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Risk evaluation and distribution of arsenic concentration in groundwater resources of villages in Jiroft County, Kerman Province, Iran

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ABSTRACT
In this study, the arsenic polution of drinking water wells of rural areas was investigated for obtaining the extent of this pollution and also finding the possible sources for this pollution. So, the distribution of arsenic in 19 wells with different depth from 5 to 100 m and water flows were examined in a 6-month period from September 2016 to February 2017. These samples were compared with the international standards. Effects of well depth, water flow, rainfall, soil and land usage on the arsenic concentration were evaluated. The results show that places with the inceptisols have higher water pollution. The highest and lowest arsenic concentrations are reported in Daryache and Hokerd villages with 153 and 0.5 μg L^{-1}, respectively. In addition, matching the geographical map of water pollution with the land use map by hot spots analysis indicated that more polluted water wells have been located around the agricultural land. The results also indicated that the accuracy of the RBF method for obtaining the zoning arsenic concentration is higher than the other methods. The results of Pearson's correlation test indicated that there is no significant relationship among the depths, flows and rainfalls of wells and the arsenic concentration.

Keywords: Groundwater, Arsenic, Jiroft county, Zoning, Pollution.

INTRODUCTION
Among heavy metals, arsenic is toxic and cancerous metalloid (Pourret 2018). In many parts of the world, concentrations of arsenic in ground and surface waters are higher than national and international drinking water standards (Smedley & Kinniburgh 2002). Millions of people around the world are exposed to arsenic natural disasters in drinking water (Smith *et al.* 1998; Focazio *et al.* 2000). Arsenic is widely distributed in the Earth's crust, which contains about 3.4 ppm arsenic (Rasool *et al.* 2016). It has been detected in rainwater at average concentrations of 0.2-0.5 μg L^{-1} (Kapp 2016). It has also been detected in human tissues, including blood, kidney, hair, nails, and internal organs. Data are available for populations exposed in the workplace and for the general population (Keil & Richardson 2016; Tual *et al.* 2017; Boonkhao *et al.* 2017). Anthropogenic sources of arsenic releases to water include mining, nonferrous metals (especially copper), smelting, waste water, dumping of sewage sludge, coal burning power plants, manufacturing processes, urban runoff, atmospheric deposition and poultry farms (Garbarino *et al.* 2003). Arsenic enters the environment through natural or anthropogenic processes. Anthropogenic activities include the dumping of industrial hazardous waste, melting and purifying arsenic minerals, coal combustion, groundwater recovery and agricultural activities (Ali *et al.* 2019). In many parts of the world, especially in areas such as Iran, groundwater is considered as an important source for meeting drinking and farming needs. Therefore, it is very important to study the quality of these waters and the

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zoning of the pollution levels of these waters. Arsenic is susceptible to leaching in soil and it leads to groundwater pollution, although its vertical penetration is slow (Meharg & Rahman 2003). Several authors studied the distribution of different pollutants in different areas (Nikravesh *et al.* 2018; Asadifard & Masoudi 2018; Rafiee *et al.* 2019; Navabian *et al.* 2020; Fallah *et al.* 2021). Nevertheless few of them are about the distribution of arsenic in groundwater resources. Andrade & Stigter (2013) studied the distribution of arsenic in groundwater resources of Central Portugal. They mapped the zoning of relevant elements using geostatistical models. Their results showed that the average concentration of the studied elements was less than the standards that have been set by the World Health Organization (WHO). Rahnama *et al.* (2012) studied the process of quantitative and qualitative changes of groundwater resources in Jovain plain of Khorasan Razavi Province, Iran. They studied and evaluated the fluctuations of groundwater quality in different seasons of the year using the Kriging method and Geographic Information System (GIS) software. Francisca & Perez (2009) used ground-based arsenic in groundwater assessment to determine the spatial distribution of arsenic. They concluded that over 90% of the area exceeded the standard limit for the arsenic. Cinti *et al.* (2007) examined the affecting factors on the arsenic concentration in the underground water. They found that the soil taxonomy affects the arsenic level.

Given the development of agriculture around the Jiroft County and the excessive usage of manures and poisons, the present study compares the arsenic concentrations, provides spatial distribution maps and obtains probability of the arsenic pollution of the underground water resources in this area. It is observed that wells in recharge areas are more vulnerable from the surface contamination, similar to the Moran *et al.* (2004) study. The main aim of this study is to obtain locations with high arsenic pollutions, the values of these pollutions in water wells and also the possible sources of these pollutions.

MATERIALS AND METHODS

Sampling was performed using polyethylene bottles previously washed with 1% nitric acid and distilled water twice distilled off. Two samples were taken at each sampling site. The sampling was carried out in such a way that no air was present in the upper part of the bottle. The samples were acidified with pH 2 under nitric acid to prevent the possible precipitation of cautions and to increase the pH and growth of microorganisms. In addition, the coordinates of the wells were collected by GPS and other well information was obtained from the documents available at the Kerman Water and Wastewater Company, Iran. Samples were taken from different wells to the laboratory and arsenic was measured by atomic absorption device.

To check the accuracy of the analytical method, standard solutions (Merck, Germany) with different contents of arsenic (from 0 to 25 ppb) were used for the calibration. The accuracy of the used analytical method in this study was acceptable for detecting more than 10 ppb arsenic concentration. The t-test statistical method was used in this study to determine a significant difference between the means of analyzed data. It is mostly used when the data sets follow a normal distribution and may have unknown variances. A t-test is used as a hypothesis testing tool, which allows testing an assumption applicable to a population. There are well-known Tables for presenting the obtained results from t-test. In these Tables, N is the number of valid (i.e., non-missing) observations used in calculating the t-test, Mean is the mean of the variable, standard deviation (SD) calculates the standard deviation of the variable, standard error (SE) of mean estimates standard deviation of the sample mean, t is the student t-statistic, which is the ratio of the difference between the sample mean and the given number to the standard error of the mean, df is the degrees of freedom for the single sample t-test simply the number of valid observations minus 1 (we loose one degree of freedom because we have estimated the mean from the sample), Sig (2-tailed) is the two-tailed p-value evaluating the null against an alternative that the mean is not equal to 50 (it is equal to the probability of observing a greater absolute value of t under the null hypothesis, Mean Difference is the difference between the sample mean and the test value and 95% Confidence Interval of the Difference are the lower and upper bound of the confidence interval for the mean.

Statistical analysis

For statistical analyzing, the SPSS22 software was used, which is an efficient software in the field of statistical analysis. These analyses were based on observations in both summer and winter seasons. These tests included determining the allowable water consumption of different wells for consumption (one-sample test), the correlations between depth and water flow with amount of arsenic (Pearson test) and dependence of these

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observations on rainfall (Paired samples test). In all statistical tests, the significant level was less than 0.05. Geostatistical analysis of this study was performed using the ArcGIS 10.5 software. For investigating the spatial variations and estimating the quality of measured characteristics, three statistical methods Kernel interpolation (KI), inverse distance weighting (IDW) and radial basis functions (RBF) were investigated using this software. In this software, the contaminated places with wells were examined using the hot spot analysis. The results show that the radial basis functions (RBF) method has a very strong mathematical foundation based on the ordering hypothesis to solve such problems.

