Desalination and Water Treatment
www.deswater.com
doi:10.5004/dwt.2017.20341

68 (2017) 170–176
March

Temporal and spatial variation of chemical parameter concentration in drinking water resources of Bandar-e Gaz City using Geographic Information System

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Received 9 April 2016; Accepted 9 November 2016

ABSTRACT

One of the serious challenges in ensuring and promoting community health is gradual increase in contamination levels of drinking water of communities across the world. The purposes of this study were (1) to evaluate the chemical quality of groundwater in the Bandar-e Gaz city and (2) to determine spatial distribution of groundwater quality parameters (total hardness (TH), chloride, nitrate and fluoride concentrations, and (3) mapping the quality of groundwater using Geographical Information System (GIS) software. In this study 20 groundwater samples were collected from 5 wells in two successive 2010–2011, in the rainy and dry seasons. Sample preparation and analysis, according to standard methods were done. Based on the findings of this study, it can be expressed that the average concentration chloride and nitrate parameters in Bandar-e Gaz drinking water is within the 1053 standard limit in Iran, except fluoride content is lower than the standard and hardness was high in majority of water sample groundwater. According to the zoning maps of groundwater, in the dry season's nitrate and hardness concentration is greater than rainy seasonal. The data showed falling and rising trend in CL concentrations, respectively. This study indicated that all parameter within the standard except fluoride then, its necessity to addition fluoride in that's regions population food chain and drinking water. Management of the utilization and protection greed underground waters should be as a basic principle in the planning Bandar-e Gaz city.

Keywords: Groundwater; Chemical parameters; Spatial changes; ArcGIS; Bandar-e Gaz

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1. Introduction

Humans need water of appropriate quality and quantity for a comfortable life and to carry out their various activities. For this reason, conservation of water resources, especially freshwater resources, is one of the most important factors for public health and sustainable development of communities [1]. Groundwater resources in Iran and many other areas that have similar climates are the most important resources of water for drinking and agriculture. This water is naturally refined during passage through the lower layers of the soil. Physical and microbial contamination is removed at the lowest cost in terms of time and energy [2].

Population growth, industrialization and improved standards of living in human societies require further use of groundwater resources; however, mismanagement and increased consumption of groundwater resources have degraded their quantity and quality [3]. High amounts of contaminants in drinking water can cause health problems. For example, the presence of high concentrations of nitrates in drinking water can cause methemoglobinemia [4]. Fluoride is advantageous to human health and a small amount of fluoride daily can strengthen teeth against decay. Even so, excessive intake of fluoride is harmful and can cause diseases like dental and skeletal fluorosis [5,6].

Knowledge of ground water quality through GIS spatial distribution mapping of pollutants and the resulting information on water quality could be useful for policymakers and health care personnel when taking remedial measures. These maps can determine the temporal and spatial fluctuations of water resources and show trends of future change [7]. Many studies on the quality of groundwater using GIS technology have been carried out globally and in Iran [8–13].

The lack of a buffer zone of wells in Bandar Gaz has exposed underground aquifers to agricultural, municipal and industrial wastewater and inappropriate disposal of solid waste. This has created a high potential for groundwater pollution in this area. Monitoring the quality of water resources in Bandar Gaz is essential as a primary action for conservation of surface and underground water resources. The present study analyzed and evaluated spatial variations in the chemical parameters of drinking water wells, including nitrates, fluoride, chloride and total hardness (TH) of groundwater resources over the course of two years using GIS.

2. Materials and methods

2.1. Study area

The study area is located in western Golestan province and is bordered to the north and south by the Caspian Sea and the Alborz Mountain range, respectively. Bandar Gaz is located at 54°21′ to 54°29′ E longitude and 36°47′ to 36°52′ N latitude. Bandar Gaz has a total area of 270 km^2. Plains make up 65% of the area and highlands making up the rest.

2.2. Collection and analysis of water samples

This was a descriptive cross-sectional study. To identify the scope, 1:50000-scale topographic maps were used. Eleven piezometric wells were selected that belong to Golestan Water Company and were used to check the static level and chemical quality of the water. Five drinking water wells in the area were also selected. A total of 20 samples were collected over two consecutive years in 2011 and 2012 during the low-rain season (spring) and rainy season (autumn). The water samples were collected from the wells in the sterile plastic 2 l containers.

