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The geochemical assessment of the quality of Borazjan's groundwater and the determination of its quality for agricultural purposes

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Abstract: The Increase in water consumption that is due to population growth has decreased the quantity and quality of recoverable water. Given this situation, it is necessary to recognize the appropriate qualitative and quantitative resources for a sustainable agriculture. In this study, we examine the quality of groundwater used for agriculture in Borazjan plains located in the north of Bushehr. We analyzed the 21 groundwater samples according to the concentration of HCO^{3-} K^+, Na^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, NO^{3-}. Sodium, chlorine, nitrate were compared to irrigation water standards. Some parameters such as total dissolved solids (TDS), sodium adsorption ratio (SAR), and permeability index (PI), residual carbonate (RC), electrical conductivity (EC) and ground water quality index (GWQI) were evaluated as well. The results showed that the quality of ground water and sodium chloride plain Borazjan based on the factor of EC, chlorine, sodium is greater than the standard.
Analyzing the quality of groundwater spatially showed that the groundwater in this plain has a medium quality for agricultural purposes. The GQI map shows that says that the index is between 68 to 82 percent, and this means that the north and the center of this plain has an average quality; while the southern part of the plain has more suitable water for irrigation.
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Keywords: Species richness; beta-diversity; taxonomic diversity; forest

1. Introduction

Bushehr province is located in the south of Iran and because of its geographical location and some other factors it is considered as a dry area.
Therefore, due to the lack of rainfall and the lack of a uniform distribution of rainfalls, the agriculture is a fundamental principle in this area. The limitation of surface water resources and increase in acreage has increased the exploitation of groundwater resources especially in areas under palm cultivation. And also the use of brackish water for irrigation states the importance of unconventional groundwater sources (National Research Center of Russia, 1387). But lower quality in water makes some tensions and restrictions for agricultural produce, thus caution must be taken in the management of water.
One of the most effective ways of using this kind of water is the knowledge of the water quality in relation to agriculture. First of all, accurate information is required for any accurate planning and we can optimally use the water for agricultural purposes when we know the qualitative features of it. The use of water resources in agriculture plays an important role in a rapid reduction of the quantity and quality of water (González, et al., 2010; Foroozani and Karami, 2011). Sustainable product is a system in which the resources are kept in balance. Production and the other usage are suitable for not only agriculture but also society and sustainable agriculture (Gold, 2007). The limitation in water resources in arid and semi- arid areas naturally reduce the quantity and quality of water and soil sources. The quality of water is one of the factors that influences the quality and quantity of agricultural product. For example, the use of low quality water reduces the quantity and quality of the product (Lichfoz, 2010). The salinity of water and the addition of heavy metals to the soil through irrigation have a great influence on the concentration of solution, soil and plant absorption (Bartlz and Sankar, 2005; Salah and Barrington, 2006; Lichfoz, 2010). On the other hand, Saline water causes dehydration of plant cells that through release of intracellular water reduce the

volume vacuoles and Sytosl volume.The metabolic processes such as reduction of photosynthesis, of growth, of seed germination, leaf blight, and lack of magnesium and calcium in plants and production of plant abscisic acid hormones are the initial signs of water salinity (Bartlz and Sankar, 2005; Salah and Barrington, 2006; Lichfoz, 2010).Increased production resulting from population growth had a lot of environmental implications such as an increase in the rate of irrigation, the use of pesticides and fertilizersand results in washing and displacement of the different layers of the soil and groundwater (Ehteshami et al., 2000). On the other hand, in order to increase the the yield per unit area, human activities have decreased the quality of groundwater (Maclay, et al, 2001).

Nitrates are those factors that pollute the groundwater sources. Due to the expansion of agriculture and human activities, these factors have increased in the groundwater (Movahedian, 2002). The outcome of nitrate consumption is the excessive plant growth and dark green leaves.The purposes of this research are the followings: 1. The study of the spatial changes of the quality of groundwater that is used for irrigation purpose 2. mapping the quality of Borazjan for the agricultural purpose.

