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Evaluation of Groundwater Quality for Industrial Using GIS in Mountainous Region of Isfahan Province, Koh-Payeh, Isfahan, Iran

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Abstract: *Groundwater quality is gradually deteriorating due to agricultural activities and its evaluation is there for eneeded before use. The aim of this study was to evaluate groundwater quality for use in the foundry industry using water quality data, including PH, EC, TDS, Cl and HCO3, from 26 wells located in Jolgeh and Bon-Rud districts, Iran. Zoning and classification of the area were done, based on groundwater quality, using a GIS software and the existing standards for water use. Results showed that groundwater in the East, North and Southwest of the area was of acceptable quality for use in the foundry industry, but water quality deteriorated from the East to the West of the area. It was found that for foundry industry about 4 percent of area ground water could be used without any limitation, 2 percent with low limitation, 7 percent with moderate limitations, and the rest with high limitation or even unusable. Agricultural activities in the region are having a negative impact on the quality of groundwater.*

Keywords: *Water quality, zoning, foundry industry, PH, EC, TDS, Cl, HCO_3, Jolgehand Bon-Rud*

1. Introduction

In recent years, many countries, especially those with dry climate, have been facing water shortages and have therefore resorted to indiscriminate use of groundwater that has led to the deterioration of ground water quality and reduction of groundwater resources. It has been estimated that Iran has 413 billion cubic meters of available water and56 billion cubic meters are extracted from underground aquifers. In 2001uncontrolled exploitation of about 5.5 billion cubic meters was recorded. Ground water is the main source of water supply in dry and semi-dry areas [1-3] as well as for domestic consumption in many cities of Iran and for agricultural use. Therefore, attention should be paid to the quantity and quality of groundwater resources and their management, especially in dry and semidry areas. Given the scarcity of fresh water resources, crop management and decision-making on land use are of particular importance. Isfahan province, like many other parts of the country, has experienced tworare drought periods over the past 18 years since 1999.Droughts, particularly in the East of Isfahan, have led to drying of about 43 thousand hectares of agricultural land, causing huge damages to farmers who are leaving farmland, and migration from the region to other are asin several cases which is leading to negative social, cultural and economic consequences. In some areas, water quality has deteriorated to the extent that groundwater is not usable agriculture. Under these conditions, solutions that can prevent increasing damages to residents are sorely needed. Also careful management of groundwater resources is needed. One of the remedies is land use change that can avert the crisis and help with the subsistence of families. Taking into account the climatic characteristics, topography of the area, the quality and quantity of water resources, area demands, etc., different uses including the construction of industrial workshops can be defined, which are consistent with the existing circumstances and family needs. Because of the water used in industry, water quality in the region should be evaluated and groundwater quality maps of the area should be prepared using GIS Geographical Information System. In the GIS environment, information obtained from various studies can be simultaneously examined. Information on each field forms a layer on the map and the layers can then be combined and analyzed [4-7].

There have been many studies on groundwater quality in Iran. Shabani 2008investigated groundwater quality changes in Arsanjan plain using different geo-statistical methods, including ordinary and simple Kriging, Inverse Distance Weighting method (IDW), radial basis function (RBF), and local and general estimator. His results showed that ordinary and Simple Kriging (SK) methods were superior in the preparation of TDS and pH maps [8].In order to update information and zoning of groundwater in terms of total hardness and total suspended solids, and determination of the most appropriate areas for the exploitation of groundwater considering potable water standards in Shiraz, samples taken from 137 wells were imported to Arc GIS software and using OK, SK, IDW and RBF interpolation methods and spherical, circular, exponential and Gaussian models, zoning maps of groundwater were developed in another study. Results showed that SK method was the best method for determining suitable areas for ground water exploitation.

