Assessment of the chemical quality of groundwater drinking resources using Geographic Information System mapping (A case study: Khorramabad city)

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Abstract

Quality of groundwater for drinking was determined by its chemistry parameters. The purpose of this study was analysis the chemical quality of groundwater drinking resources in Khorramabad city. The ground water samples were analyzed for physico-chemical parameters like Electrical Conductivity (EC), Hydrogen ion concentration (pH), Bicarbonate (HCO3), Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K), Sulphate (SO4), and Chloride (Cl). The Geographical Information System using Inverse Distance Weighted (IDW) was used to prepare the distribution map of different groundwater quality status based on selected parameters in Khorramabad city. The results of study show that the groundwater samples in the springs and wells don’t have deviation from water quality standards and the physio-chemical parameters values indicated good quality water for drinking. It could be helpful if the bacteriological contamination will be investigated as an effective factor on groundwater quality.

Keywords: Drinking water, Groundwater resources, water quality, Geographic Information System, physicochemical parameters.

Introduction

Access to safe and adequate drinking water has been an important national goal in different countries. On the other hand, the possibility of microbial contamination and lack of control water quality chemicals is of concern to health authorities in societies. In our country, water requires will increase every day. This is not only due to population increase, but also for other uses of health, agricultural and industrial (Rahmani et al, 2012). Groundwater resources are the most important sources of drinking water in many communities. Groundwater resources are highly essential to the survival of human beings, particularly in areas where other sources of potable water are lacking. However, many sources of contamination contribute to the impairment of this precious resource (Balathandayutham et al, 2015). All groundwater contains minerals carried in solution, the type and concentration of which depend upon the surface and subsurface environment, rate of groundwater movement and source of groundwater (Prasad et al 1999; Umar et al, 2003; Venkateswaran and Deepa, 2015).

Accordingly, the major sources of spot and dispersive contaminants arising from human activities on the ground and penetration of these contaminants into the ground tend to reduce the quality of the ground water (Balathandayutham et al, 2015). In addition, the cation and anion concentration depends upon the solubility of the minerals present in the formation and the time duration of water in contact with the rocks and the amount of dissolved CO2 present in the water (Viessman et al, 1989; Venkateswaran and Deepa, 2015). Therefore, preventing the ground water from contamination is essential to the management of ground water resources (Melloul and Collin, 1994; Balathandayutham et al, 2015). This work investigates the chemical quality of groundwater drinking resources using Geographic Information System in Khorramabad city.

Study Area

The study area, lies between the latitudes 48°16’ N to 48°24 N and longitudes 33°26’ E to 33°34’ E covering an area of 6450 km^2 (fig. 1). Khorram Abad city located in the center of area. The major source for recharge of water in this area is ground water resource.

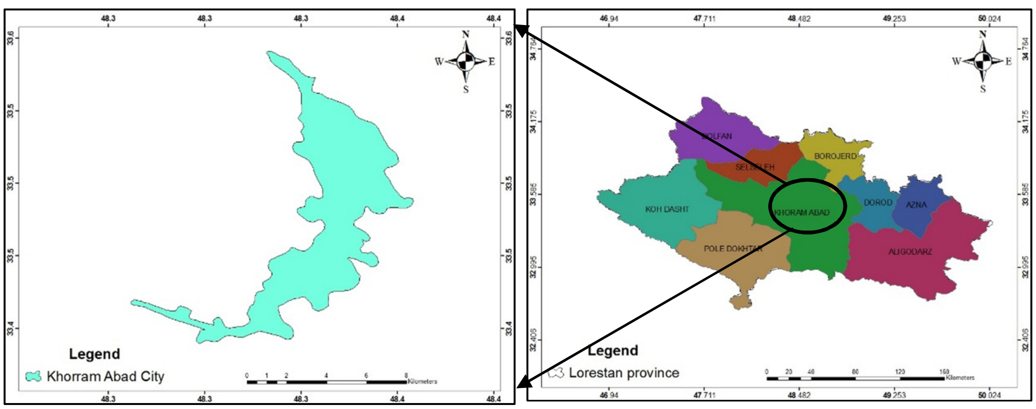


Fig.1: location map of Study Area in Lorestan Map

Materials and methods

Methodology

In this study, a total of important sampling groundwater wells and springs are chosen from the Khorram Abad city (Fig. 1).