2. Material and Methods

The geographical position of thescope of the study The scope of the study is located on the basin of Shapur and Dalaki. The longitude of this area is between 49º 29´ until 53º 00´and the latitude of this area is between 32º 22´ until 32º 45´. this scope of study reaches to the ganaveh on the north and on the south, it reaches the Ahrem and on the west it reaches the Shapur and Dalaki. In terms of climate, the average of annual rainfall is 259.8 mm and the average of temperature is 29.9 centigrade and according to Amberzhe it has a moderate hot climate. Borazjan is located in the Zagros fold and thrust belt and it is also adjacent to foothill. TheInfluence of tectonic forces on the area cause anticlines, crushing or breakingthe rigid formations and creating thrust faults and diametric fault –the direction of Kazeroon that is from the north-south passes through the eastern part of the plain.

The simplified geological map of this area is shown in figure1.

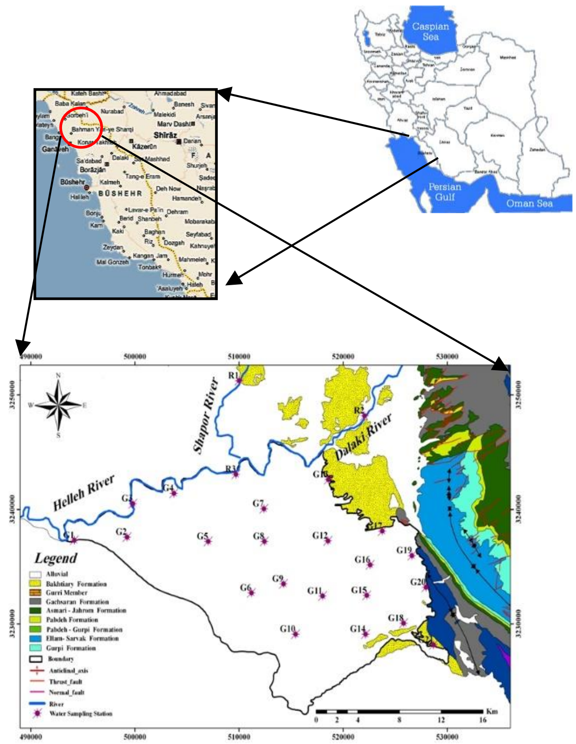

Figure 1. The position of studied positions and sampling points

To evaluate the groundwater of Borazjan geochemically, 21 water samples were collected from wells in the area (Figure 1). The sampling from wells have been conducted in May 1391. The samples were stored in polyethylene containers and were transferred to Zagros Abshenas Fars laboratory to analyze it chemically. To measure the rate of total dissolved solids [TDS] and electronic conductivity [EC] in the samples we used conductivity meter system, and to measure the amount of anions and cations the spectrometer was used. We used the geological and hydro-chemical method to evaluate the quality of groundwater resources for agricultural purposes. Meanwhile, geological maps were plotted using the software Arc Gis9.2. In the Geochemical processes in Borazjan we used composition diagrams which are drawn up by Excel 2007, and the quality of water for agriculture was determined through diagrams, required indexes and comparison with international standards.

The discussion

The chemistry of Groundwater

Using standard methods in the laboratory these items were evaluated Ca^{2+}, K^{+}, Na^{+}, Mg^{2+}, Cl^{-}, SO_4^{2-}, HCO_3^{-}, NO_3^{2-}, pH, TH, TDS and EC in the groundwater samples. The results are shown in (Table 1).

