drinking water causes noticeable taste and might contribute to the corrosion of distribution system(WHO, 2011).The recommended upper limit is 400 mg/l in water intended for human consumption. Sulfate concentration ranges from(4500) ppm to (700) ppm with a mean value of (1317.2) ppm in the samples of the study area. The high concentration of sulfate in groundwater of the study area is due to extend of Miocene sediments that containing gypsum and limestone (Qusay and Al-Mansory, 2003). Figure (12) shows the spatial distribution of sulphate in the study area.

4.10. Bicarbonate (HCO^{3-})

Dissolution of carbonate rocks causes a high concentration of bicarbonate (Hem, 1991). Bicarbonate is expressed in mg/l as$CaCO_3$ .The maximum concentration of bicarbonate in the study area was (4792) ppm and the minimum concentration was (1215) ppm with a mean value of (2163.2) ppm. Figure (13) shows the spatial distribution of HCO^{3-} in the study area.

4.11. Nitrate (NO_3)

The excessive concentration of nitrate in groundwater becomes toxic to human when exceeds 45 ppm. The maximum concentration of nitrate was (53.79) ppm and the minimum was (8.75) ppm with a mean value of (27.5) ppm in the samples of the study area. Figure (14) shows the spatial distribution of NO_3 in the study area.

4.12. Phosphate (PO_4^{3-})

It is an essential element for plant life, but when there is too much of it in water. Soil erosion is a major contributor of phosphorus to streams. The maximum concentration of phosphate in the study area was (2.68) ppm and the minimum concentration was (0.08) ppm with a mean value of (0.36) ppm. Figure (15) shows the spatial distribution of PO_4^{3-} in the study area.

The results of groundwater classification for (29) wells in the study area by using WQI method are shown in the table (5) and figure (16). Water quality index (WQI) varied from poor class to unsuitable class for drinking purpose.

Table5. WQI range and type of water classification in the study area

Sample	WQI	Type of water	Sample	WQI	Type of water
W1	248.3	Very poor	W16	243.43	Very poor
W2	308.39	Unsuitable	E1	304.98	Unsuitable
W3	271.53	Very poor	E2	452.99	Unsuitable
W4	209.03	Very poor	E3	301.21	Unsuitable
W5	144.97	Poor	E4	339.55	Unsuitable
W6	373.41	Unsuitable	E5	341.58	Unsuitable
W7	285.93	Very poor	E6	365.29	Unsuitable
W8	426.02	Unsuitable	E7	321.50	Unsuitable
W9	298.17	Very poor	E8	754.33	Unsuitable
W10	327.93	Unsuitable	E9	231.28	Very poor
W11	428.67	Unsuitable	E10	258.52	Very poor
W12	267.05	Very poor	E11	303.33	Unsuitable
W13	278.00	Very poor	E12	314.16	Unsuitable
W14	307.12	Unsuitable	E13	291.58	Very poor
W15	294.36	Very poor			

Conclusions

Generally, the concentration of salts and major ions in groundwater of the study area are high. Most of the water parameters are above the permissible limits of standards of WHO and IQS.

The overall view of the WQI (table 5) of the present study shows a higher WQI which exceeds the limitation of standards. The results of the study confirm the unsuitability of all samples in the study area for human drinking.

Acknowledgement: The authors acknowledge the general authority for groundwater- Basrah branch and Basrah environment directorate for providing and testing of samples.