Notably, the one-sample test was performed to examine the fact that the sample was obtained from a statistical population with an average of 10, and this test was used based on the nature of the two-way test hypothesis. The null hypothesis, given its positive nature, assumes that the average is 10, equal to the standard amount of arsenic. Pearson test was used for the relationship between the two sets of observations and only the correlation coefficient was used in this test. The value of this coefficient can indicate a linear and direct relationship (if equal to 1) or a linear but inverse relationship (if equal to -1) between two data sets. Another performed test was Paired samples test to evaluate the effect of rain on arsenic. In this test, the effect of rain was investigated by measuring arsenic in two periods (summer and winter). The null hypothesis indicates that precipitation has no effect on the amount of arsenic.

Case studies

Jiroft (13º 40′ 28″ N, º17 44′ 55″ E) is a city in the Kerman Province (Iran) around the Hellirud River and the southern slopes of Jabalbarz. This city is 650 m above the sea level, by about 200000 population and has been located at 230 km south-east of Kerman and 1375 km south-east of Tehran. The area of this city is about 8602 km^2, equal to 4.65% of its province. Kerman, Anbar Abad, Bam, Baft and Rabar surround this city. This city has 5 villages. In this area there are about 5000 wells (semi deep and deep), 1100 springs and 300 aqueducts, which apply a total flow of 950 m^3 per year to the Jiroft aquifer. The Kerman Water and Wastewater Company covered about 70 cases of these wells. The aquifer's water table level has fallen by about 32.1 m $year^{-1}$ in a seven-year period from 2001 to 2008, (Abbas Nejad *et al.* 2013). Fig. 1 shows the location of the study area in Kerman Province.

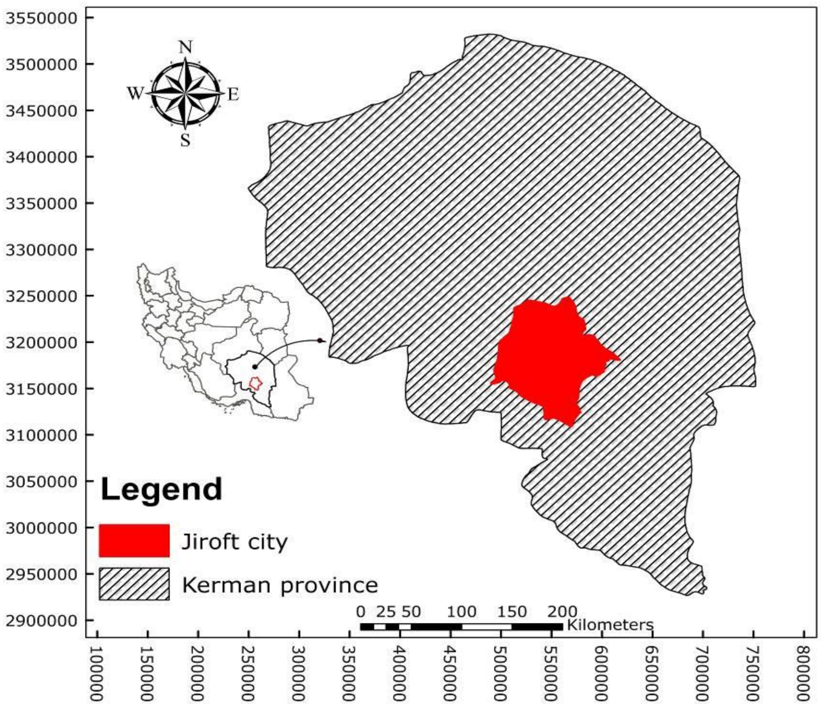

Fig. 1. Location of the study area in Kerman Province.

The sampling points were selected according to the map, which has a good dispersion to cover the entire villages under the supervision of Kerman Rural Water and Wastewater Company (see Fig. 2 and also Table 1). So, 19 drinking water wells were selected.

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Table 1. Location of 19 wells examined in Jiroft County in the UTM N zone 40 and some of their attributes.

No.	Name	Depth	Coordinate (UTM)		Flow (L s^{-1})
			X	y	
1	Dehno	100	569261	3147745	16
2	Harandi	80	574887	3143352	5
3	Amirabad	69	575572	3144857	5
4	Daroei	50	553913	3125744	4
5	Jazfatan	60	563968	3123701	10
6	Dehdar	100	572487	3147847	7
7	Dashtkoch	100	578545	3175862	4
8	Omran	100	580785	3160784	16
9	Romerz	60	574249	3163897	5
10	Khatonabad	100	576985	3152149	15
11	Daryache	41	566560	3173506	6
12	Darjoei	100	570244	3176167	17
13	Hokerd	80	570506	3166558	14
14	Seroni	50	576701	3157671	6
15	Dolatabad	100	513735	3176562	13
16	Delfard	100	557374	3210578	6
17	Seghdar	5	586162	3190770	4
18	Pidengoei	10	592002	3186328	2
19	Korgaz	12	533820	3229797	3

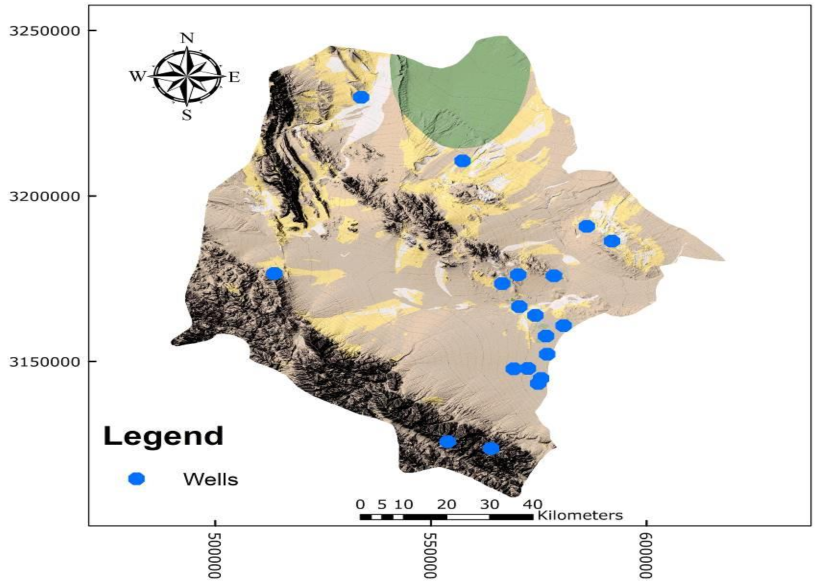

Fig. 2. Distribution of samples in Jiroft County.