Table 1. The chemical parameters of groundwater samples of Borazjan plain

Sample	mg/l							
	TDS	SO_4	HCO_3	Cl	Ca	K	Na	Mg
G_1	1647.3	824.1	107.7	1687.4	653.9	8.8	1087.6	346.9
G_2	1312.2	239.1	70.4	656.7	242.2	4.07	422.1	127.7
G_3	2986.5	602.4	78.7	1233.6	478.1	6.46	795.1	253.6
G_4	1822.5	332.6	98.04	913.6	337	5.6	587.1	177.7
G_5	1531.7	748.4	71.7	393.9	763.6	7.8	239.3	117.5
G_6	7532	1341.2	169.8	3491.6	1198.2	47.3	1874.3	858.3
G_7	7244.2	1553.4	169.8	3382.7	1358.7	56.8	1895.1	878.2
G_8	1483.4	269.5	79.4	740.5	273.1	4.5	475.9	144.03
G_9	2208	401.2	118.2	1102.2	406.5	6.8	708.3	214.3
G_{10}	5009.6	631.2	137.5	2525	620	11.8	1475	451.2
G_{11}	4588.5	580.4	126.4	2321.8	570.1	10.9	1356.3	414.9
G_{12}	3032.4	380.2	82.8	1521.1	373.4	7.1	888.5	271.8
G_{13}	8076.4	1242	174.8	1698.3	1159	10.7	1102.8	552
G_{14}	4312	1167.2	164.2	1596.1	1089.4	10.2	1036.4	518.7
G_{15}	4535.6	1454.5	172.7	1678.2	1145.4	12.1	1018.2	545.4
G_{16}	3336.7	1273.8	111.6	1363.9	986.7	10.6	827.02	436.7
G_{17}	2350	1323.4	136.1	949.4	1649.5	13.4	619.5	321.2
G_{18}	5274.6	1424.3	200.4	1947.6	1329.3	12.2	1264.6	633
G_{19}	4643.3	1262.2	177.6	1725.9	1178	10.8	1120.7	560.9
G_{20}	4628.4	7.8	1.1	1707	7.3	0.1	1108.4	3.5
G_{21}	5212.1	1386.2	195.1	1895.4	1293.7	11.9	1230.8	616

Table 1.

Sample	T ^{oc}	EC µm /cm	pH
G_1	14.5	2890	8.6
G_2	14.8	2430	7.8
G_3	16	5430	7.2
G_4	15.3	3037.5	7.6
G_5	14.8	2785	7.7
G_6	16	13450	7.6
G_7	19.7	12490	7.5
G_8	16.6	2697	7.6
G_9	15.4	3450	7.8
G_{10}	18	8080	7.4
G_{11}	16.7	8050	7.2
G_{12}	15.6	5320	7.3
G_{13}	17	13240	7.5
G_{14}	19	7700	7.1
G_{15}	17.8	7820	8.1
G_{16}	20	5470	8.3
G_{17}	14.3	4270	7.4
G_{18}	15.2	8940	7.9
G_{19}	16.1	7870	7.6
G_{20}	15.2	8120	7.9
G_{21}	14.3	8834	8.9

3. Results

The Water quality samples collected from an agricultural perspective.

To evaluate the quality of Agricultural water, the following parameters and indexes were used:.

1. The salinity and alkalinity
2. sodium adsorption ratio (SAR)
3. permeability index (PI)
4. residual carbonate (RC)
5. magnesium absorption ratio (MAR)
6. KR groundwater
7. (GWQI)

In our analysis, we used the standard table and histogram elements to compare the concentrations of major elements in water samples with irrigation water standards.

Table 2. The comparison between the major elements of sampling and the maximum ratio of it (Iris and Wescot, 1994)

The parameters in water	Abbreviations	Unit	The usual range of irrigation	Average
Electrical conductivity	EC_w	µmoh/cm	0-3000	6779.7
Total dissolved solid	TDS	mg/l	0-2000	3941.3
Calcium	Ca^{+2}	meq/l	0-20	64.6
Magnesium	Mg^{+2}	meq/l	0-5	50.7
Sodium	Na^{+}	meq/l	0-40	53.5
Bicarbonate	HCO_3^{-}	meq/l	0-10	3.2
Chloride	Cl^{-}	meq/l	0-30	53.4
Sulfate	SO_4^{-2}	meq/l	0-20	28.7
Nitrate	NO_3- N	mg/l	0-10	17.4
Potassium	K^{+}	mg/l	0-20	12.9
Acidic-alkaline	pH		6-8.5	7.8
Sodium absorption ratio	SAR	meq/l	0-15	7.2
The percentage of sodium dissolved in water	SSP	meq/l	40>	37.6
The remaining Sodium bicarbonate	RSBC	meq/l	1.25- 2.5	-40.2
Permeability index	PI		0.19-7.15	0.51
Magnesium absorption ratio	MAR		50>	44.9
Collizzi Ratio	KR		1	0.63