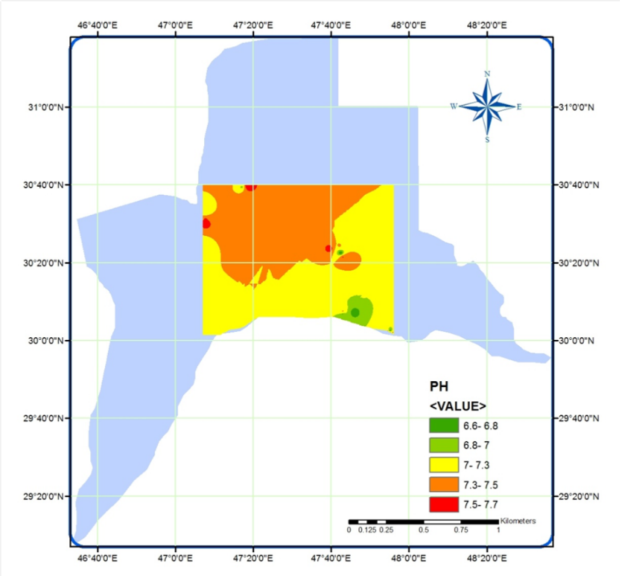

Fig.4.Spatial distribution of pH in the study area

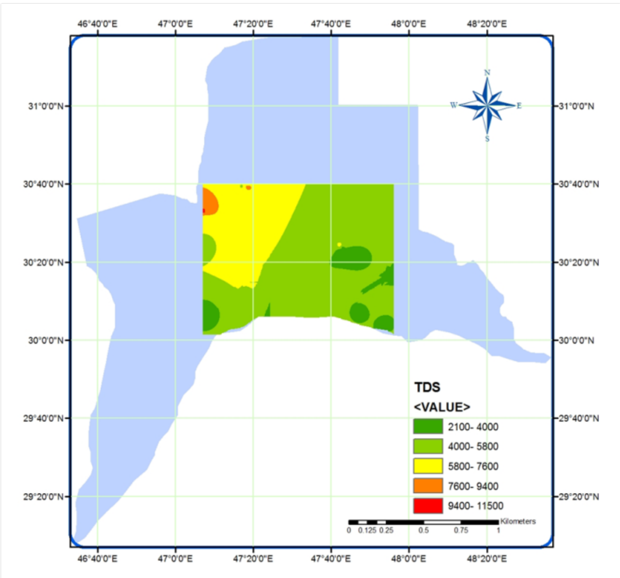

Fig.5. Spatial distribution of TDS in study area

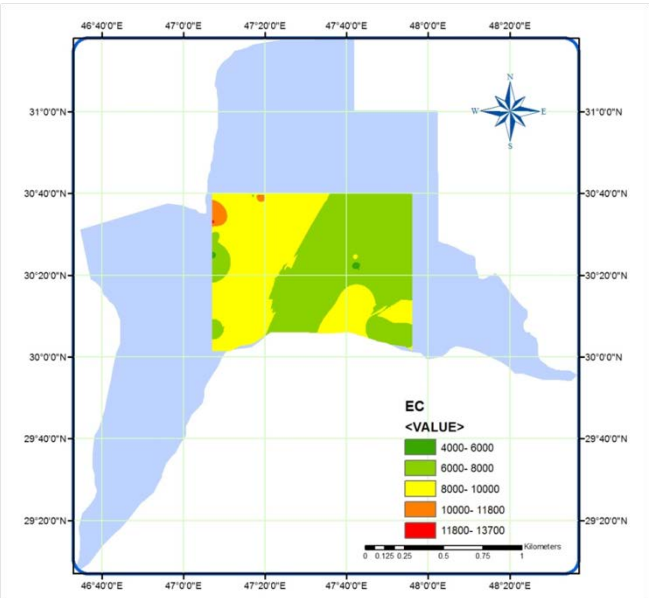

Fig.6.Spatial distribution of EC in study area

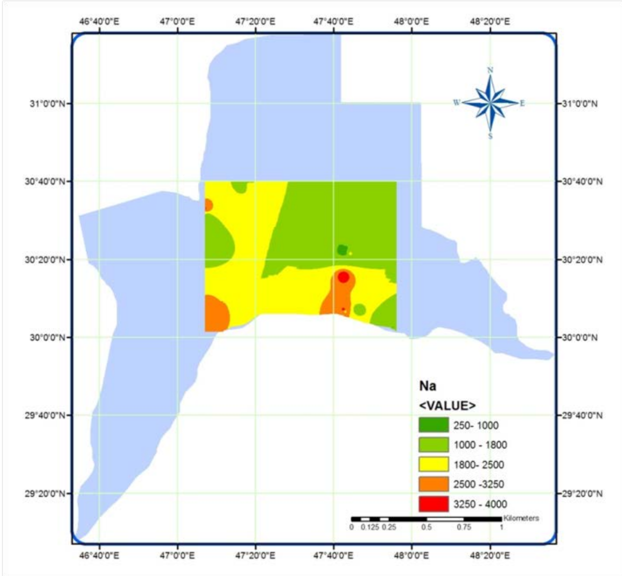