RESULTS AND DISCUSSION

Comparison of arsenic with standard value

Previous studies have shown that a number of large aquifers in the world have problems with the presence of arsenic at concentrations greater than 50 µg L^{-1}. According to the WHO guidelines, the arsenic concentration in drinking water should not exceed 0.01 mg L^{-1} (Smith *et al.* 2000). In Iran, the maximum permitted arsenic in urban drinking water before 2009 was 50 mg L^{-1}. However, in 2009, the National Standard No. 1053 reduced the acceptable arsenic concentration in water to 0.01 g L^{-1}, equal to 10 µg L^{-1} (Mahram *et al.* 2013). Meanwhile, in mineral water, the maximum arsenic concentration is 10 µg L^{-1}. In this study, examining the water resources in the villages of Jiroft county (under the responsibility of Abfar Company, see Figs. 3 and 4) indicates that the average concentrations of arsenic in the water resources of the Daroei, Dashtkoch, Khatonabad, Darjoei, Hokerd, Dolatabad, Delfard, Pidengoei and Korgaz were below the standard level, while those of other wells were above this standard. The highest and lowest arsenic concentrations are reported in Daryache and Hokerd villages with 153 and 0.5 µg L^{-1}, respectively. These amounts are normal in comparison with the maximum concentration of arsenic in groundwater throughout the Lanyang plain of Northeastern Taiwan by 70.32 µg L^{-1}

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(Lee *et al.* 2007), Xiangjiang watershed, central-south China by 21.2 µg L^{-1} (Chai *et al.* 2010) as well as Kampong Cham and Kratie provinces in Cambodia by 2.37 and 140.60 µg L^{-1}, respectively (Phan *et al.* 2010).

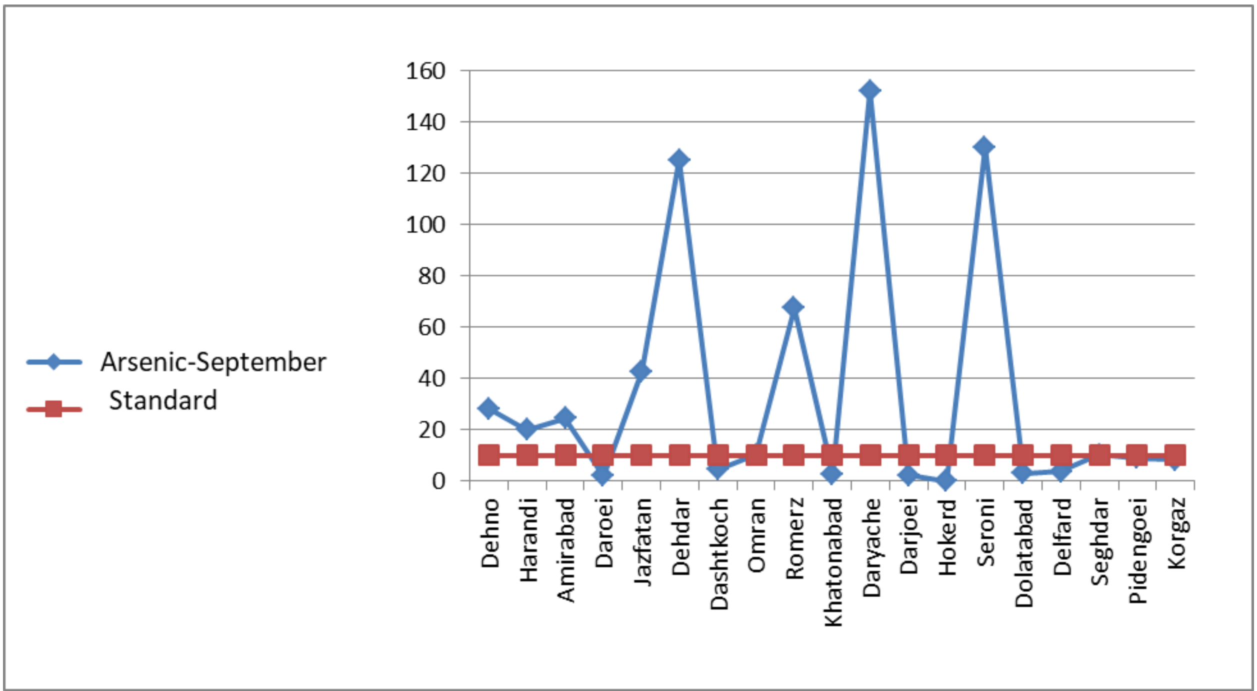

Fig. 3. Comparison of arsenic concentrations with standard values in September 2016.

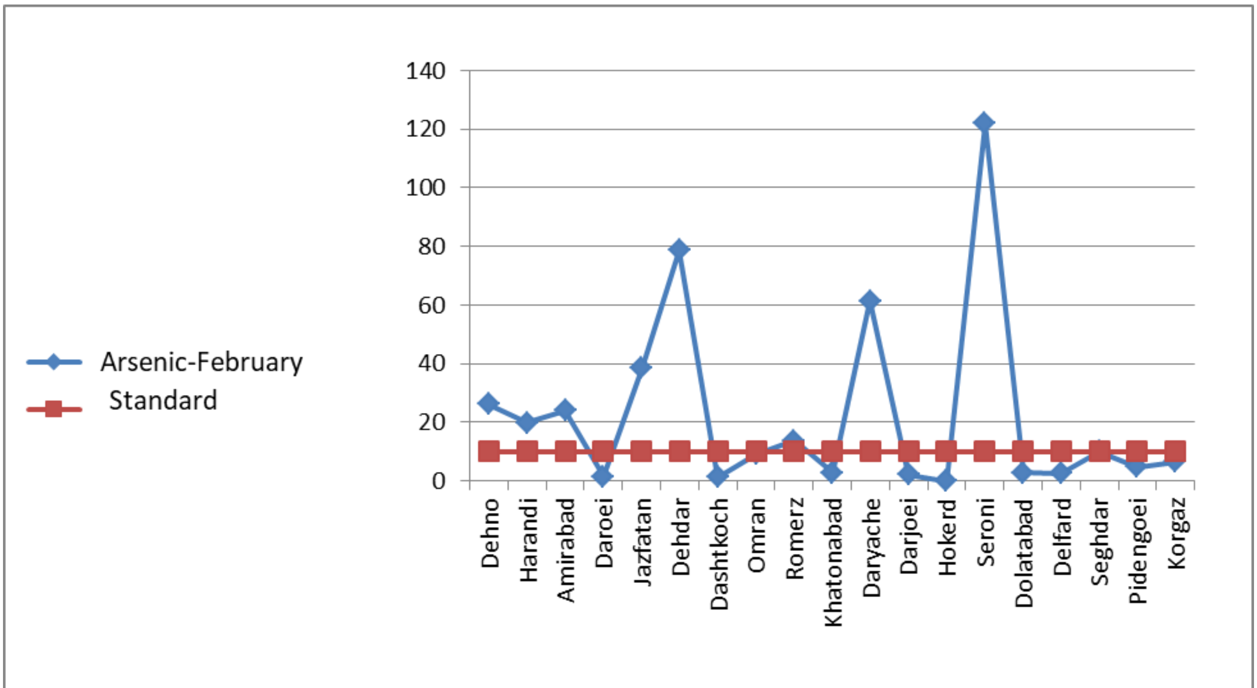

Fig. 4. Comparison of arsenic concentrations with standard values in February 2017.