Electrical conductivity (EC)

The electrical conductivity of the water indicates the presence of salts in the water which depends on temperature, ionic concentration and type of ions in water (1991). Therefore, the EC offers a qualitative picture of the groundwater. The maximum amount of EC for groundwater is 3000 µmoh / cm (Park, et al.). According to the EC waters of the area studied (13450 -2430µmoh / cm) 19% of the samples are in class 4 (suspicious) and 81% of samples are in class 5 (poor)(Table 3), and this shows that the water is unsuitable for agricultural purposes. Figure 2 (a) shows the mapping of studies area based on the electrical conductivity of groundwater. Generally, the electrical conductivity of groundwater gradually decreases from the surrounding plains to the east of the western plains.

Table 3.the classification of the quality of agricultural water based on EC (park, et al, 2005).

درصد نمونه هاي منطقه برازجان	EC(µmoh/cm)	Water quality	Water class
-	<250	Very good	1
-	25-750	Good	2
-	750-2000	قابل استفاده	3
%19	2000-3000	مشکوک	4
% 81	>3000	نامناسب	5

Chloride (Cl): Halite is the main source chloride in the mineral water. The most common reason for poisoning plants is the irrigation related to chloride ion. Since some plants are more sensitive to such ions, experimental classification of irrigation water is necessary according to chloride concentration (table2). If the chlorine concentration in leaves is more than the standard, psychological symptoms such as burning leaves or dried leaf tissue will be created. The results obtained show that all samples except G2 G8, G5, G4 and G17 have a concentration more than the standard (Table 1). According to the map, the chloride of Borazjan aquifer is specified (Figure 2b), this shows that the maximum chloride concentration in the groundwater near the Dalaki river in the north of plains is 98.5 meq / l.

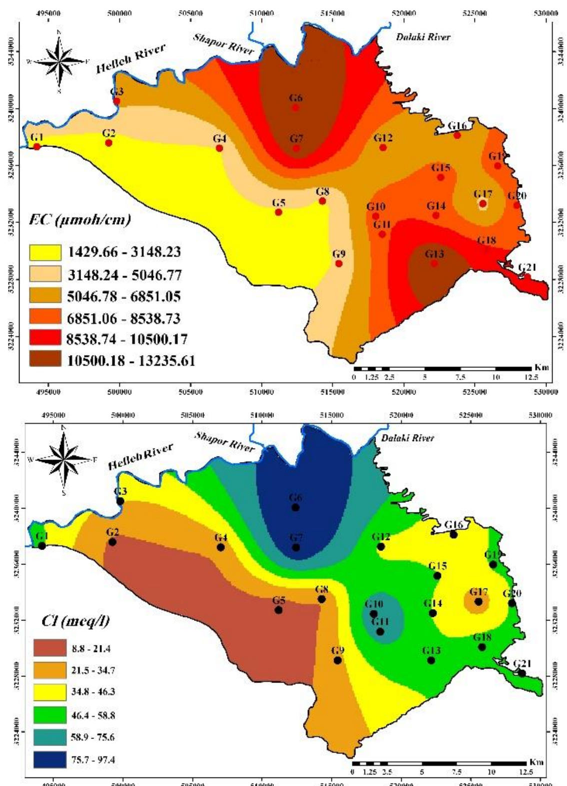

Figure 2.A. (A) the map of the same value of hydraulic conductivity, (b) the map of the same value of chloride in the groundwater of Borazjan

Nitrate (NO3): Nitrate is the most important source of nitrogen used by plants which is naturally in soil, water, plants, hay barn, crops, weeds, animal tissue, and livestock waste. This element can be added to the soil through animal or chemical fertilizers. High nitrate concentrations lead to juicy, crispy and breakable stems and leaves. The Lack of nitrogen leads to growth retardation, shrinkage of leaves, weakness in old leaves, and falling off early. A Comparison between nitrate concentrations (Table 1) with the limits of nitrates in the irrigation water (mg / l10) shows that except G20, G9, G8 and G21, the other wells have the concentrations more than our limits (Fig. 3).

