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Risk Assessment and Effect of Different Factors on Nitrate in Groundwater Resources of Jiroft County

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ABSTRACT: Nitrate is a major contributor to water contamination, which can affect humans' and animals' health. Due to increased sewage production, growth of agricultural activities, and development of urbanization, recent years have seen an increase of Nitrate in water resources. Drinking water resources in both rural and urban areas of Jiroft City are supplied by water wells, scattered throughout the region. Thus the present research analyses the Nitrate pollution of 31 drinking water wells in summer and winter of 2016, in the urban area of Jiroft City and by means of GIS as well as statistical analysis, presents the results as zoning and survey maps. It also studies and evaluates the effect of rainfall and soil type on the amount of Nitrate. Results from statistical analyses show that the amount of water pollution to Nitrate is independent from the type of land use as well as the soil type. Furthermore, statistical results show that the amount of Nitrate in the wells under test is affected by precipitation, being higher in the winter. Therefore, considering the agricultural density in this area and the untapped use of nitrogen fertilizers, it is necessary to take into account the use of chemical fertilizers for proper management, scientific and practical control, and maintenance of the wells' health safety.

Keywords: Groundwater pollution, Nitrate, Jiroft City, Statistical Analysis, Geostatistical analysis

INTRODUCTION

Nitrate is considered as the most common pollutant in groundwater. In addition to natural sources of nitrogen, it can also enter water and soil through raw human and industrial wastewater, agricultural wastewaters, solid municipal and industrial waste, and destruction of forests and pastures (Abu-Jabal et al., 2014; Marghade et al., 2012). The scatter plot of $NO3^{-}/Cl^{-}$ ratio versus Cl^{-} in meq/L can be used to distinguish Nitrate sources and whether farming inputs and/or municipal sewage inputs play significant roles to the observed groundwater chemistry (Murgulet and Tick, 2013; Wang et al., 2016). This element's concentration grows as a result of agricultural runoff leaching or pollution from human or animal wastewater (Eswar et al., 2015). Sometimes, the rain moves this fertilizing element to surface or underground water (Hoveidi et al., 2013). The concentration of Nitrate, which occurs naturally in surface and underground water resources is meagre and many processes intensify the pollution of groundwater into Nitrates (Pejman et al., 2009; Vosoogh et

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al, 2017). Since organic fertilizers contain considerable amounts of soluble compounds such as Nitrates, they enter the soil solution through rain or irrigation, eventually entering groundwater; therefore, one of the important indicators to show the quality of drinking and agricultural water is the amount of Nitrate it has. Since the 1970s, groundwater pollution with Nitrate has become a major environmental concern, and there are reports of Nitrate pollution in many parts of the world. Progressively, regulatory decisions, based on consideration of the ecosystem services of soils, will tend towards a range of spatial scales that are significantly larger than typical agricultural fields or farms (Smith et al., 2012; Dale et al., 2013), and will need to adopt an integrated and comprehensive perspective (Zhanget al., 2013; Padash et al., 2015).

Nitrate is a mixture of nitrogen, naturally existing in average concentrations in many environments. In many parts of the world, especially in places like Iran, groundwater is considered an important source to meet drinking and farming needs; therefore, it is very important to study these waters' quality and determine the extent of their pollution (Taghiof et al, 2013). A lot of research has been done in this area, some of which are briefly cited below: Jalali (2011) studied groundwater pollution into Nitrate in the city of Toyserkan. The concentration of Nitrate in 9 wells was more than 55 mg/L, within the range of 25-55 mg/L in 51 wells, and less than 25 mg/L in 34 wells. Fytianos, K. and Christophoridis (2004) studied the Nitrate levels of drinking water in 52 rural areas of Thessaloniki in northern Greece, using GIS (Padash et al. 2016). Nitrate concentration was reported to range between 1.4 and 141 mg/L, while four regions had a Nitrate concentration above 55 mg/L.

Lalehzari et al. (2009) reviewed the monthly changes in groundwater in Shahrekord Plain and zoned, using GIS. Results from measuring the concentration of Nitrate in 120 samples, collected from 10 wells in this plain showed that the middle parts of the plain had lower Nitrate concentrations, compared to the northern and southern ones. In their study, Rahnama et al. (2012) studied the process of quantitative and qualitative changes of groundwater resources in Jovain Plain, Khorasan Razavi, studying and evaluating the fluctuations of groundwater quality in different seasons of the year, by means of Kriging Method and GIS Software. Results from this study indicated a decline in groundwater quality in recent years. Rezaei et al. (2010) assessed the spatial variations of some quality indices of Guilan Province's groundwater, using Kriging and inverse distance methods. The zoning of qualitative properties showed that the level of electrical conductivity of groundwater in most areas of the province was low.