Descriptive statistics including the mean and standard deviation of observations of arsenic concentrations in September in all drinking water wells in the studied villages have been presented in Table 2 and have been compared with the national and international standards by t-test. The results of this comparison have been presented in Table 3. Tables 4 and 5 depict similar data for the measured arsenic concentrations in February.

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Table 2. One-sample statistics Arsenic in September 2016.

	N	Mean	SD*	SE**
Arsenic	19	31.2053	49.33066	11.31723

*-Standard deviation, **-Standard error.

Table 3. One-sample test for September 2016 arsenic (Test Value = 10).

	t	df	Sig. (2-tailed)	Mean of differences	95% Confidence interval of the differences	
					Lower	Upper
Arsenic in September 2016	1.874	18	0.077	21.20526	-2.5714	44.9819

Table 4. One-sample statistics for February 2017 arsenic.

	N	Mean	SD*	SE**
Arsenic in February 2017	19	22.5237	32.31617	7.41384

*-Standard deviation, **-Standard error.

Table 5. One-sample test for arsenic in February (Test Value = 10).

	t	df	Sig. (2-tailed)	Mean of Difference	95% Confidence interval of the difference	
					Lower	Upper
Arsenic in February 2017	1.689	18	0.108	12.52368	-3.0522	28.0996

Comparing Tables 3 and 5 indicates that there is no significant difference between the arsenic levels in the village well waters of Jiroft County in comparison with the international standard in September and February. Therefore, the arsenic concentration of the studied wells is in the standard level (Given the significant level of less than 0.05).

Determination of the relationship between depth and arsenic

The arsenic concentrations in Pleistocene sediments can range up to 100 µg L^{-1} beneath deep paleo-channels at depths between 120 and 180 m (Mc Arthur *et al.* 2016). The holocenic sediments made of grey clay minerals and sand are not weathered. They often contain peat organic matter, which severely impairs water quality. These Holocene sediments are highly productive and quickly renewed. Their aquifers are anoxic, favoring the mobilization of arsenic (Smedley & Kinniburgh 2002) and characterized by high levels of calcium, magnesium, and iron (Ravenscroft *et al.* 2009). Individual layers cannot be distinguished horizontally or vertically over longer distances. These sandy and muddy layers can be considered as aquifers of limited size. Whereas the Pleistocene aquifers are mostly free of arsenic, this is not the case for the Holocene aquifers, which are rich in arsenic. The highest arsenic contamination is observed in those Holocene aquifers, which are approximately 3000 years old (Dowling *et al.* 2002). The waters of the upper Holocene aquifers are approximately 100 years old and contain less arsenic. However, the Holocene layers are not homogenous and settled but are characterized by gaps and holes enabling the vertical extension of arsenic contamination. This explains the marked depth-dependence of the arsenic contamination. The highest concentrations are found in 20-70 m, which corresponds to shallow and young aquifers. On the other hand, the depth of aquifers is not a sufficient criterion for waters being free of arsenic. Moreover, it is possible that arsenic is dissolved into the waters from deeper aquifers by the pumping activity of wells for drinking water production (Mc Arthur *et al.* 2016). Pearson's correlation test was used to obtain the relationship between the depth of well and the amount of water pollution in terms of arsenic. As shown in Tables 6 and 7, there is no significant relationship between depth of wells and pollution levels in both September and February, due to the significance level of more than 0.05. Based on these results, among the arsenic pollution is not a function of the depth of these wells.

Table 6. Correlations between arsenic and depth in September 2016.

		Arsenic	Depth
Arsenic	Pearson Correlation	1	-0.118
	Sig. (2-tailed)		0.630
	N	19	19
Depth	Pearson Correlation	-0.118	1
	Sig. (2-tailed)	0.630	
	N	19	19

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Table 7. Correlations between arsenic and depth in February 2017.

		Arsenic	Depth
Arsenic	Pearson Correlation	1	-0.094
	Sig. (2-tailed)		0.702
	N	19	19
Depth	Pearson Correlation	-0.094	1
	Sig. (2-tailed)	0.702	
	N	19	19

Determination of the relationship between water flow and arsenic

A primary source of arsenic to water wells is from water flowing through arsenic-rich rocks and soil. It can be further released into the environment through natural activities such as volcanic action and forest fires, as well as through human actions. In order to determine the relationship between the water flow and arsenic concentration, the correlation coefficient of arsenic concentration in samples (in February and September) was evaluated by Pearson's correlation test. The obtained results have been depicted in Tables 8 and 9. These results indicate that there is no meaningful relationship between the water flow and arsenic concentration in these months. Therefore, it suggests that there is no water flowing through arsenic-rich rocks and soil or there are no important arsenic-rich rocks and soil in the studied area.

Table 8. Correlations between arsenic and water flow in September 2016.

		Arsenic	Water flow
Arsenic	Pearson Correlation	1	-0.225
	Sig. (2-tailed)		0.355
	N	19	19
Water Flow	Pearson Correlation	-0.225	1
	Sig. (2-tailed)	0.355	
	N	19	19

Table 9. Correlations between arsenic and water flow in February 2017.

		Arsenic	Water flow
Arsenic	Pearson Correlation	1	-0.154
	Sig. (2-tailed)		0.528
	N	19	19
Water flow	Pearson Correlation	-0.154	1
	Sig. (2-tailed)	0.528	
	N	19	19

Determine the relationship between rainfall and arsenic

Some industries release considerable amounts of arsenic into the environment. Once released, arsenic remains in the environment for a long time. It is removed from the air by rain, snow, and gradual settling. Once on the ground or in surface water, arsenic can slowly enter ground water. High arsenic levels in private wells may come from certain arsenic containing fertilizers used in the past or industrial waste. Given the rainfall in the studied area from September to February, t-test was paired with the measured arsenic concentrations in September and February. Table 10 depicts the statistical characteristics of the samples and the result of the test has been presented in Table 11, exhibiting that there are no significant differences between the arsenic values in September and February. Therefore, the amount of rainfall has no effects on the arsenic concentration. This result suggests that the developed industries in this area do not produce considerable arsenic pollutions.

Table 10. Paired samples statistics.

		Mean	N	SD	SE
Pair 1	Arsenic in September 2016	31.2053	19	49.33066	11.31723
	Arsenic in February 2017	22.5237	19	32.31617	7.41384

*-Standard deviation, **-Standard error

Table 11. Paired samples test (paired differences).

		Mean	SD*	SE**	95% Confidence interval of differences		t	df	Sig. (2-tailed)
					Lower	Upper			
Pair 1	Arsenic in September 2016 – February 2017	8.68158	26.68184	6.12123	-4.17865	21.54181	1.418	18	0.173

*-Standard deviation, **-Standard error.