In this study data of 12 wells and 13 springs for chemical testing (from 2001 to 2014) were collected from the study area. Fig. 2 shows the locations of the groundwater samples wells and springs.

Groundwater samples from wells and springs sources were collected in pre-cleaned bottles during the period of September 2001 to September 2015. Collected samples were brought to the laboratory.

In addition, water of the Khorram Abad River was sampled at the outlet of the Khorramabad basin (from October 2014 to September 2015) (Fig. 2).

Water quality parameters were analyzed in the laboratory according to the methods given in APHA 1998. PH and Electrical Conductance (EC) were measured on-site using portable meters (PH and EC meter, model:WA-2017SD). Calcium (Ca2+), magnesium (Mg2+), bicarbonate (HCO3-) and chloride (Cl−) were analyzed by volumetric titration methods, sodium (Na+) and potassium (K+) were measured using the flame photometer, sulphate (SO42−)was determined by spectrophotometric technique. The results of 4 main springs for drinking in Khorram Abad city were analyzed with SPSS software.

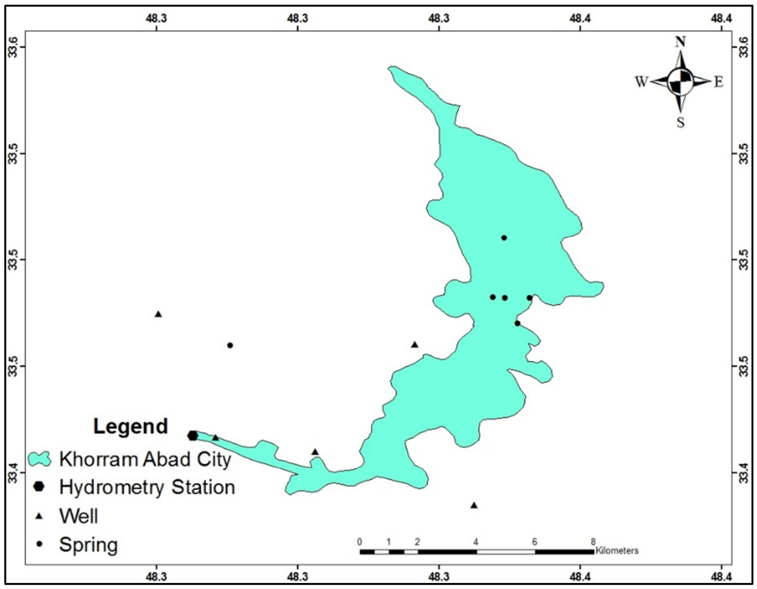


Fig. 2: Locations of Sampling wells, springs and hydrometry station in Khorram Abad map

GIS can be a powerful tool for developing solutions for water resources problems for assessing water quality, determining water availability, preventing flooding, understanding the natural environment, and managing water resources on a local or regional scale (Collet, 1996; Balathandayutham et al, 2015). Spatial analysis module in Arc GIS (version 9.3) software has been used for this study. The base map was prepared using Digital Elevation Model on 1:50,000 scale. Spatial analysis of drinking water quality was carried out by interpolation of sampling points by the algorithmic method 'Inverse Distance Weighted' (IDW). The locations of the sampling stations were imported into GIS software as point layer. Each sample point was assigned by a number and stored in the point attribute table. The attribute data file contains values of all chemicals data in separate columns for each sampling station. The geodatabase was used to generate the spatial distribution maps of the analyzed water quality parameters like pH, EC, and the results were given.

Result and Discussion

Groundwater Quality evaluation for agriculture

The statistics of samples collected from spring of Kio, Golestan, Motaheri and Gerdab Sangi are given in Table 1 to 4 and Table 5 shown the statistics of samples collected from Khorram Abad River.