The samples of the ground water were analyzed for the physical and chemical parameters of TH, chloride, nitrate and fluoride using standard analytical methods [14]. The methods used for estimation of the physico-chemical parameters are tabulated in Table 1. To analyze the results, the central tendency of variables was calculated using Excel software. Afterwards, the maximum, mean and minimum of each parameter was determined for each well for each year and the mean change between years were compared with Iranian national standards and standard permissible limits recommended by the World Health Organization (WHO) for drinking water. A non-parametric test (Wilcoxon test) was applied using SPSS software to compare the results between seasons. The temporal variation and spatial distribution of parameter concentrations in underground water resources were studied using ArcGIS software

3. Results

Statistical evaluation of groundwater quality parameters is shown in Tables 2 and 3. All samples fell into the permitted range for hardness, fluoride, nitrate and chloride. Fluoride in the year 2011 in all cases was lower than the standard limit but, in some samples, was within the standard range.

The wells were mapped according to their distribution and topography. The location of the wells in Bandar Gaz is shown in Fig. 1. After entering the concentrations of nitrate, fluoride, chloride and hardness, the layers were prepared in ArcGIS based on field information. The distribution map is illustrated in Figs. 2–9.

4. Discussion

The nitrate concentration in the low-rain and rainy seasons was 0.6–5.27 mg/l and 7.15–25.96 mg/l, respectively. The lowest value was observed in well 2 (eastern Gaz) in low-rain season and the maximum concentration was observed in well 1 in the rainy season. The amount of nitrate in the water samples was lower than the permissible limit national standard of Iran and WHO [15,16]. The placement

Table 1
Methods for measuring the parameters

S.No	Parameter	Method
1	Nitrate (mg/l)	Spectrophotometric method
2	Fluoride(mg/l)	Ion selective electrode
3	Chloride(mg/l)	Titrimetric method (With $AgNO_3$)
4	TH (mg/l)	Titrimetric method (with EDTA)

Table 2
Statistical analysis descriptive sampling and chemical factors of groundwater resources in the study area the Low and rain season rain in 2012

Chemical parameters	n (in each season)	Low season				Rain season				WHO	Iran National standard 1053	
		Max	Min	Mean	SD	Max	Min	Mean	SD		Maximum allowable	Minimum allowable
Nitrate	20	13	5.27	8.07	2.92	12	7.47	9.33		45	50	–
Fluoride	20	0.44	0. 15	0.31	0.21	0.19	0.016	0.1	0.10	1.5	1.5	0.5
TH	20	292	208	206	56.3	352	270	287.4	33.3	500	500	200
Chloride	20	62	16	24.4	24.5	42	10	27.8	21.4	250	400	250

Table 3
Statistical analysis descriptive sampling and chemical factors of groundwater resources in the study area the low and rain season rain in 2013

Chemical parameters	n (in each season)	Low season				Rain season				WHO	Iran National standard 1053	
		Max	Min	Mean	SD	Max	Min	Mean	SD		Maximum allowable	Minimum allowable
Nitrate	20	14.97	5.5	11.18	2.92	25.96	8.32	13.38	7.55	45	50	0
Fluoride	20	0.62	0.15	0.42	0.21	0.62	0.35	0.53	0.10	1.5	1.5	0.5
TH	20	312	172	270.4	56.3	422	204	332.2	92.3	500	500	200
Chloride	20	60	6	30.8	24.5	60	10	29.6	19.0	250	400	250

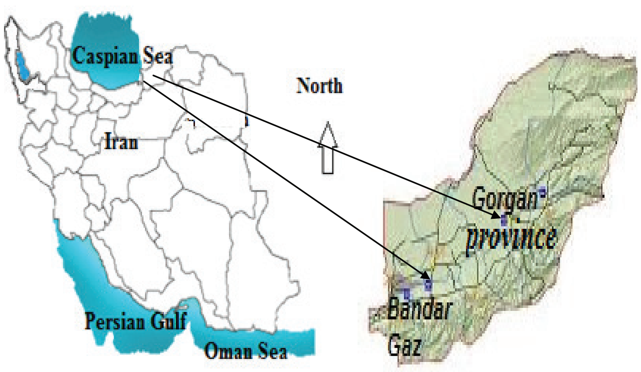

Fig. 1.