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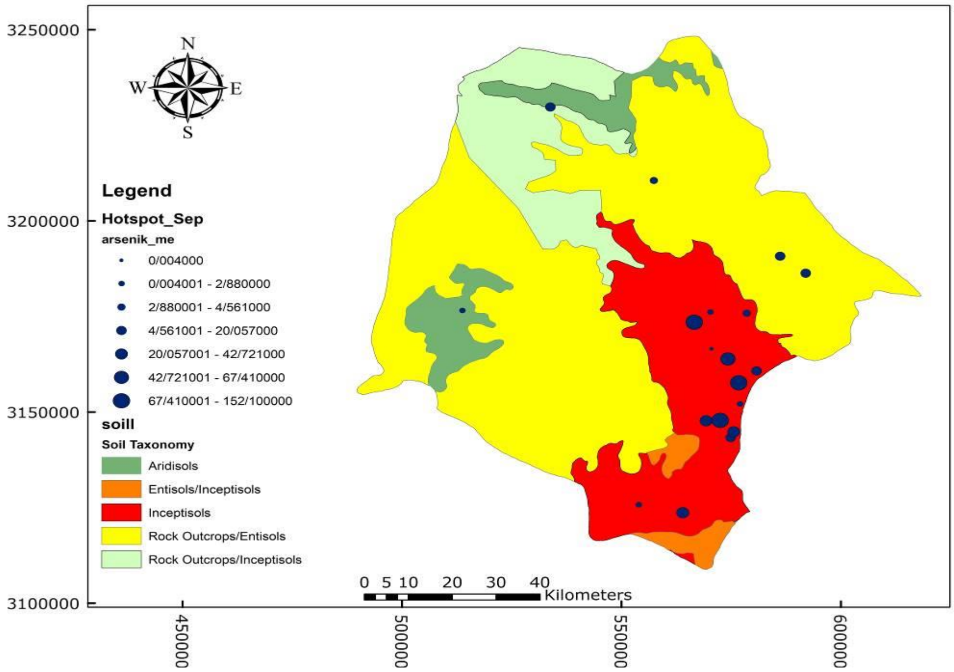
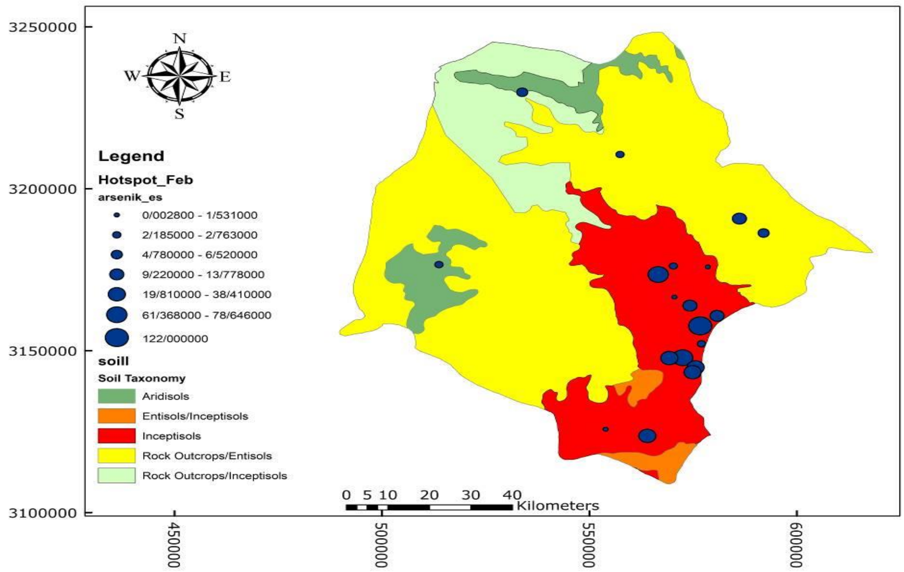
Hot spot analysis

The geographical distribution map of GIS was adapted to the soil map to determine the species of area that are in the geographical distribution of water pollution. Based on soil taxonomy in Jiroft, 14 wells (from the existed 19 wells) were in inceptisols, three wells were in rock outcrops/entisols, and one well was in rock outcrops/inceptisols. Hot spot analyses of the arsenic pollutions in September and February have been presented in Figs. 5(a) and (b), respectively. These analyses show locations of the spatial clustering, or in another word, it is a tool for visualizing the breadth and model of clustering. In looking to the main reasons of forming clustering, paying attention to their location is very important. Using general g statistics, hot and cold spots can be distinguished throughout the study area, hot and cold spots are known as spatial concentrations. This analysis indicates the locations with high or low values clustering issues. A high-value item is interesting, but it may not be significant statistically, because a hot statistical point should also be surrounded by other high values complications. Therefore, it is observed that in places where the soil was inceptisol, water contamination from arsenic is much higher than the limit.



(a) Arsenic in September 2016.



(b) Arsenic in February 2017.

Fig. 5. Hot spot analyses exhibiting the relationship between soil taxonomy and arsenic concentration (Standard deviation = 447).

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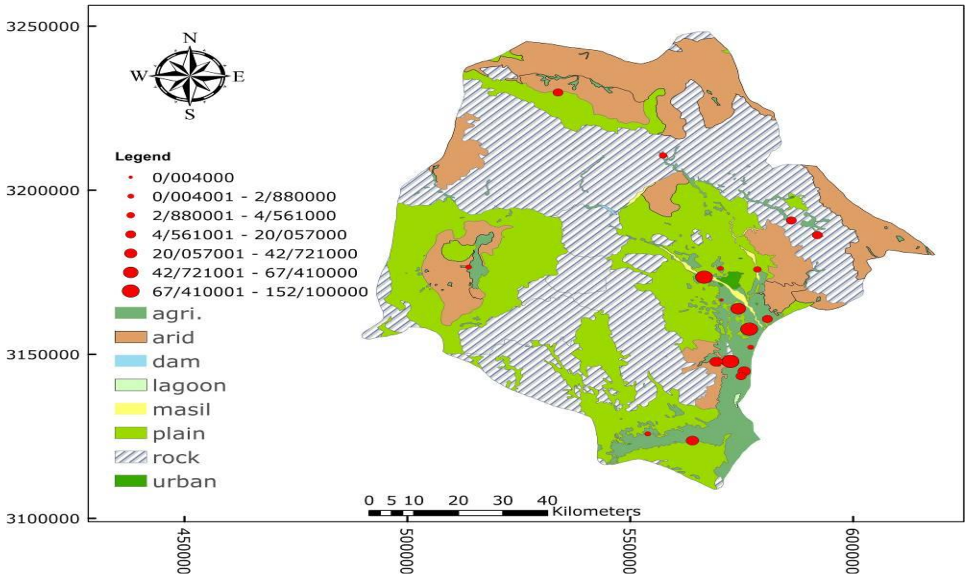
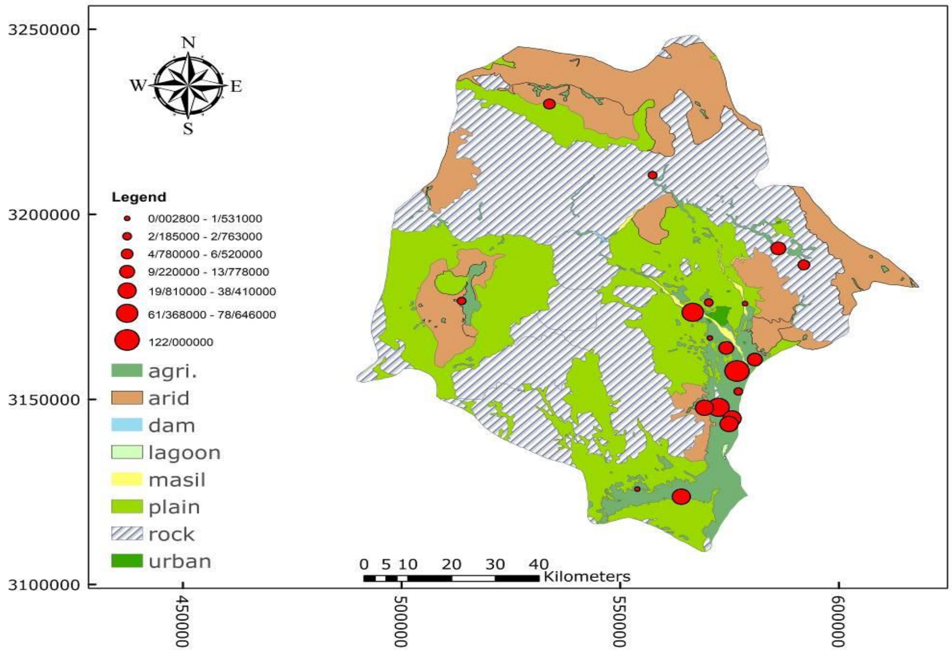
In addition, matching hot spot analysis with land use map (Fig. 6) show that contaminated water wells are located in agricultural fields or beside agricultural land.