Table 1. Statistical analysis of chemical parameters of water quality of Motaheri spring

Parameters	unit	Min	Max	Average	Standard deviation	Standard Error
EC	µs/cm	365	591	478.917	54.831	7.914
PH	-	6.15	8.57	7.348	0.430	0.062
HCO_3	mg/L	2.6	4.6	3.851	0.442	0.064
Cl	mg/L	0.2	1.0	0.560	0.189	0.027
SO_4	mg/L	0.01	1.23	0.375	0.271	0.039
Ca	mg/L	2.1	3.8	3.094	0.406	0.059
K	mg/L	0.0	0.09	0.028	0.031	0.004
Mg	mg/L	0.5	2.7	1.339	0.501	0.072
Na	mg/L	0.04	0.74	0.390	0.202	0.029

Table 2. Statistical analysis of chemical parameters of water quality of Golestan spring

Parameters	unit	Min	Max	Average	Standard deviation	Standard Error
EC	µs/cm	317	570	430.766	53.133	7.669
PH	-	6.2	8.3	7.342	0.483	0.070
HCO_3	mg/L	2.3	4.3	3.561	0.451	0.065
Cl	mg/L	0.2	1.15	0.493	0.236	0.034
SO_4	mg/L	0.01	1.04	0.318	0.275	0.040
Ca	mg/L	1.6	3.8	3.017	0.526	0.076
K	mg/L	0	0.17	0.030	0.034	0.005
Mg	mg/L	0.3	2.5	1.174	0.469	0.068
Na	mg/L	0.01	0.67	0.196	0.167	0.024

Table 3. Statistical analysis of chemical parameters of water quality of Gerdab Sangi spring

Parameters	unit	Min	Max	Average	Standard deviation	Standard Error
EC	µs/cm	329	640	482.828	71.106	10.263
PH	-	6.39	7.96	7.373	0.387	0.056
HCO_3	mg/L	2.7	4.3	3.588	0.465	0.067
Cl	mg/L	0.4	1.6	0.840	0.299	0.043
SO_4	mg/L	0.01	1.32	0.293	0.287	0.041
Ca	mg/L	1.9	4	3.166	0.506	0.073
K	mg/L	0	0.15	0.045	0.046	0.007
Mg	mg/L	0.1	2.5	1.162	0.553	0.080
Na	mg/L	0.04	0.79	0.393	0.226	0.033

Table 4. Statistical analysis of chemical parameters of water quality of Kio spring

Parameters	unit	Min	Max	Average	Standard deviation	Standard Error
EC	µs/cm	280	590	403.853	57.345	8.277
PH	-	6.4	8.16	7.469	0.494	0.071
HCO_3	mg/L	2.1	4.1	3.357	0.535	0.077
Cl	mg/L	0.2	0.9	0.436	0.177	0.025
SO_4	mg/L	0.01	0.84	0.286	0.261	0.038
Ca	mg/L	1.8	4.4	2.915	0.503	0.073
K	mg/L	0	0.25	0.029	0.046	0.007
Mg	mg/L	0.3	2.4	0.979	0.413	0.060
Na	mg/L	0.01	0.65	0.205	0.172	0.025

Table 5. Statistical analysis of chemical parameters of water quality of Khorram Abad River

Parameters	unit	Min	Max	Average	Standard deviation	Standard Error
EC	μs/cm	350	1020	744.457	173.833	25.091
PH	-	6.45	8.69	7.750	0.573	0.083
HCO_3	mg/L	2.9	6.6	4.845	0.853	0.123
Cl	mg/L	0.4	2.4	1.409	0.393	0.057
SO_4	mg/L	0.01	2.35	0.637	0.568	0.082
Ca	mg/L	2.2	5.6	3.951	0.692	0.100
K	mg/L	0.6	3.4	1.955	0.672	0.097
Mg	mg/L	0.06	1.7	0.862	0.533	0.077
Na	mg/L	0.02	1.13	0.194	0.251	0.036

Table 6 presents the Rote mean square Error for spatial distribution map of groundwater quality parameter.