In a study using 84 wells in Isfahan it was concluded that Kriging and Co-Kriging methods were not significantly different, but because of a lower RMSE value, Co-Kriging was used in Arc GIS for zoning of groundwater quality [9].Taghi-Zadeh et al.2008 used Co-Kriging to develop groundwater zoning maps in the Ardakan plain, Yazd[10-11]. Imranet al.2014 used data from 36 wells in Southwest of Greece to develop water quality maps of the area by using ordinary Kriging. Results showed that the circular Variogram Method best fitted the EC, Cl and sodium adsorption ratiodata and the spherical model best fitted the nickel and zinc data [12-13]. Yaoet al. 2014investigated an aquifer surface using 8 methods e. g. ordinary, simple, and universal Kriging, etc. and indicated that the Kriging methods yielded more accurate results than other interpolation methods [13-15]. In another study, Ordinary Kriging (OK) and (IK) index were used to find the spatial and temporal variability and the possibility of increasing groundwater salinity. It was concluded that the Kriging method was a useful technique for observation, evaluation and management of groundwater resources [16-19].

As mentioned before, water crisis, especially in the East of Isfahan including Jolgeh and Bon-Rud areas, has caused a lot of problems. For example, the average groundwater surface in the area has dropped from 16. 41 meters in 2002 to 17.29 meters in 2009, and the average groundwater EC has increased from 9.192 in 1995to 11.453dS/m in 2012with an approximate increase in salinity of 25%.In this area there are large amounts of low-quality water. Under these conditions, the revival of low-water-consuming industries can help sustain local economy as well as industries for which water quality does not matter much, such as industries in which water is used as a coolant in keeping with regulations.

In this study, considering different geostatistical methods and existing standards of water consumption in industry, the foundry industry was selected for the Jolgeh and Bon-Rud districts in the Southeast of Isfahan province. Therefore, the aim of this study was to investigate the quality and spatial changes in groundwater characteristics, including EC, PH, TDS, and CL, and develop maps and perform feasibility study for application in the foundry industry using the Arc GIS software [20-24].

2. MATERIALS AND METHODS

2.1. Study Area

The study was conducted on the Jolgeh and Bon-Rud districts located in the southeast part of Isfahan province. Jolgeh district with a population of 19,822 is limited to the Kuhpayehfromnorth, to the Bon-Rud from east, to the central part of Isfahan from west and to the Jarqavieh from south. It includes Rudasht and EmamzadehAbdol Azizvillages. The area of the district is 1824.6 square kilometers and is located between the eastern lengths of 52°03' 58" and 53°03' 27" and northern latitudes of 32°09' 37"and 32° 41' 31"with an altitude of 1,540 meter above sea level.

Bon-Rud district with a population of 26,299 is limited to the Kuhpayeh from north, to Yazd province from east and to the Jolgeh from south and west and includes Eastern Rudasht and Gavkhuni villages. The area of the district is 1721.4 square kilometers and is located between the eastern lengths of 52°24'48" and53°03'33" and northern latitudes of 32°17'09" and 32°37'50" with an altitude of 1,477 meter above sea level. The location of Jolgeh and Bon-Rud districts is shown on the map in Figure 1 [25-32].

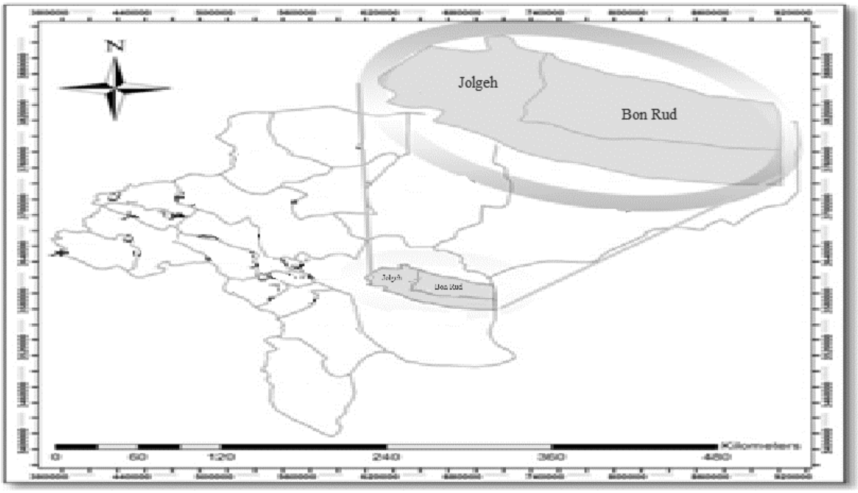

Figure1. *Location of the Jolgeh and Bon-Rud districts on the map of Isfahan province*