(a) Arsenic in September 2016.



(b) Arsenic in February 2017.

Fig. 6. Hot spot analyses exhibiting the relationship between land-use and arsenic concentration (Standard, deviation = 213).

Therefore, based on the present study in the villages of Jiroft County, due to specific geological conditions and the usage of fertilizers in agricultural land, some drinking water sources were contaminated with arsenic. It means that the source of this pollution is weathering and the resulting changes in sulfide minerals containing arsenic such as realgar and orpiment in the area lead to the release of pollution to surface and groundwater in the area.

Geostatistical analyzes to determine the distribution of arsenic in the studied area

In order to obtain the source of drinking water pollution in the villages of Jiroft County, it is necessary to identify the directional distribution of contaminants, using the GIS analysis. For investigating the spatial variations and estimating the quality of measured characteristics, three statistical methods including Kernel

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interpolation (KI), inverse distance weighting (IDW) and radial basis functions (RBF) were applied using the ArcGIS 10.5 software. RBF has a very strong mathematical foundation based on the ordering hypothesis to solve problems. These networks, in general, are composed of three layers, including input, hidden and output. Regular RBFs are used as the function of stimulating hidden secret neurons. Networks are organized so that transformations in hidden units form a set of functions in order to map input patterns to output patterns (Evenbly & Vida 2016). The KI is a variant of a first-order local polynomial interpolation in which instability in the calculations is prevented using a method similar to the one used in the ridge regression to estimate the regression coefficients. When the estimate has only a small bias and is much more precise than an unbiased estimator, it may well be the preferred estimator. Tsiona & Tasiopoulos (2016) presented more details on ridge regression. The IDW method is one of the most common methods for the interpolation of spatially dispersed points in space, based on the hypothesis that, at an interpolation level, the effect of a parameter on the surrounding points is not the same and that the points near and distances are less affected. Moreover, the distance from the source increases, the effect of the parameter decreases.

Cross-validation technique has been used to compare the methods used in the present study and to select the most appropriate method of land statistics. In this method, an observation point was eliminated in each step and it was estimated using the rest of the viewing points. This was repeated for all observation points, so that ultimately there will be estimated values for the number of viewing points. Estimates were also calculated using the obtained models in some of the points where the measurements were made and, at the end, with actual and estimated values, the error and deviation of the method used were estimated. There are various criteria for this, which can be referred to as the root mean square error (RMSE) which is used in the present study. The RMSE in this case is for the points involved in the process of forming the model. At the next step, a number of wells were used as checks to examine which interpolation model was better for the realities. In such a way that the test wells do not interfere in the formation of the model and are used only to determine the optimal model. In this way, for the checked wells, we compared the estimated value with the actual amount of arsenic and selected any model with the lowest RMSE at the checked wells as the optimal model. In Fig. 7, the distribution of wells used as checks is shown with other wells used in the formation of the model.

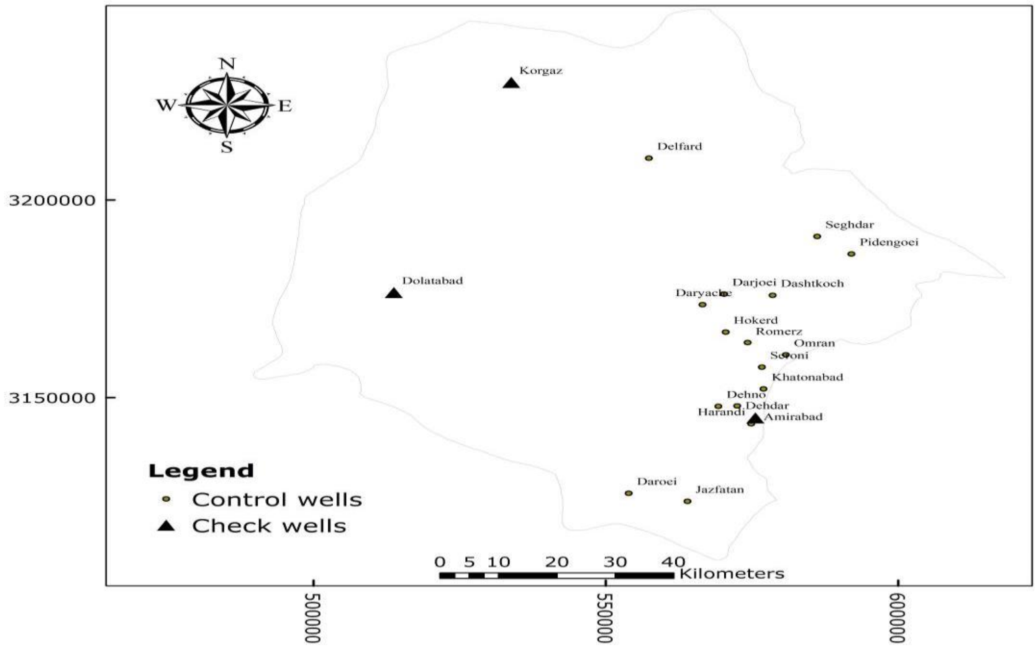

Fig. 7. Checked (triangles) and other (circles) wells distribution.

Fig. 8 illustrates the pattern of geographical distribution of contamination, which was obtained using Kernel Interpolation with Barriers method.