Fig.7.Spatial distribution of Na in the study area

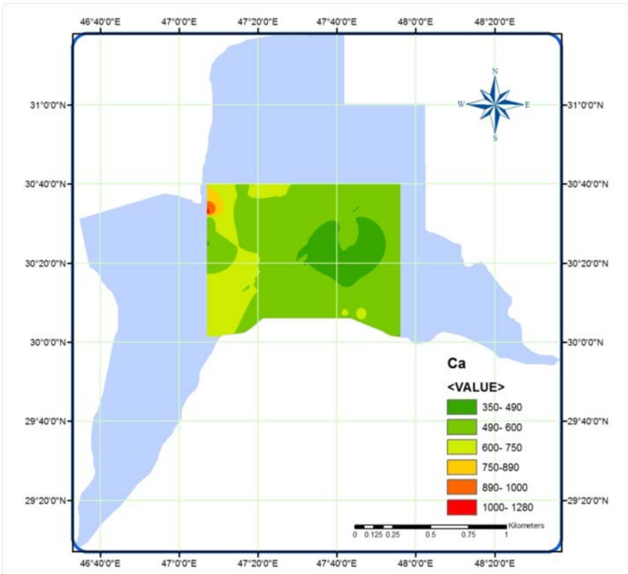

Fig.8.Spatial distribution of Ca in study area

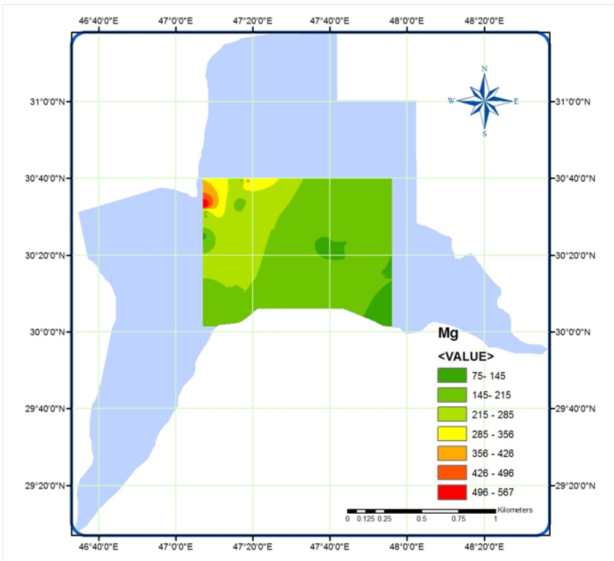

Fig.9. Spatial distribution of Mg in study area

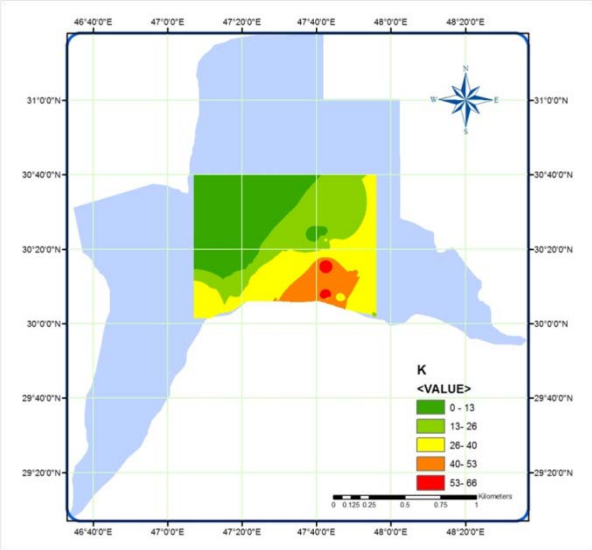

Fig.10.Spatial distribution of K in the study area