2.2. Methodology

Data was collected by the Isfahan Regional Water Company in 2012 and consists of UTM coordinates of wells and PH, EC hydraulic conductivity, TDS (Total Dissolved Solids), CL and HCO3valuesfor each well. To map groundwater quality changes in the area, the GIS software was used. The GIS software can produce, process, analyze and manage geographic information spatial information. It is a computer software to manage and analyze spatial information with the ability to collect, store, analyze and display geographic spatial information. The ultimate goal of a GIS is to support decision-making, based on spatial information and its basic function is to obtain information from a combination of different layers of data obtained with different methods and with different perspectives [33-39].

Data was entered into the GIS and the zoning of study area was initiated. The normality of the data was examined by using the histogram. Then, zoning of the groundwater quality was done using three interpolation methods of IDW, Radial Basis Function and ordinary Kriging methods, as in the study of Zahedifar, Mousavi and Rajabi who used Ordinary Kriging for the zoning of groundwater quality [40-52].Then, based on the lowest Root Mean Square Error RMSE and Mean Error ME values, the best interpolation was selected. However, results showed that in some of the interpolations, concentration ranges exceeded the minimum and maximum values. Therefore, an accurate estimate of the area was not achieved, since the above-mentioned methods were used for areas with normal data. However, Jahanshahi, Moghadam and Dehvary used Kriging in a study and obtained accurate results, because the data in the study area was normal [53-59]. Finally, groundwater quality interpolation was done again using the Topo to Raster interpolation method and EC, PH, TDS, Cl and HCO3 changes maps were developed separately. The maps were then classified and evaluated using Reclassify and Weighted sum functions in terms of water quality using Table 1 standards which was an estimation of the American standards for the industrial units' construction as well as European, Malaysian and Korean Standards [60-78], to be used in the foundry industry.

Table1. *Standards of water quality for use in the foundry industry*

Parameter	No limitation	Moderate to low limitation	High limitation
EC (dS/m)	< 3/5	3.5-8	>8
TDS (mg/L)	<1500	1500-3500	>3500
Na^{2} (meq/L)	< 5	> 5	-

Na^{2} (mg/L)	< 115	>115	-
CL^{2} (meq/L)	< 4.75	> 4.75	-
CL^{2} (mg/L)	< 285.5	>285.5	-
HCO_3(meq/L)	<1.5	1.8-5.5	>8.5
HCO_3 (mg/L)	<400	400-620	>620
PH	Normal value (6.8 -5.4)		

3. Results

Zoning results of groundwater quality for the foundry industry:

Figure 2 shows the EC changes in the study area. In addition, Table 2 shows the area classification based on the foundry industry standards.

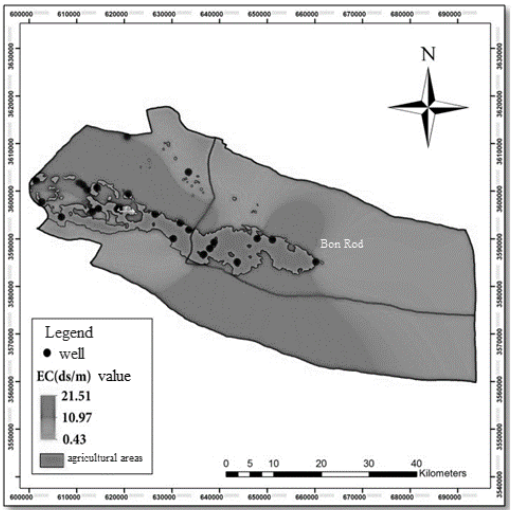

Figure2. *EC changes of the Jolgeh and Bon-Rud groundwater*

Table2. *Area corresponding to each EC class*

range	limitation	Area	Area percent
<3.5	No limitation	31526.5	10.2
3.8-5	Moderate to low limitation	87912.214	28.4
>8	High limitation	190200	61.4

As can be seen from Figure 2, the EC ranged from 0.43 to 21.51 dS/m with the highest value in the south and northwest of the area.