of drinking water wells downstream of agricultural land and the high usage of fertilizers have caused the nitrate concentration during the rainy season to increase. Figs. 3 and 7 show the distribution maps of nitrate concentration in the low-rain season. Because agricultural fertilizer is not used in the rainy season, the nitrate concentration decreased. Statistical analysis (Wilcoxon test) demonstrated that there was no significant difference between the nitrate concentrations of samples collected in the rainy and low-rain seasons ($p > 0.01$). These results are similar to findings by other researchers [17], but Dash et al. studied spatial variability of groundwater depth and quality parameters in the National Capital Territory of Delhi. Their results showed in a 36% of the study area and the nitrate concentration exceeded 45 mg l (–1) [18]. Mohammadi et al. found seasonal variations in nitrate concentration in the groundwater resources of the city of Babol using GIS and these results are not compatible

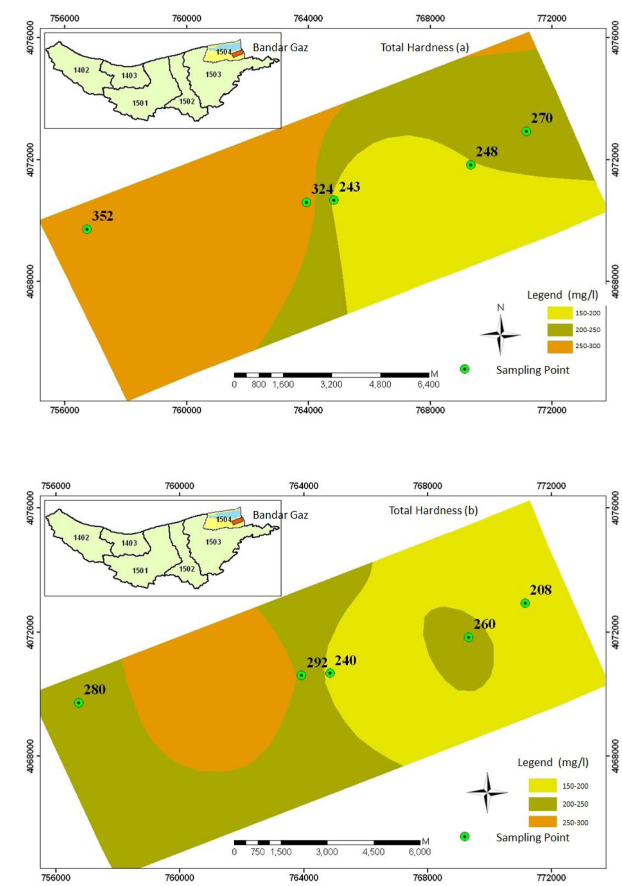

Fig. 2. Spatial distribution of TH in wet (a) and dry (b) season in 2012.

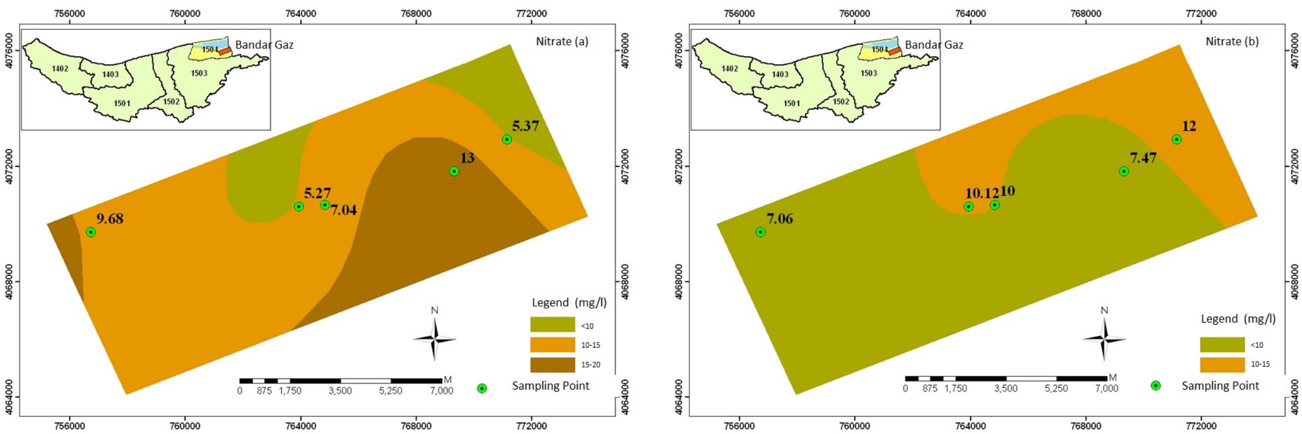

Fig. 3. Spatial distribution of nitrate in wet (a) and dry (b) season in 2012.