Table 6. Mapping error for groundwater quality parameter using IDW

Parameter	EC	PH	HCO_3	Cl	SO4	Ca	K	Mg	Na
RMSE	104.8	0.195	0.618	0.404	0.322	0.381	0.021	0.476	0.314

PH

PH is one of the most important operational water quality parameter. The pH of a solution is the negative logarithm of hydrogen ion concentration in moles per liter. In general, pH is the measure of acidity or alkalinity of water. It is one of the most important operational water quality parameters with the optimum pH required often being in the range of 7.0-8.5 (Tikle et al, 2012; Mishra, 2014; Balathandayutham et al, 2015). The maximum permissible limit of pH for drinking water as given by the BIS – 10500 (2004-2005) is 8.5 (Mishra, 2014). In the study area, pH level of water varies from 7.342 in Kio spring to 7.468 in Golestan spring (tables 1 to 4). The Interpolated Distance Weighted (IDW) map presented in figure 3 shows the spatial distribution of pH. The Rote Mean Square Error for spatial distribution map of PH is 0.195 (table 6). The average of pH values in surface water is 7.74 (table 5). The values of the chemical parameters of the groundwater in the Khorram Abad city indicate that pH ranges from 7.34 to 7.6. The maximum of pH has been viewed in southwestern parts of Khorram Abad city (fig. 3). This shows that the groundwater in the study area is slightly alkaline in nature and is between the maximum permissible limits of WHO standards. The slight alkalinity may be due to the presence of bicarbonate ions, which are produced by the free combination of CO_2 with water to form carbonic acid, which affects the pH of the water (Azeez et al, 2000).

Electrical Conductivity (EC)

The EC is a good measure of salinity hazard to crops. Excess salinity reduces the osmotic activity of plants and thus interferes with the absorption of water and nutrients from the soil (Saleh et al., 1999). Table 1 to 4 indicated EC values for Kio, Golestan, Gerdab Sangi and Motaheri springs. This tables indicated that EC values ranged from 403.85 (Kio spring) to 482.82 (Gerdab Sangi spring) μS/cm. The average of EC values in surface water is 744.4

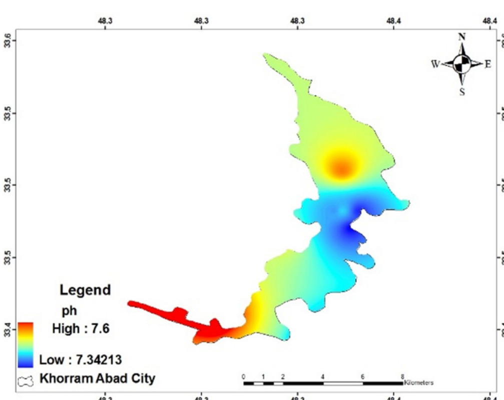
μS/cm in Khorram Abad River (table 5). Figure 4 illustrates the spatial distribution of EC over area of study. The maximum and minimum of EC has been viewed in south and center parts of Khorram Abad city respectively (fig. 4). Although the large variation in EC is mainly attributed to geochemical process like ion exchange, reverse exchange, evaporation, silicate weathering, rock water interaction, sulphate reduction and oxidation processes (Ramesh 2008). The higher values of EC in study area may be due to long residence time and existing lithology of the region.

Calcium (Ca)

Generally, calcium and magnesium maintain equilibrium in most waters (Hem, 1985). Calcium is one of the most abundant substances in the water. Dissolve calcium and Magnesium in water are the two most common minerals that make water hard (Balathandayutham et al, 2015). The average of Ca values in surface water is 3.95 mg/l. The IDW map presented in figure 5 shows the spatial distribution of Ca. The maximum and minimum of Ca has been viewed in south and center parts of Khorram Abad city respectively (fig. 5). The RMSE for spatial distribution map of Ca is 0.381 (table 6). In the study area, Ca level of water varies from 2.91 mg/l in Gerdab Sangi spring to 3.16 mg/l in Kio spring (tables 1 to 4). Insufficiency of calcium causes severe rickets; excess causes concretions in the body such as kidney or bladder stones and irritation in urinary passages (CPCB 2008).