According to Table 2, most parts of the area had an EC over 8 dS/m and the average EC was 7.15 dS/m.

Figure 3 and Table 3show Cl changes and classification of the area based on the foundry industry standards.

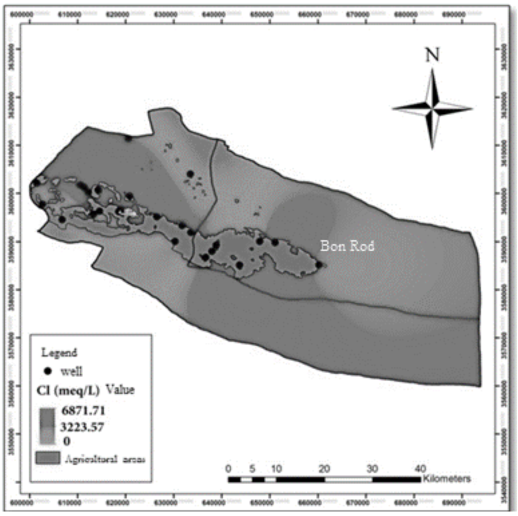

Figure3. *Changes of groundwater Cl in Jolgeh and Bon-Rud districts*

Table3. *Area of each class CL*

range	limitations	area	Area percent
<285.5	No limitation	225.2	0.07
>285.5	Moderate to low limitation	309400	99.95

According to Fig. 3, Cl changes from 0 to 6871.71 meq/L and the highest value was observed in the center and northwest of the area.

According to Table 3, most parts of the area had aCl concentration over 285.5 meq/L and the average Cl concentration was about 290 meq/L.

Figure 4 and Table 4show Na changes and classification of the area based on the foundry industry standards.

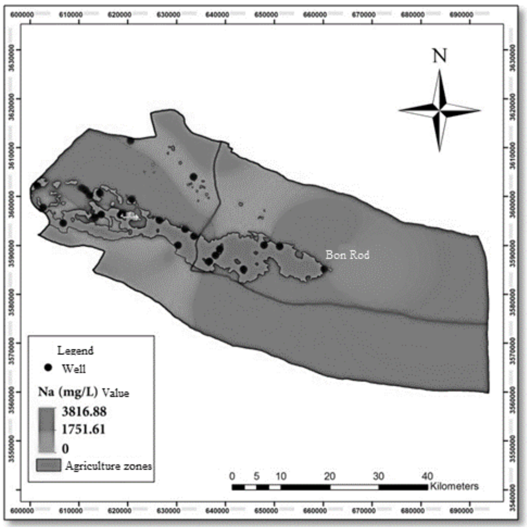

Figure4. *Changes of groundwater Na in Jolgeh and Bon-Rud districts*

Table4. *Area of each Na class*

range	Limitations	area	Area percent
<115	No limitation	5897	1.9
>115	Moderate to low limitation	303700	98.1

According to Fig. 4, Na changed from 0 to 3816.88 mg/L and the highest value was observed in the center and west of the area.

According to Table 4, most parts of the area had a Na concentration over115 mg/L and the average Na concentration was 124 mg/L.

Figure 5 and Table 5show HCO3changes and classification of the area based on the foundry industry standards.

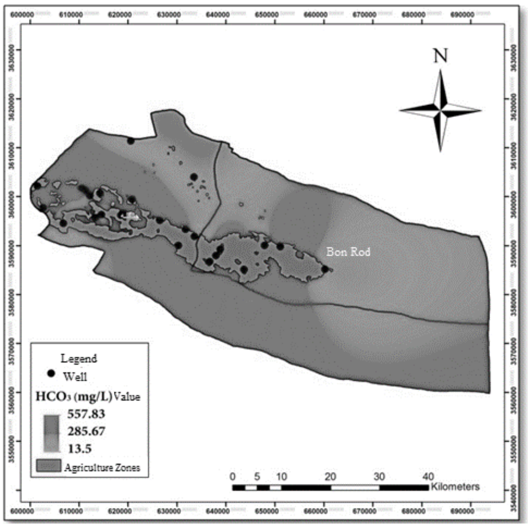

Figure5. *Changes of groundwater HCO3 in Jolgeh and Bon-Rud districts*

Table5. *Area of each HCO3 class*

range	Limitations	area	Area percent
<400	No limitation	250800	81.01
400-620	Moderate to low limitation	58789	18.9