Considering the development of agricultural use in rural areas of Jiroft City, the excessive use of fertilizers by farmers, and non-observance of elements accumulated in groundwater resources, this study compared concentrations and preparation of spatial distribution maps and the probability of groundwater resources' pollution. The area's groundwater resources was converted to Nitrate. Water testing is the only way to determine the concentration of Nitrate as well as the acceptable or unacceptable standard, based on its results. In order to prevent Nitrate pollution in drinking water, the main solution is to select the right place for development and improvement. Proper management can reduce the risk of contamination in areas, where fertilizer and animal waste are present and help maintaining and safeguarding water supplies.

MATERIAL AND METHODS

The city of Jiroft is a city in Kerman Province, near Hellirud River and on the southern slopes of Jabalbarz. The city is 650 meters above sea level with 209,746 inhabitants, located 230 km south-east of Kerman and 1,375 km south-east of Tehran. The city has an area of about 8,602 square km, equivalent to 4.65% of the province. To the north is the city of Kerman; to the south, the city of Anbar Abad; to the east, the city of Bam; and to the west, the cities of Baft and Rabar. The city has five rural areas. In the area of Jiroft Plain, and based on the last survey in 2005, there are about 5,129 wells (semi-deep and deep), 1090 springs, and 294 qanats, all responsible for a total annual water flow of 950 cubic meters of Jiroft Aquifer. There are about 70 wells in the rural areas, covered by Jiroft Water and Wastewater Organization. Based on observed phreatic-zone fluctuations in a seven-year period, from 1380 to 1387, the aquifer's water table level has fallen by about 32.1 m/year (Dehghani and Abbas Nejad, 2011). Fig. 1 shows the location of the study area within Kerman Province.

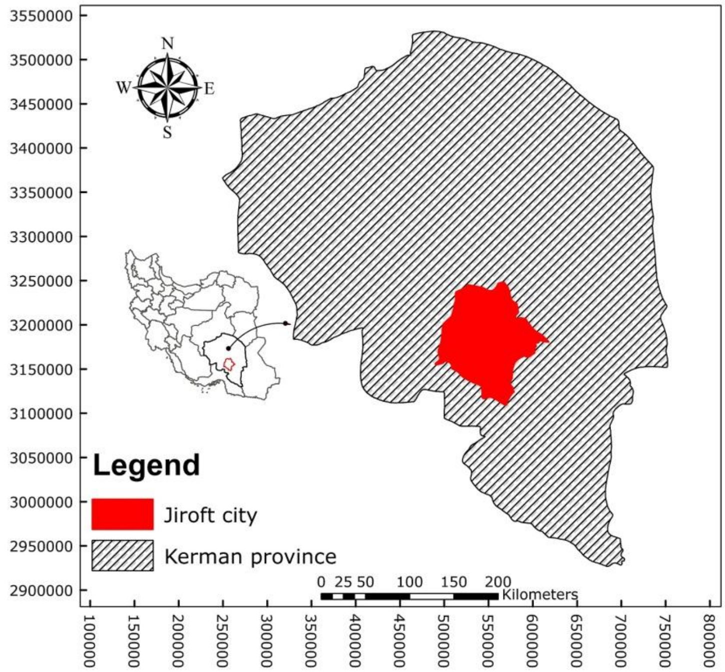

Fig. 1. Location of study area in Kerman province

As for the present study, only 19 drinking water wells were used in the rural areas along with 12 drinking water wells in urban areas. One-liter polyethylene canisters were employed to collect and transport samples. First, the dishes were washed with well water before sampling in place and then filled to 900 ml to provide enough space in the bottle to shake and mix the contents thoroughly during the test. Once the location of the sampling as well as its date was recorded, the samples were transferred to the laboratory under standard conditions to be analysed with DR2800 spectrophotometer. The Nitrate specimens should be determined immediately after sampling; otherwise, they have to be kept at 4 °C for 2 days. Disinfected solutions were stable for more than 14 days at least without acid. If Nitrite was present, the acidification of the sample would cause the heterogeneous conversion of Nitrite to Nitric Oxide (NO), which can be oxidized, hydrolysed, and converted to Nitrate. Hence, the Nitrate sample amount may be total Nitrate and Nitrite and the samples should not be used to detect acid Nitrate (Parveen et al., 2010; Karbassi et al., 2015). The sample size was 18 litres (18000 ml) per month and 102 litres for 6 months. Sampling operations from 31 the wells took place in winter and summer, 2017. The specimens were transferred to the Jiroft Abfa laboratory after collecting and the samples were read by DR2800 spectrophotometer.