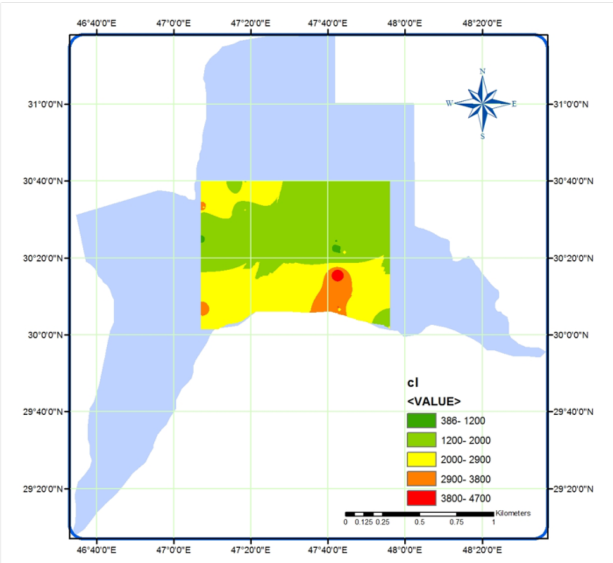

Fig.11. Spatial distribution of Cl in the study area

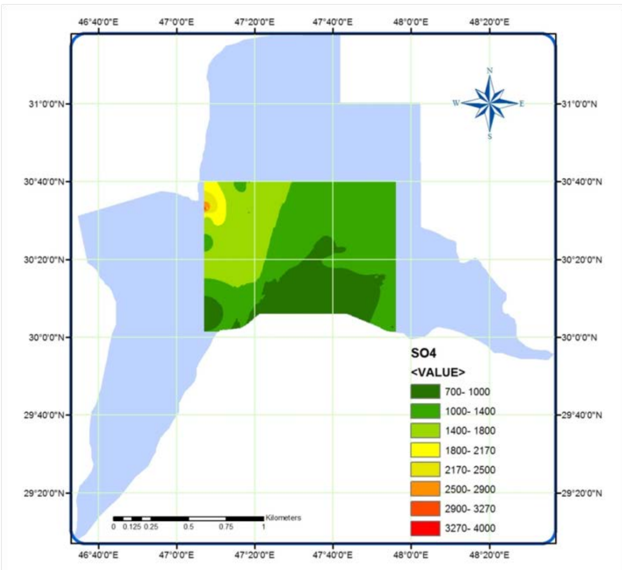

Fig.12. Spatial distribution of SO4 in the study area

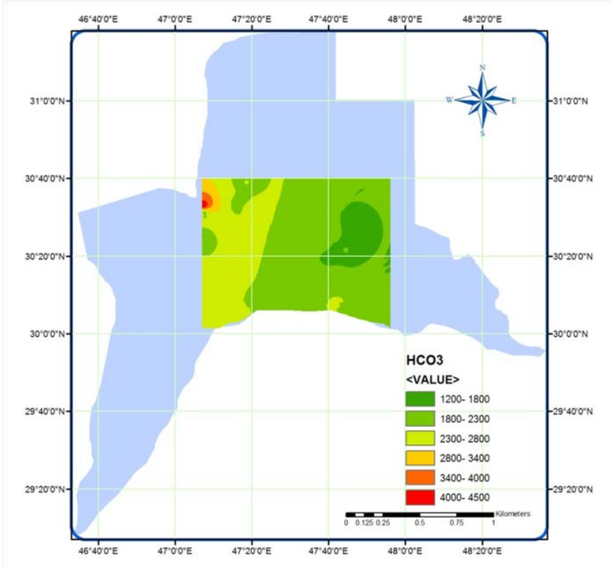

Fig.13. Spatial distribution of HCO_3 in the study area

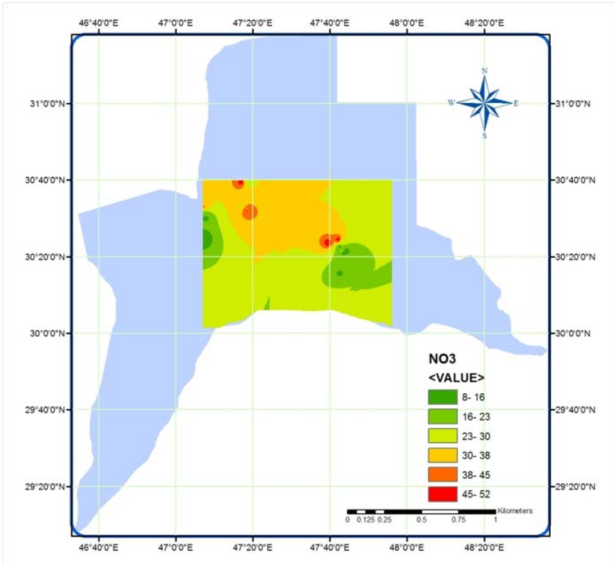