According to Fig. 5, HCO3 changed from 13.5 to 557.83 mg/L and the highest value was observed in the center, south and west of the area.

According to Table 5, most parts of the area had anHCO3 concentration less than 400mg/L and the averageHCO3 concentration was 340 mg/L.

Figure 6 and Table 6show PH changes and classification of the area based on the foundry industry standards.

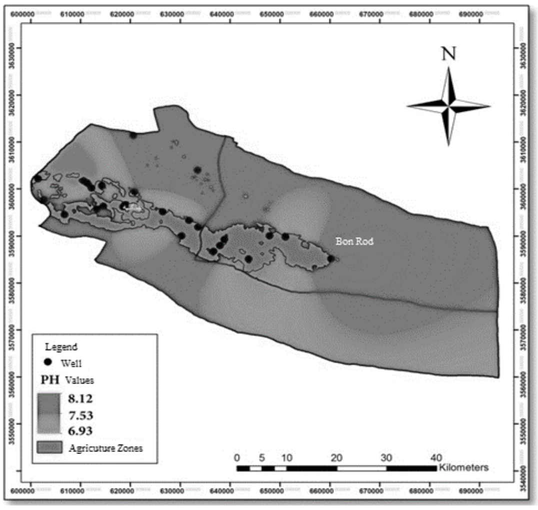

Figure6. *Changes of groundwater PH in Jolgeh and Bon-Rud districts*

Table6. *Area of each PH class*

Range PH	Area(ha)	Area percent(%)
6.5-8.4	309634.9	100

According to Fig. 6, PH changes from 6.9 to 7.93 mg/L and the highest value was observed in the north and east of the area.

According to Table 6, whole groundwater of the area can be used in the foundry industry with no limitation.

Figure 7 and Table 7show TDS changes and classification of the area based on the foundry industry standards.

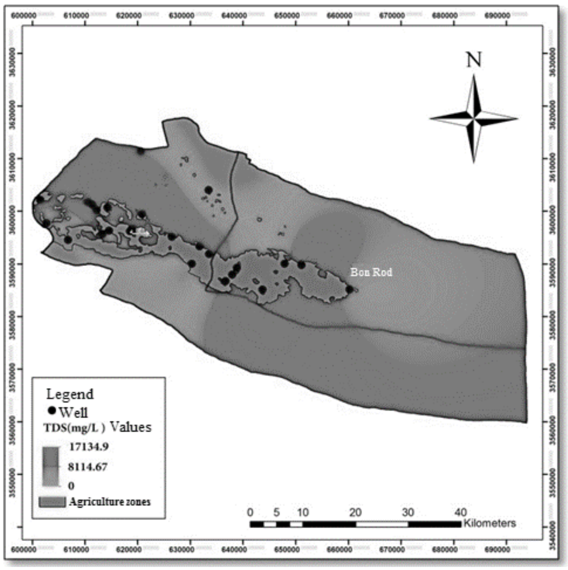

Figure7. *Changes of groundwater TDS in Jolgeh and Bon Rud districts*

Table7. *Area of each TDS class*

range	limitations	area	Area percent
<1500	No limitation	11871.9	8.3
1500-3500	Moderate to low limitation	21263	6.9
>3500	High limitation	276500	89.3

According to Fig. 7, TDS changes from 0to 17134.0 mg/L and the highest value was observed in the center and west of the area.

According to Table 7,most parts of the area had a TDS concentration over3500 mg/L and the average TDS concentration was 3872.5 mg/L

Figures8 and 9 show the classification of the area based on all mentioned components' standards. In Figs. 8 and 9, the same and different factors of the impact can be observed, respectively.