Due to regional climate of the region, two season testing were appropriate for evaluating the groundwater pollution. While more testing would increase the sensibility and accuracy of the results, limitations in the time and resources confined testing periods leads to choose two in summer and winter.

The sampling points were selected according to the study map, which had a good dispersion to cover the entire rural and urban areas, under the supervision of Jiroft Water and Sewage Company. For this purpose, 19 drinking water wells in rural areas and 12 drinking water wells were selected. Table 1 presents the geographic coordinates of the studied wells along with the number of meters in both summer and winter seasons for drinking water wells in both rural and urban areas.

Figure 2 illustrates the position of the sample wells.

Table 1. Supplying drinking water wells with Nitrate in summer and winter

No.	**Name of rural sample**	**Coordinate(UTM)**		**Nitrate-Summer (mg/L)**	**Nitrate-Winter (mg/L)**
		x	**y**		
		supplying rural drinking water sample points			
1	Dehno	569261	3147745	4.48	7.42
2	Harandi	574887	3143352	41.61	48.8
3	Amirabad	575572	3144857	9.724	13
4	Daroei	553913	3125744	22	21.14
5	Jazfatan	563968	3123701	11.492	30
6	Dehdar	572487	3147847	3.978	10.12
7	Dashtkoch	578545	3175862	6.7	10.608
8	Omran	580785	3160784	4.26	8
9	Romerz	574249	3163897	5	13.702
10	Khatonabad	576985	3152149	20.744	21.21
11	Daryache	566560	3173506	13.11	17.11
12	Darjoei	570244	3176167	31.17	13.2
13	Hokerd	570506	3166558	7.8	13.2
14	Seroni	576701	3157671	13	11.21
15	Dolatabad	513735	3176562	5	4.862
16	Delfard	557374	3210578	7	11.7
17	Seghdar	586162	3190770	24.22	9.724
18	Pidengoei	592002	3186328	4	13.41
19	Korgaz	533820	3229797	8	5.13
		supplying urban drinking water sample points			
1	Urban1	570870	3174950	16.1	22.7
2	Urban2	571446	3175266	11.3	16.7
3	Urban3	567498	3173611	3.9	25
4	Urban4	567998	3173922	4.9	7.3
5	Urban5	573548	3176660	6.5	6.7
6	Urban6	571543	3178134	7.5	12.3
7	Urban7	572527	3178817	2.9	7.5
8	Urban8	573569	3178593	3.5	6.4
9	Urban9	574210	3177878	3.4	10
10	Urban10	574029	3178707	3.6	8
11	Urban11	573180	3178089	6.7	6.7
12	Urban12	572781	3177591	6	6