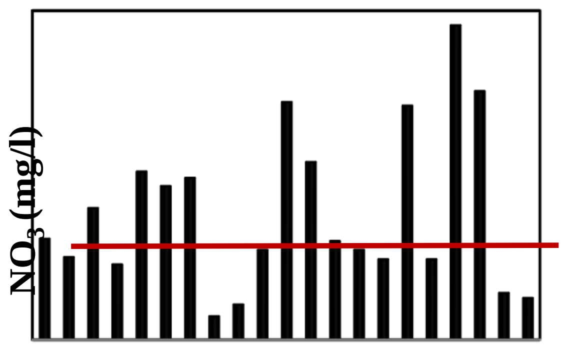

Figure3. The diagram of the nitrate ratio in the wells and comparing it with the standards

The sodium adsorption ratio (SAR): The sodium adsorption ratio shows the absorption of sodium in the soil (Abifoona and Sharif, 2010); this ratio is calculated using the formula given by (Richard, 1954) (Equation1). According to the Table 2, the average level of SAR in the groundwater is less than our limit i.e. 15.

$$SAR = \frac{Na^{+}}{\sqrt{(Ca^{++} + Mg^{++})/2}} \qquad \text{Equation 1}$$

The sodium solution parameter (SSP): According to equation (2), this parameter can be calculated with concentrations of calcium, sodium and magnesium in the water (Todd, 2005). SSP is an important parameter in studying the salinity. The high percentage of solved sodium may stop plant growth or reduce the permeability of soil (Joshi, et al.; 2009). According to Table 2 and Figure 4, half of the samples with SSP are higher than our standard.

$$SSP = \frac{Na}{Ca + Mg + Na} * 100 \qquad \text{Equation 2}$$

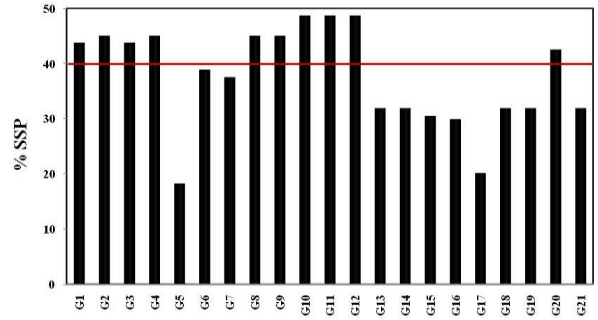

Figure 4. The Diagram of SSP in the groundwater and comparing it with the standards

The remaining amount of sodium bicarbonate (RSBC) was calculated according to equation (5) (Gupta and Gupta, 1978). Water with large amount of RSBC has high PH. Thus irrigating with this water causes desertification and drought and on the other hand precipitating of sodium bicarbonate (Eaton, 1950). Due to the increase in sodium leads to reduction of permeability, the amount RSBC in water must be less than 1.25 (Abifoona and Sharif, 2010). The amount of RSBC calculated in all water samples is less than that mentioned amount, so there is no risk of precipitation of sodium bicarbonate.

$$RSBC = HCO_3^{-} - Ca^{+2} \qquad \text{Equation3}$$

The permeability index (PI): The prolonged use of irrigation affected soil permeability and the effective parameters of it are total dissolved solids, sodium carbonate and type of soil. The suitable range of permeability index is between 19/0 to 15/7 (Abifona and Sharif, 2010). According to Table (2) The Average of in PI is in an acceptable level that is calculated by (equation 4) (Soba, 2006).

$$PI = \frac{Na + \sqrt{HCO_3 \times 100}}{Ca + Mg + Na} \qquad \text{Equation4}$$

Magnesium absorption ratio (MAR): The amount of water magnesium is one of the most important criteria for determining the quality of irrigation water. Magnesium and calcium are usually in balance in most of water. The more Magnesium in water the more salty water is and this reduces products (Joshi, et al.; 2009). The Limit for this parameter is 50% (Aires and Wiscot, 1985). Most of samples of magnesium absorption rates are lower than the standard.