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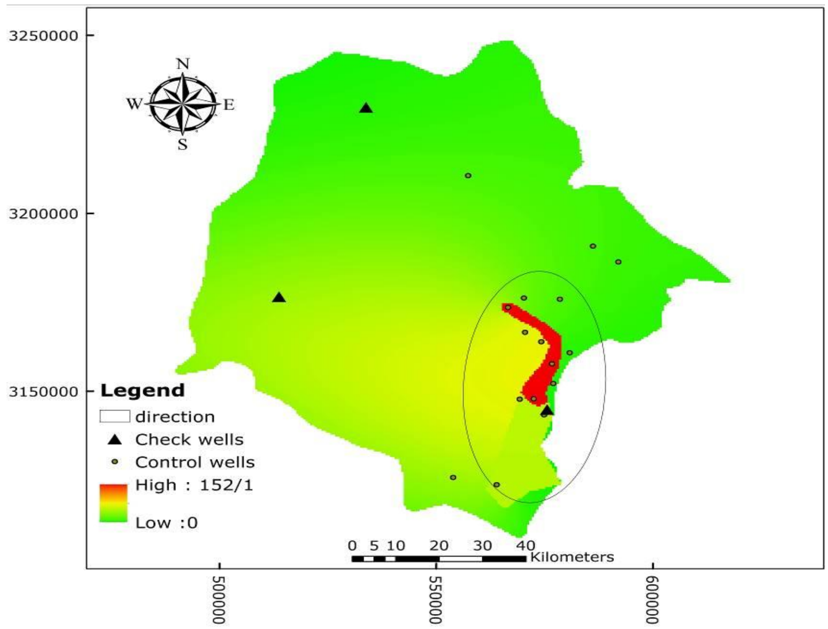
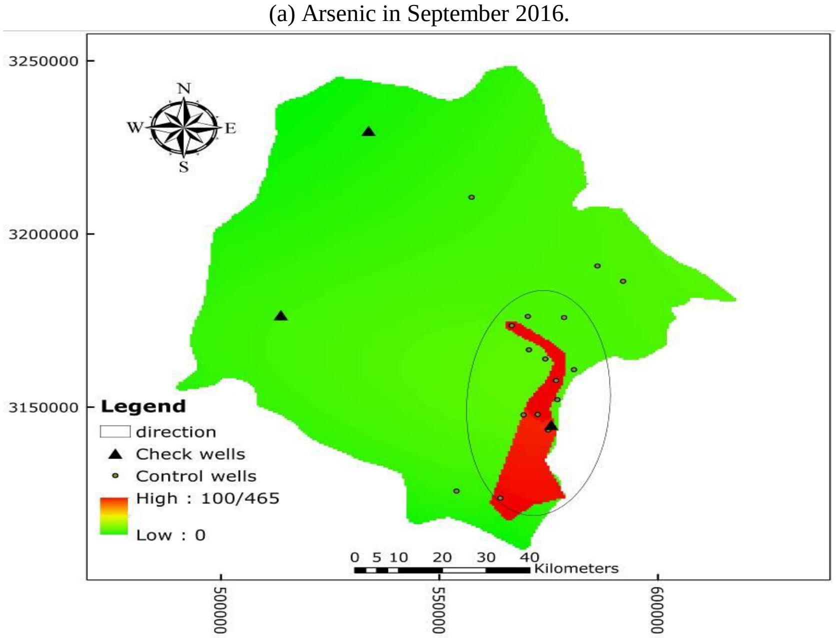


(a) Arsenic in September 2016.



(b) Arsenic in February 2017.

Fig. 8. Results using the Kernel interpolation (KI) with barriers method at sampling wells in Jiroft, Kerman.

Figs. 8 to 10 show the geographic distribution of water pollution from the Romerz village toward the south (the villages of Harandi and Dehno). Three out of the 19 studied wells (Korgaz, Dolatabad and Amirabad) were selected as check wells, and the RMSE for these wells in different methods were presented in Table 12, for September and February, respectively. As presented in Table 12, we have the lowest RMSE in RBFs, so, this method is a suitable method for prediction map.

Fig. 10 illustrates the pattern of geographical distribution of contamination, which was obtained using the inverse distance weighting (IDW) method.

CONCLUSION

In this study, the arsenic pollution of drinking water wells of rural areas was investigated. The distribution of arsenic in 19 wells of studied area was investigated from September 2016 to February 2017. These samples were compared with the international standards. Effects of well depth, water flow, rainfall, soil, and land usage on the arsenic concentration were studied. The results showed that the average concentrations of arsenic in the water resources of the Daroei, Dashtkoch, Khatonabad,

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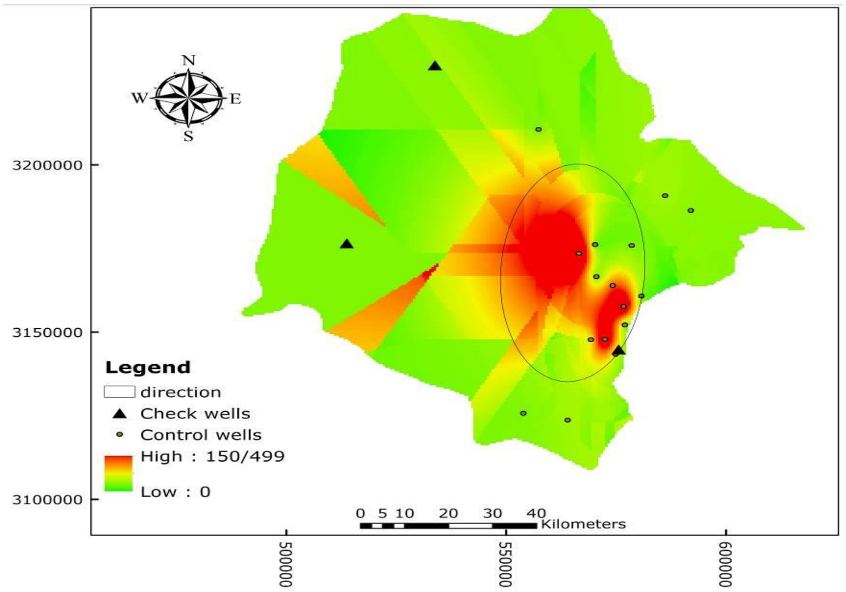
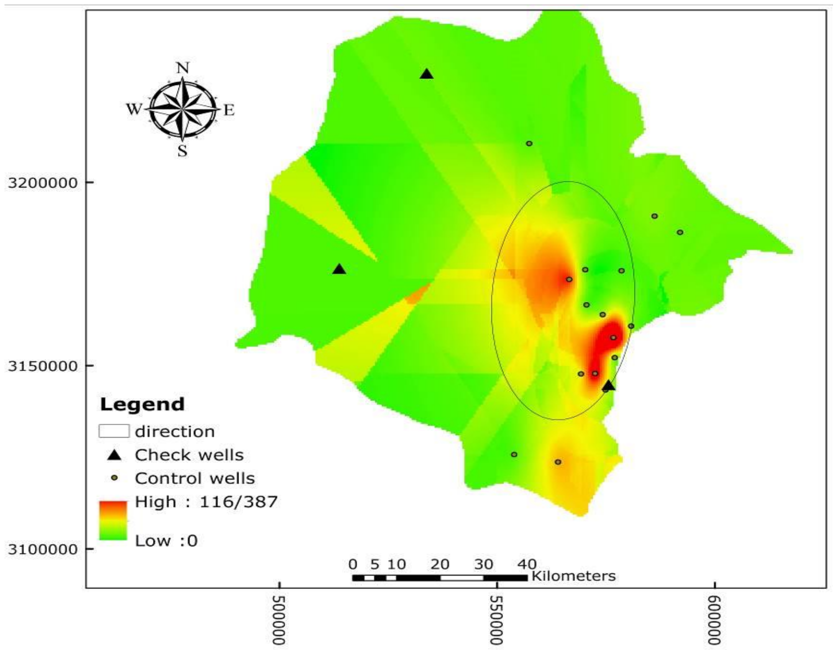
Darjoei, Hokerd, Dolatabad, Delfard, Pidengoei and Korgaz are below and the rest of the wells above the standard level. The results of the t-test showed that there was no significant difference between the levels of arsenic in the water of the villages of Jiroft County in comparison with the international standard in September and February (by significant level of $p < 0.05$). For obtaining the pollution source of drinking water in villages of Jiroft County, a combination of directional distribution and geological maps with GIS were used. The results showed that in places where the soil was inceptisols, arsenic concentration in the water is high. In addition, the implementation of a geographical map of water pollution with a land usage map indicates that contaminated water wells are located in agricultural lands or beside agricultural lands. Therefore, due to specific geological conditions and the usage of fertilizers in agricultural lands, some drinking water sources were contaminated with arsenic. Therefore, the source of this pollution was weathering and the resulting changes in sulfide minerals containing arsenic such as realgar and orpiment in the area leading to the release of pollution to surface and groundwater in the area.