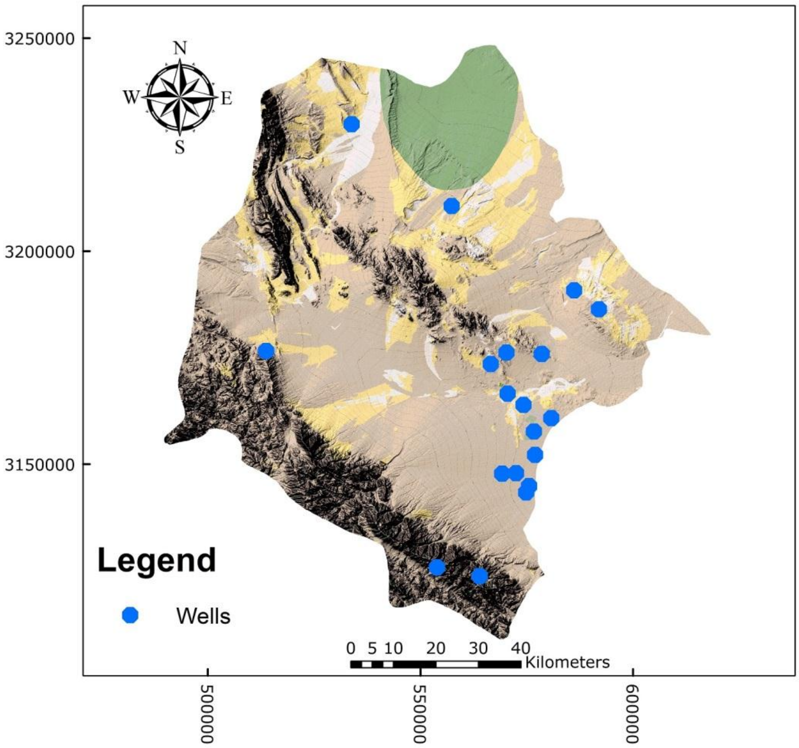

Fig. 2. Distribution of the wells

RESULTS AND DISCUSSION

Nitrate ions are soluble in water and, unlike ammonium ions, are not attached to soil particles; therefore, they move along the surface of the water and can enter groundwater and surface water. It should be noted that the Nitrite in surface water rarely exceeds 1 mg/L. Unless severely-contaminated with sewage, high concentrations of Nitrate in water indicates contamination and sometimes can lead to microbial contamination. The ability of Nitrate to enter water sources depends on soil conditions as well as the depth of the well (Hansen and Djurhuus, 1997). Concerns about nitrous oxide in groundwater are beyond mere toxins, for it is an indicator of groundwater pollution. Contrary to many physical and chemical factors, the increase of which can be detected through addition of a certain flavour, Nitrate ion does not cause water to taste strangely even when its concentration goes above the limit. The Nitrates Directive establishes that both surface freshwater and groundwater should be regarded as affected by Nitrate pollution when their Nitrate contents exceed 50 mg/L. Nitrate levels above this limit are considered dangerous to human health and to the environment (Sutton et al., 2011). Considering the health hazards of Nitrate and Nitrite, World Health Organization has set the standard amount of 50 mg/L for Nitrate in drinking water too (European Commission, 2000). Also on this basis, a standardized standard value of 3 mg/L has been established for Nitrite. In 1962, the American Public Health Board recommended the limit of Nitrate in drinking water in terms of nitrogen to be 10 mg/L (in accordance with 50 mg/L Nitrate). The Institute of Standards and Industrial Research of Iran, No. 3510, considers the desirable and maximum Nitrate levels to be zero and 50 mg respectively (Parastoo et al., 2015).

Considering that Nitrate standard for both World Health Organization and National Iranian Standard is up to a maximum of 50 milligrams per liter (in term of Nitrate), the results from the experiments conducted on water wells in Jiroft City were compared with this standard value.

Results show that the average Nitrate concentration in summer and winter was lower than the standard in the water resources of the rural areas. The fluctuations of this parameter can be seen in Fig. 3.

Table 2 presents the mean and standard deviation of Nitrate concentration in all wells and drinking water springs of rural water resources, comparing them with national and international standards. The results of the T-test showed that the Nitrate level in waters of the rural areas was lower than the international standard (considering the significance level below 0.05 and the upper and lower limit of the negative).

In addition, results for Nitrate in winter indicate that the average Nitrate concentration in water resources of rural areas in Jiroft was below the standard. Results of the T-test show that the Nitrate level in the water of the rural areas of Jiroft city was lower than the international standard. The fluctuations of these results can be seen in Fig. 3 (considering the significance level below 0.05 and the upper and lower limit of the negative).