$$MAR = \frac{Mg \times 100}{Ca + Mg} \qquad \text{Equation 5}$$

Collizzi ratio (KR): The limit of this components in irrigation is 1 (Abifona and Sharif, 2010). Using Table 2, we understand that the sample wells with average values of 0.63 are in the good condition. (equation 6).

$$KR = \frac{Na}{Ca + Mg} \qquad \text{Equation 6}$$

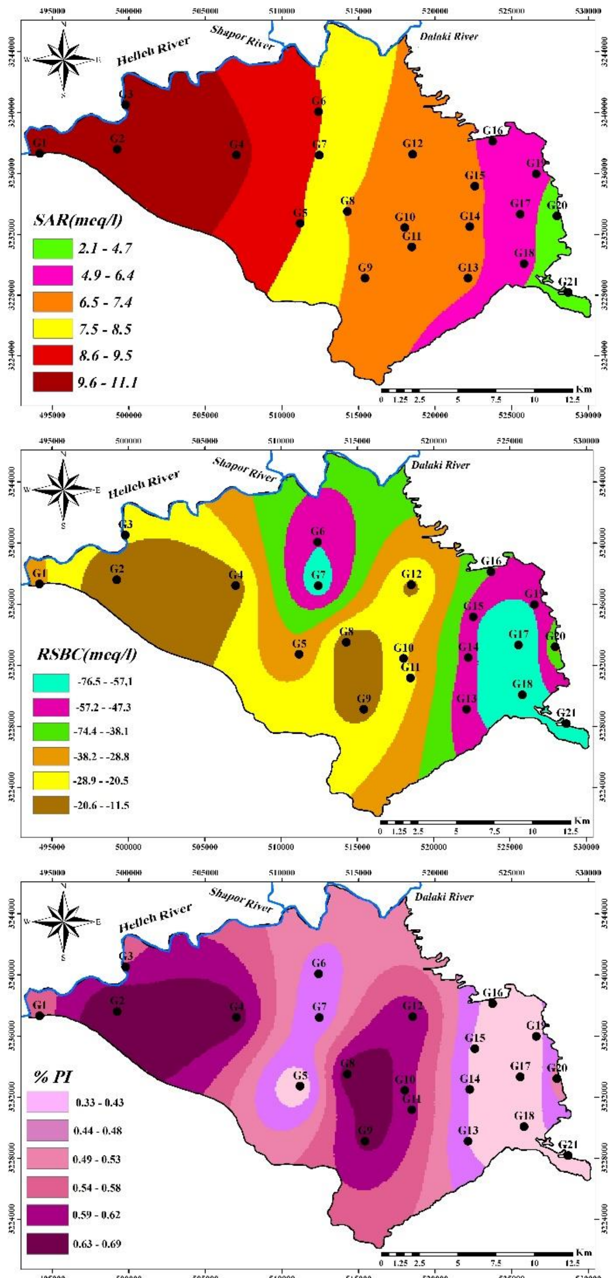

Figure 5. The mapping SAR, RSBC and PI of groundwater samples in Borazjan
Wilcox digram.

Wilcox (1955) indicates two parameters of EC and SAR to determine the quality of agricultural water (Fig. 6). According to positions of sampling, 14% of these samplings are in class C3S1 and 90% of these sampling are in class C2S3 therefore this shows the moderate to high risk of salinity and low alkalinity and this water is used for agricultural purpose when appropriate tasks were applied.

Table 4. The different levels and types of water quality based on Wilcox classification (Wilcox, 1954)

level of water	The Quality of water for agriculture
C_1S_1	Without salt – without hazard for agriculture
C_1S_2 ،C_2S_2 ، C_2S_1	A little salty – almost good for agriculture
C_1S_3 ،C_2S_3 ،C_3S_1 ، C_3S_2 ،C_3S_3	Salty – good for agriculture , but with
C_4S_1 ،C_4S_3 ،C_4S_4 ، C_3S_4 ،$C_2S_4C_1S_4$	Very salty - harmful to agriculture