Magnesium (Mg)

Magnesium is present in the groundwater from natural sources like granitic terrain which contain large concentration of these elements (Balathandayutham et al, 2015). The Magnesium values of the analysed samples in Kio, Golestan, Gerdab Sangi and Motaheri springs ranges from 0.979 (in Kio spring) to 1.338 (in Motaheri spring) mg/L (table 1 to 4) with an average value of 1.955 mg/L in surface water (Table 5). The IDW map presented in figure 6 shows the spatial distribution of Mg. The maximum and minimum of Mg has been viewed in south and west parts of Khorram Abad city respectively (fig. 6). The geochemistry of the rock types may have an influence in the concentration of Mg in groundwater.



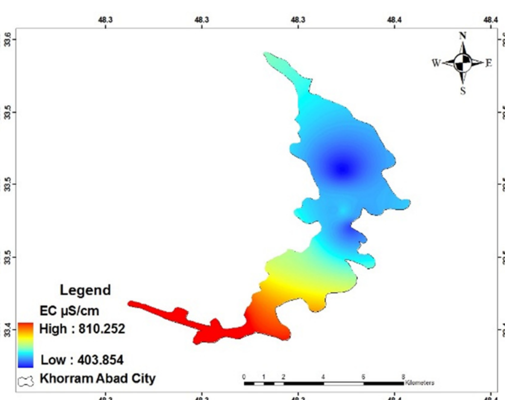
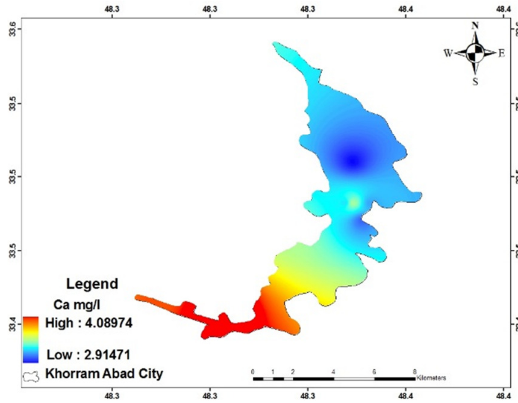


Fig 3. Spatial distribution of PH in the study area Fig 4. Spatial distribution of EC in the study area



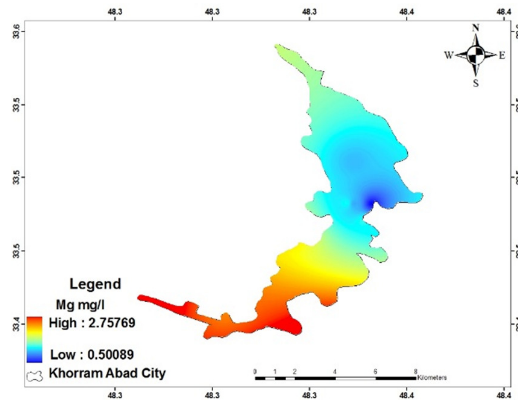


Fig 5. Spatial distribution of Ca in the study area Fig 6. Spatial distribution of Mg in the study area

Sodium (Na)

Sodium is the most important minerals occurring naturally. The major source of sodium is weathering of rocks besides the sewage and industrial efflents discharge onto the ground (Latha and Rao, 2010; Balathandayutham et al, 2015). The spatial patterns of Na are illustrated in Fig 7. Excess Na causes hypertension, congenial diseases, kidney disorders and nervous disorders in human body (Ramesh and Elango, 2011; Annapoorna and Janardhana, 2015). According to Hem (1985), high values of Na in groundwater may either be due to chemical weathering of feldspars or over exploitation of groundwater resources. The maximum and minimum of Na has been viewed in south and north parts of Khorram Abad city respectively (fig. 7). The RMSE for spatial distribution map of Na is 0.314 (table 6). In the study area, maximum and minimum of Na has been viewed from Gerdab Sangi (0.393 mg/l) and Golestan (0.196 mg/l) springs (tables 1 to 4). Table 5 indicates that Na values is 0.861 mg/l in surface water.