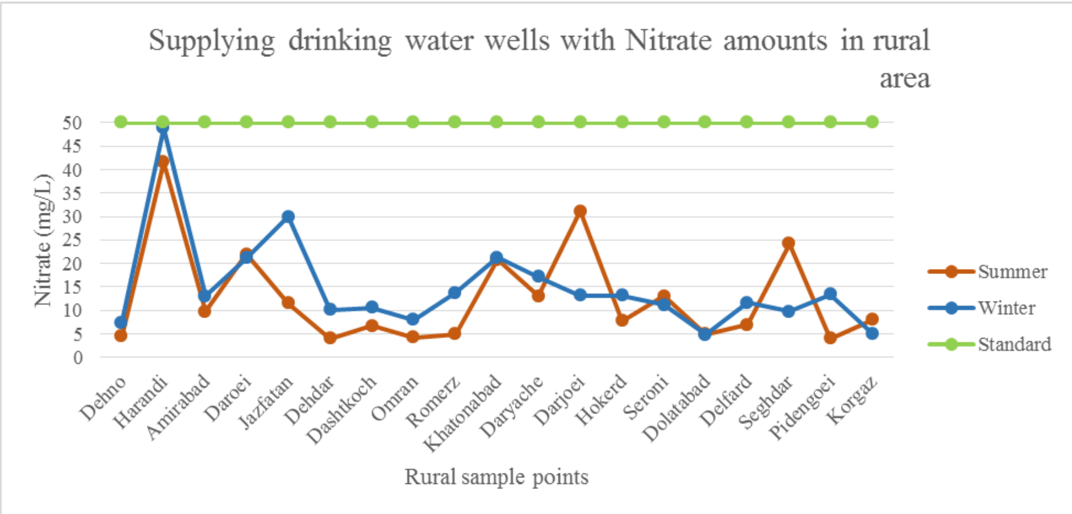

Fig. 3. Comparison of Nitrate with standard values in rural area

Table 2. One-Sample Test for Nitrate in rural areas

Nitrate	Mean (mg/L)	Std. Deviation	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
	Test Value = 50							
							Lower	Upper
Summer	12.804	10.527	-15.401	18	0	-37.195	-42.269	-32.121
Winter	14.923	10.18	-15.018	18	0	-35.076	-39.983	-30.17

The results, concerning Nitrates in the summer, show that the average Nitrate's content for the rural areas was 12.88 and for the urban areas of Jiroft, 28.6 mg/L whereas, the same results for winter show that the average for drinking water in rural and urban areas was 14.92 and 11.11 mg/L, respectively.

Independent T-test with 95% confidence level was used to study the meaning difference between drinking water in urban and rural areas. They are given in Table 3. In order to correctly use this test, we need to be informed about the equality or inequality of the variances of the two groups; therefore, Levene Test should first examine the equality of variances of the two groups.

Equivalence of variances: If the value of sig from the Levene test is greater than 0.05, it can be concluded that the variances of the two groups are equal. In this case, we use the test called "t-two independent samples in the equation of variance" to examine the significant difference between the two groups of meanings (Mattos et al, 2015).

Inequality of variances: If the value of sig obtained from the Levene test is less than or equal to 0.05, it can be concluded that the variances of the two groups are not equal. In this case, we used the t-test of two independent samples in the inequality of variances to measure the difference between the two groups of meanings (Mattos et al, 2015).

A significance level of less than 0.05 in the levene's test indicates that the two groups are not equal in terms of variance; therefore, independent t-test should be used in case of unequal variances. Independent T-test showed that there was a significant difference between the two groups in the 95% level of Nitrate in summer; therefore, it can be said that the difference between the mean of Table 3 is significant and that during the summer season the amount of Nitrate in drinking water in rural areas surpassed that of the urban ones.

A significant level greater than 0.05 in the levene test indicates that the two groups are equal in terms of variance. Therefore, the T-independent in the equation of variance test should be used. The results of independent t-test showed that there was no significant difference in Nitrate level in the winter at 95% level between the two groups, thus it can be said that the average difference from Table 3 was not significant.

Fig. 4 compares the amounts of Nitrate in the wells, supplying drinking water in both rural and urban areas.

Table 3. Comparison of the results from independent T-test of Nitrate for drinking water in rural and urban areas

Nitrate		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Summer	Equal variances assumed	8.152	0.008	2.134	30	0.041	6.516	3.053
	Equal variances not assumed			2.483	23.914	0.02	6.516	2.624
Winter	Equal variances assumed	0.627	0.435	1.168	30	0.252	3.722	3.187
	Equal variances not assumed			1.271	29.835	0.213	3.722	2.927

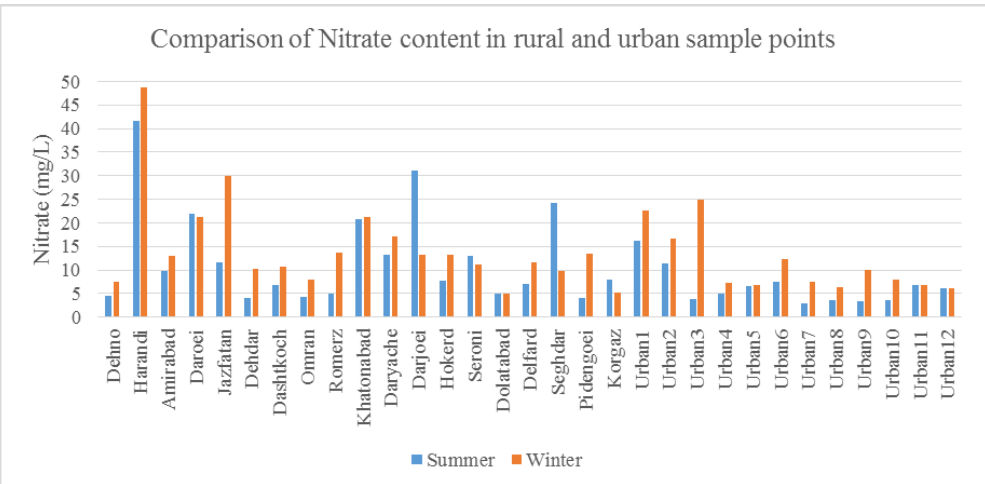

Fig. 4. Comparison of Nitrate content between rural and urban sample points

(a) (b)