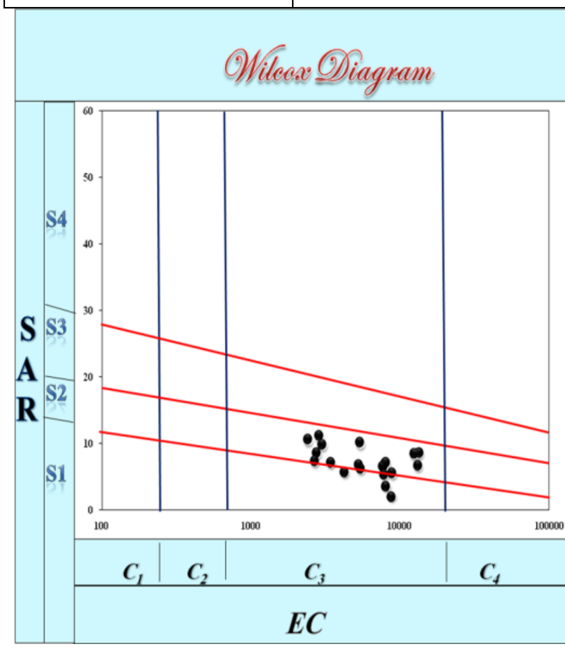

Figure 6: The Wilcox diagram related to groundwater samples in Borazjan

The Groundwater quality index (GQI)

In the GQI method, the amount of these six chemical parameters (MAR, SSP, SAR, EC, Na +, Cl-) which are more effective in influencing the irrigation water and has great influence on plants are numerically linked to FAO standards. In order to calculate GQI, the raster map concentration is provided for each six chemical parameters using ArcGIS 9.3 with kriging interpolation data points. In order to prepare a unified map that is an agent of six chemical parameters and shows the total quality condition in comparison to FAO standard, the layers of parameter are joined using GQI (Babiker, et al, 2007).

$GQI = 100 - [(r_1 w_1 + r_2 w_2 + \cdots + r_6 w_6)/6]$Equation 7

In this formula (r) refers to the rate for each pixel and (w) is an approximate weight for each pixel, and these equal to the average value ranking in the map itself.

In order to calculate GQI, the weighted average of the various parameters was used which more parameters (more different from the standard) have the relative weight, and consequently they are more effective (Tetsuya, 2010).

The amount less than 60 percent shows poor quality water, the amount between 60 and 80 percent represents the average quality and when this amount is more than 80%, it is suitable for agricultural purposes. The GQI map obtained for the Borazjan (Figure 7) shows that the north and center of plains have the average quality water for irrigation while southern half of plain has the water quality that is more suitable for irrigation.

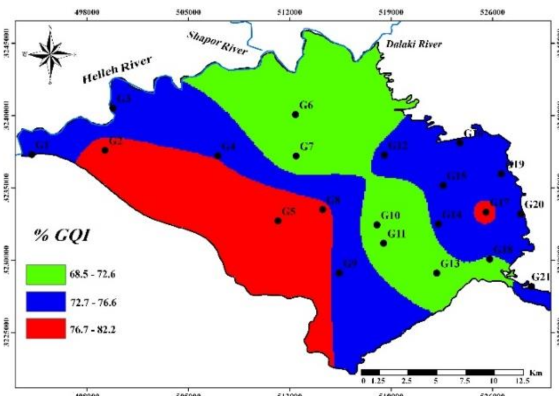

Figure 7. The Map of GQI in Borazjan

4. Discussions

According to the results obtained from this research and a study of the quality of regional ground water resources for agricultural uses, by a survey into the hazards related to salinity, sodium absorption proportion, sodium percentage,WILCOX diagram, the residual sodium carbonate, permeability index, it is observed that the water quality is partly appropriate for agricultural uses. According to the analyses done in this field, the plain is highly sensitive due to proximity to Dalaki and Helleh rivers. There should be too many attentions to exploitation of the groundwater. The groundwater of this plain was almost suitable for agriculture; there is an exception in the northern and eastern part of valley due to the proximity to Dalaki and Helleh rivers. The results showed that the salinity and the most physicochemical parameters except sodium chloride were according to FAO; so the water is suitable for irrigation.

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