Potassium (K)

Potassium is slightly less common than sodium in igneous rocks, but more abundant in all the sedimentary rocks. Potassium is an essential element for plants and animals (Latha and Rao, 2010; Balathandayutham et al, 2015). The Interpolated Distance Weighted (IDW) map presented in figure 8 shows the spatial Distribution of Potassium. The maximum and minimum of Potassium has been viewed in southeast and center parts of Khorram Abad city respectively (fig. 8). In the study area, Ca level of water varies from 0.0283 mg/l in Motaheri spring to 0.0448 mg/l in Gerdab Sangi spring (tables 1 to 4). The average of K in surface water is 0.193 mg/l (Table 5). Loss of nutrients, including K, from agricultural land have been identifid as one of the main causative factors in reducing water quality in many parts of arid and semi-arid regions (Jalali, 2005; Balathandayutham et al, 2015).

Chloride (Cl)

Chloride is one of the most important parameter in assessing the water quality and higher concentration of chloride indicates higher degree of organic pollution (Yogendra and Puttaiah, 2008; Mishra, 2014). The maximum of Potassium has been viewed in south parts of

Khorram Abad city (fig. 9). In the study area, the maximum and minimum of Cl are 0.493 mg/l in Golestan spring and 0.436 mg/l in Kio spring respectively (tables 1 to 4). In natural waters, the probable sources of chloride comprise the leaching of chloride-containing minerals (like apatite) and rocks with which the water comes in contact, inland salinity and the discharge of agricultural, industrial and domestic wastewaters (Abbasi, 1998; Balathandayutham et al, 2015).

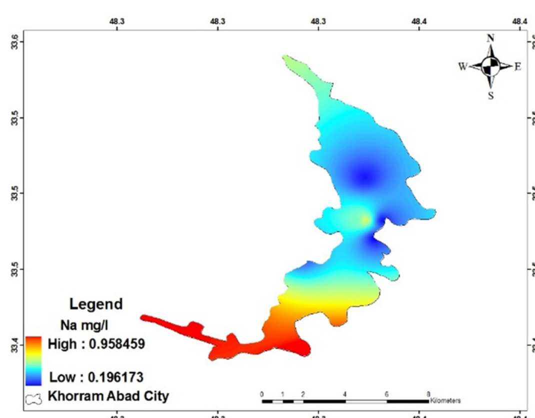
Sulphate (SO_4)

Sulphate is found in small quantities in ground water. Sulphate may come into groundwater by industrial or anthropogenic additions in the form of Sulphate fertilizers (Sridhar et al, 2014).

The IDW map presented in figure 10 shows the spatial distribution of SO_4. The maximum and minimum of SO_4 has been viewed in south and center parts of Khorram Abad city respectively (fig. 610). The RMSE for spatial distribution map of SO_4 is 0.322 (table 6). The maximum and minimum of SO_4 are 0.375 mg/l in Motaheri spring and 0.286 mg/l in Kio spring respectively (tables 1 to 4). The average of SO_4 values in surface water is 0.636 mg/l in Khorram Abad River (table 5).

Bicarbonate (HCO_3)

Bicarbonate is a major element in our body. Secreted by the stomach, it is necessary for digestion. When ingested, for example, with mineral water, it helps buffer lactic acid generated during exercise and also reduces the acidity of dietary components. Finally, it has a prevention effect on dental cavities. Interpolated Distance Weighted (IDW) map presented in figure 11 shows the spatial distribution of HCO3. The maximum of HCO3 has been viewed in south parts of Khorram Abad city (fig. 11). In the study area, the minimum and maximum of HCO3 are 3.357 mg/l in Kio spring and 3.851 mg/l in Motaheri spring respectively (tables 1 to 4). The primary source of carbonate and bicarbonate ions in groundwater is the dissolution of carbonate minerals in the study area. The decay of organic matter present in the soil releases CO2. Water charged with CO2 dissolves carbonate minerals, as it passes through soils and rocks to give bicarbonates. Bicarbonates also show high positive correlation with alkalinity (Flood, 1996; Balathandayutham et al, 2015).