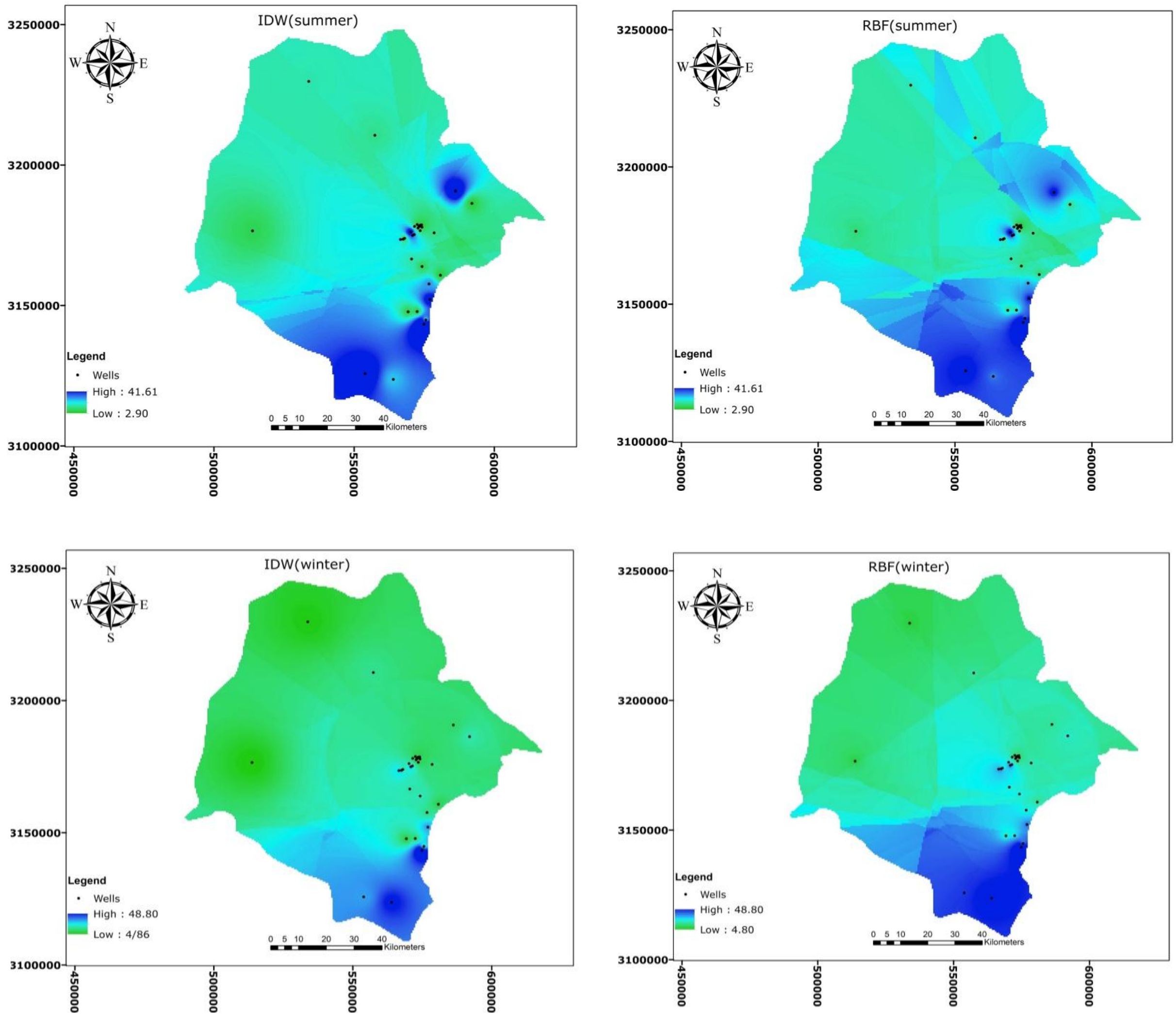

Fig. 5. Nitrate zoning map via two methods of (a) IDW and (b) RBF

In order to measure the effect of rainfall on the amount of Nitrate in drinking water in both urban and rural areas, the amount of Nitrate in the winter and summer was compared. Nitrate concentrations in groundwater were generally low under natural conditions; its abundance suggesting susceptibility to pollution (Shirazi et al., 2012). For this reason, this indicator has been widely used by many researchers to validate groundwater vulnerability models (Boy-Roura et al., 2013; Kura et al., 2015; Martínez-Bastida et al., 2010). As shown in Fig. 4, Nitrate in drinking water was significantly higher in the winter than the summer, so it can be concluded that the higher the rainfall, the greater the amount of Nitrate in the water.