(a) Arsenic in September 2016.



(b) Arsenic in February 2017.

Fig. 9. Results using radial basis function (RBF) method on sampling wells, Jiroft, Kerman.

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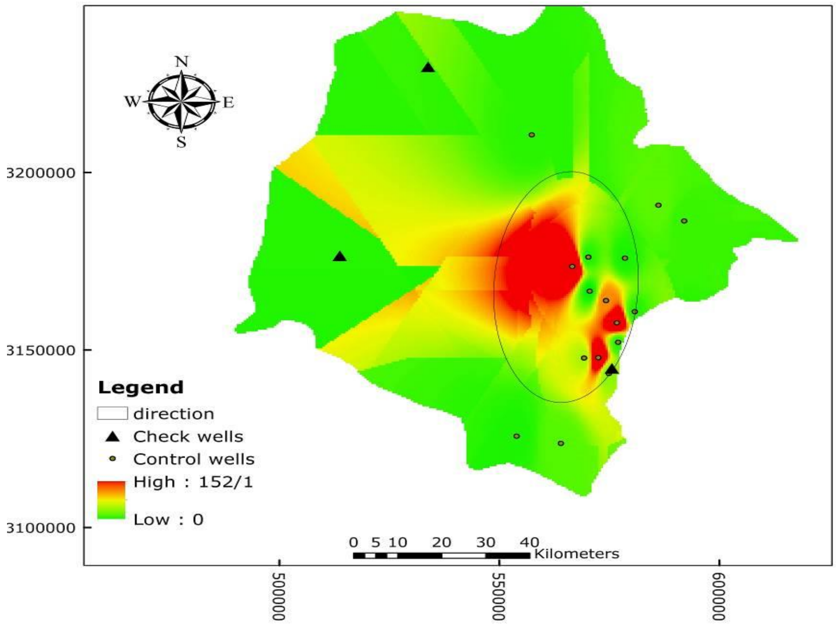
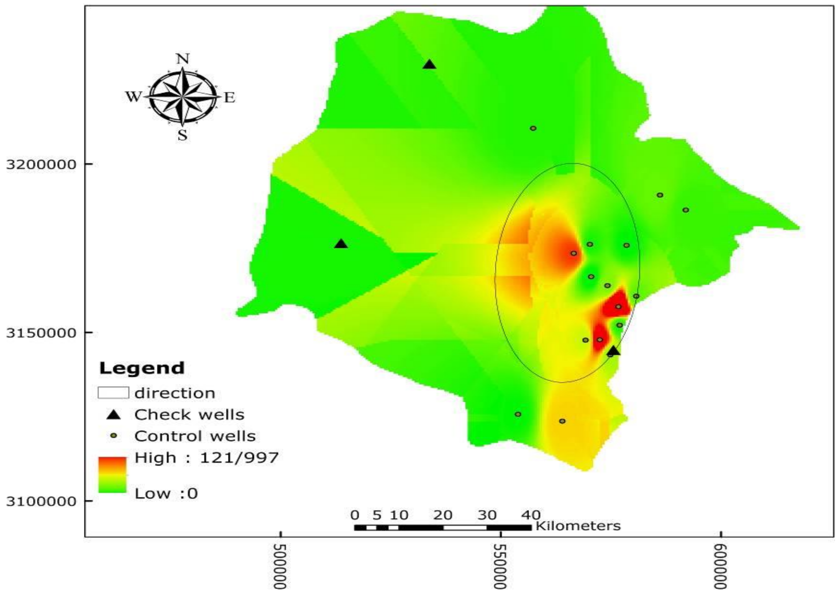
Table 12. RMSE implementing the 'KI with Barriers', 'RBF' and 'IDW' on the three wells in Jiroft, Kerman.

Time	RMSE Kernel interpolation with barriers(µg)	RMSE Radial basis functions(µg)	RMSE Inverse distance weighting(µg)
September 2016	3.78	1.93	2.74
February 2017	10.20	1.54	3.22



(a) Arsenic in September 2016.



(b) Arsenic in February 2017.

Figs. 10 (a,b). Results of using inverse distance weighting (IDW) method on sampling wells, Jiroft, Kerman.

Pearson correlation test was used to measure the relationship between well depth and water pollution. The results of this test showed that there is no significant relationship between depth of well and contamination level due to the significant level of more than 0.05. Pearson correlation test was also used to measure the relationship between the water flow and arsenic concentration in water. The results of this test showed that there is no significant relationship between the water flow and arsenic levels in water due to the significant level less than 0.05. Due to the rainfall in the study area, the t-test was paired on arsenic concentrations from September 2016 to February 2017. Results showed that there is no significant difference between the arsenic values in these two

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times. Therefore, the amount of precipitation has no important effects on the arsenic concentration. For obtaining the spatial variations and estimating the quality of measured characteristics, three geostatistical methods, i.e. KI, IDW and RBF, were used. In order to compare the methods used in this study and also to select the most appropriate method of geostatistics, the technique of examined wells was used. The results of the mean square error for the examined wells showed that the RBF method is more accurate than the other methods.

Conflict of interest

This study had no funding. The authors declare that they have no conflict of interest.

Compliance with ethical standards

Research involving no human participants and/or animals informed consent.

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