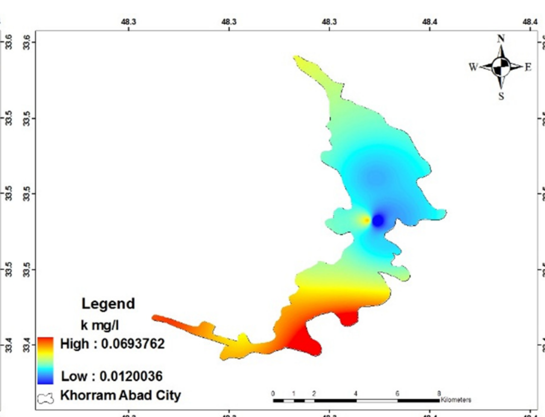
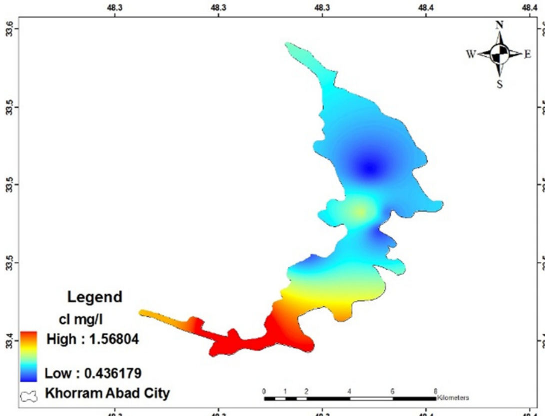


Fig 7. Spatial distribution of Na in the study area Fig 8. Spatial distribution of k in the study area



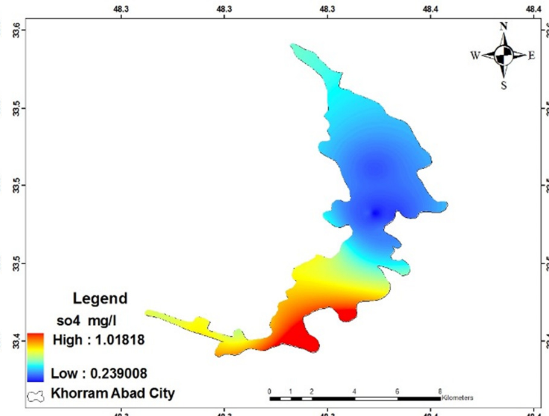


Fig 9. Spatial distribution of Cl in the study area Fig 10. Spatial distribution of SO_4 in the study area

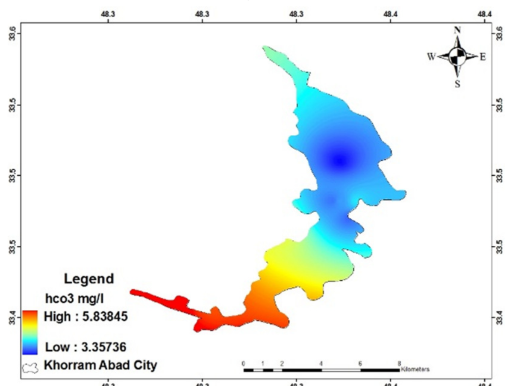


Fig 11. Spatial distribution of HCO_3 in the study area

Conclusion

On the earth, water surface and groundwater are known as indispensable natural resource and drinking water sources in both urban and rural areas. Increasing population and its requirements have led to the decline of surface and groundwater. The quality of groundwater is important as well as its quantity. Therefore, assessing and monitoring of the groundwater quality is important to confirm sustainable safe use of these resources for the drinking (Balathandayutham et al, 2015). In this research the groundwater quality has been evaluated for chemical parameter and suitability for drinking. This study indicated that areas indicated by good groundwater quality for human consumption. It could be helpful if the bacteriological contamination will be investigated as an effective factor on groundwater quality. This research helps us to find the quality of the groundwater to develop suitable management practices to protect the groundwater resources.

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