In order to measure the cause of drinking water pollution in urban and rural areas, the directional distribution of pollution ought to be identified. The directional distribution tool shows whether the distribution of geographic distributions in space has been directionally-oriented or not (Asgari, 89: 1390). In order to analyse the dispersion of Nitrate in the summer and winter, two methods of IDW[1] and RBF[2] were used in ARCGIS 10.5.

1. Inverse Distance Weighting
2. Radial Basis Functions

Fig. 5 shows the distribution of Nitrate in Jiroft city. The bright parts (north and northwest of the city) had the lowest levels of Nitrate pollution in the summer, while the dark ones (parts of east and south of the city) had the highest levels of Nitrate pollution, which is probably due to their proximity to agricultural land. Also, as can be seen in the distribution of Nitrate in winter, the bright parts (north and northwest of the city) had the lowest Nitrate pollution, and dark ones (parts of the east and south of the city), the highest levels of Nitrate pollution, probably due to their close proximity to agricultural lands.

As shown in Table 4, the lowest RMSE in Radial Basis Functions is obtained, making this method more suitable than the others for the prediction map in this scenario.

The Hot Spot analysis also took place. It is illustrated in Fig. 6, which shows the zoning of arsenic in a soil type map.

According to the results from statistical tests along with Hot Spot analysis, changes in arsenic were not affected by geological parameters of the area. Also, the implementation of the Hot Spot Analysis with the land use map, illustrated in Fig. 7, shows that the pollution of water wells with Nitrates does not correlate with land use.

Table 4. RMSE implementing the 'Inverse Distance Weighting' and 'Radial Basis Functions' on the selected 31 wells of Jiroft

Season	RMSE Inverse Distance Weighting (μgr)	RMSE Radial Basis Functions (μgr)
Summer	9.98	9.46
Winter	9.93	8.84

(a) (b)

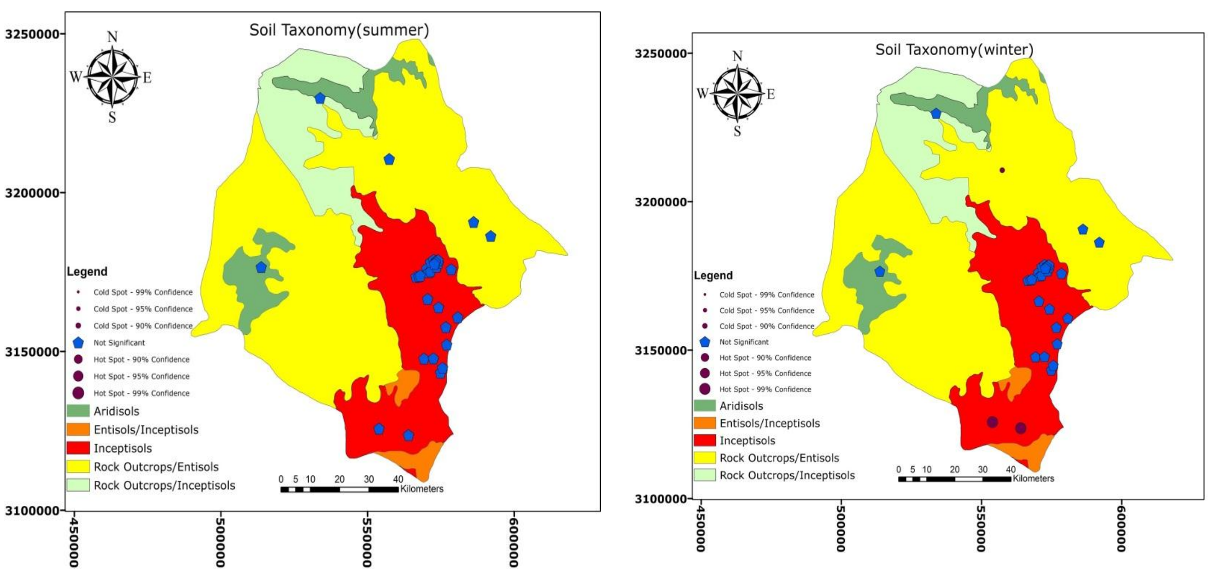

Fig. 6. Hot Spot analysis did not show any relation between soil taxonomy and Nitrate in (a) Summer and (b) Winter