Fig.14. Spatial distribution of NO_3 in the study area

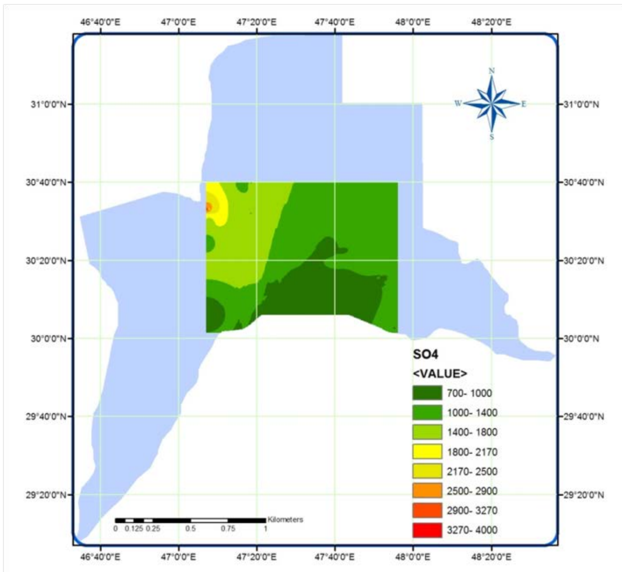

Fig.15. Spatial distribution of PO_4 in the study area

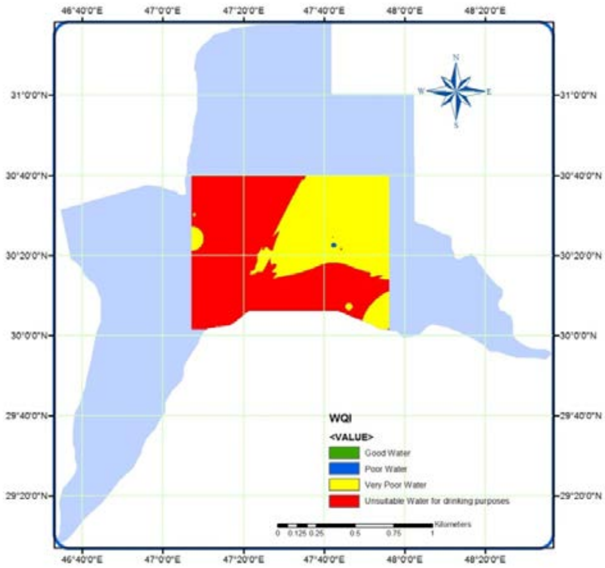

Fig.16. WQI classification for groundwater of study area

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