In Fig. 9, the impact factor of HCO3 and TDS was considered as 3 because of the possible clogging of pipes, and the impact factor of Cl was considered as 2 because of the possible corrosion of pipes, and the remaining impact factors were considered as 1. As can be seen because of different classification bases of the two figures, different limitations were observed, but in both cases the area was divided into 5 classes based on the software standards. Table 8shows the are as corresponding to different classes in Fig. 8.

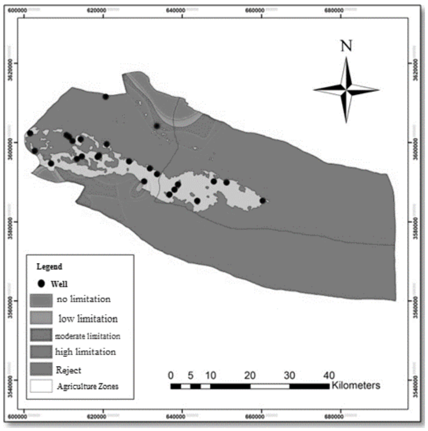

Figure8. *Classification of the area considering standard ranges of all the components with the same impact factors*

Table8. *Area corresponding to different classes in Figure 8*

row	Limitation	area	Area percent
1	No limitation	8084.51	2.61
2	Low limitation	3750.31	1.21
3	Moderate limitation	13574.21	4.39
4	High limitation	17589.08	5.68
5	Rejected	266553.87	86.11

Table 9 shows the area corresponding to different classes in Figure 9.

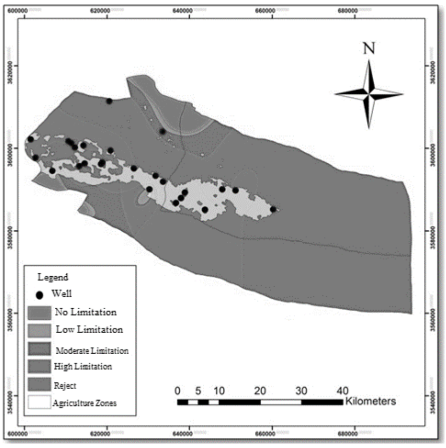

Figure9. *Classification of the area considering standard ranges of all the components with different impact factors*

Table9. *Area corresponding to different classes in Figure 9*

row	limitation	area	Area percent
1	No limitation	12010.42	3.88
2	Low limitation	4046.38	1.31
3	Moderate limitation	21809.07	7.05
4	High limitation	205415.7	66.36
5	Rejected	66270.30	21.41

According to Table 8, most parts of the area cannot be used for the foundry industry and generally,8.21 percent of the area has no limitation to low limitation for use in the foundry industry. However, according to Table 9most parts of the area have high limitation for use in the foundry industry andgenerally,12.24 percent of the area has no limitation to moderate limitation for use in the foundry industry.

4. Conclusions

Due to corrosion and clogging potential of pipes, a higher impact factor should be considered for the Cl, HCO3 and TDS parameters. Therefore, according to Table 9 only 4 percent of the total area groundwater can be used in the foundry industry with no limitation, which is too small. It is recommended to treat low limitation groundwater of other areas using water treatment devices so that can be used for industrial use.

The very small percentage of the area groundwater with no limitation for use in industry suggests that no agricultural activities should be undertaken in the area, because of 26 wells only 3 wells have an EC less than 3 dS. m. This is against what Chitsazan, Botvandi and Majediindicated in their research on zoning groundwater quality of Ghal'e Khaje plain, Khuzestan that the majority of the plain has a good to average groundwater quality for agricultural purposes, and just a small amount of the area groundwater quality is not suitable.

Not only the area groundwater is not suitable for agriculture purposes, but also just a small amount thereof is suitable for industrial use. Therefore, management practices must be considered to prevent further contamination of the area groundwater in the future as well as removing the current contamination to an acceptable level in order to render suitable for use in industry.

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