(a) (b)

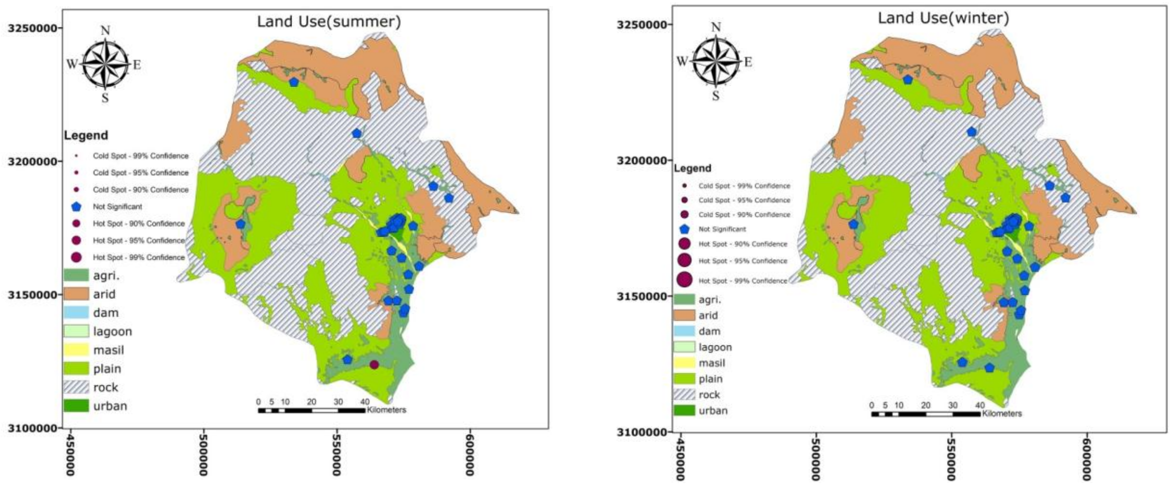

Figure 7. Hot Spot analysis did not show any relation between land use and Nitrate in (a) Summer and (b) Winter

CONCLUSION

The current paper presented mean and standard deviation of summer and winter Nitrate concentrations in all wells and springs, comparing them with national and international standards. Results from the T-test showed that Nitrate in drinking water in both rural and urban areas was below the international standard (considering the significance level below 0.05, and the upper and lower negative levels).

Results of the T-test showed that the Nitrate content in the water of rural areas in Jiroft city was lower than the international standards (considering the significance level below 0.05 and the upper and lower limit of the negative). Results for winter Nitrate amounts showed that the average for drinking water in rural areas was 14.92 mg/L, while for urban areas it was 20.11 mg/L. Results of independent T-test indicated that this difference was significant. In other words, this difference was not very great.

Results for summer season showed that the mean for drinking water in rural areas was 12.88 mg/L, and 6.28 mg/L for urban areas, with the results of independent T test showing that this difference was significant. Therefore, it can be said that the amount of Nitrate in drinking water in urban areas was less than that of the rural areas.

Rainfall in the winter increases the concentration of Nitrate. Based on the findings of this research, the concentration of Nitrate ions in the water resources, studied in Jiroft city, was affected by climatic conditions and rainfall. As such, the Nitrate content, measured after the winter rainfall, was higher, proving that rainfall does raise the Nitrate amount.

Results of IDW and RBF showed that north and northwest of Jiroft city had the lowest Nitrate pollution, while some eastern and southern parts of the city had the highest Nitrate pollution in summer and winter.

In the GIS, a geologic map was adapted to the geographic distribution of water pollution, which showed that water pollution from Nitrate was not related to the soil type of the region. Also, comparing the geographical map of water pollution with the land use map indicated that pollution was not related to the type of use.

Although the average concentration of Nitrate did not pose a serious problem in

the whole region, the following points are of high account:
- Concentration of Nitrate for health causes a problem.
- In the area under study, groundwater is the main source of drinking.
- The concentration of this ion is continuously increased in water resources of the country
As a result, it is recommended to correctly manage chemical nitrogen fertilizers, properly treat wells and waste water, protect drinking water wells, and change the land use.

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