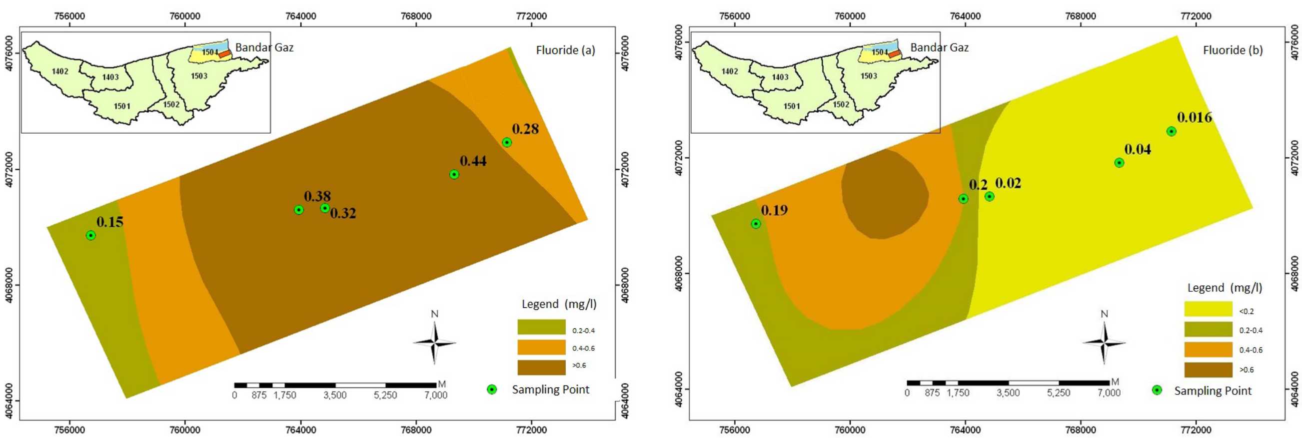

Fig. 4. Spatial distribution of fluoride in wet (a) and dry (b) season in 2012.

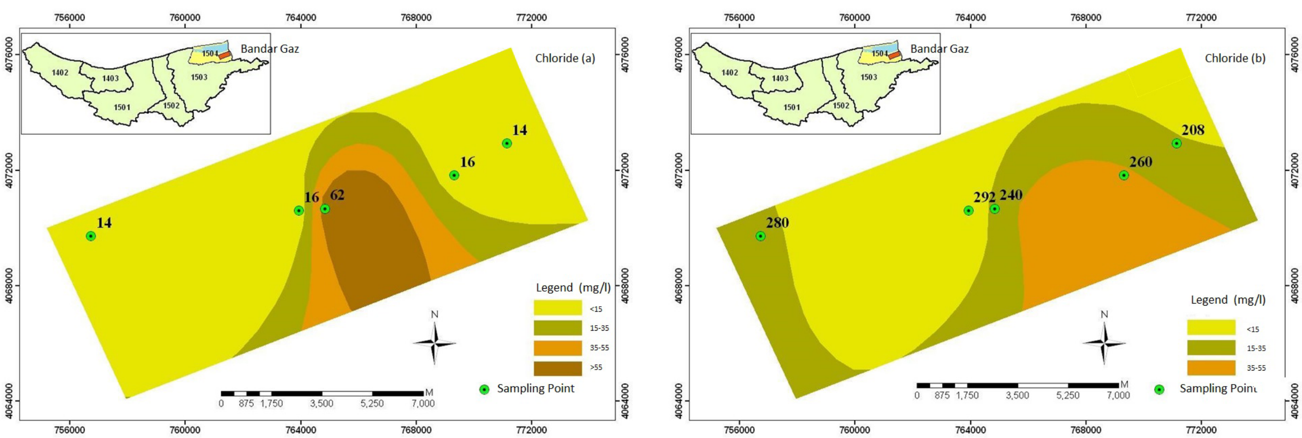

Fig. 5. Spatial distribution of chloride in wet (a) and dry (b) season in 2012.

with the results of the present study. This incompatibility may be due to different planting times, because most planting in Bandar Gaz is for wheat and barley in the autumn, but rice planting in Babol occurs in the spring [19].

According to drinking water quality standards set by the Institute of Standards and Industrial Research of Iran (ISIRI) and WHO, 100% of samples had fluoride concentrations lower than the permissible limit (0.5 mg/l) in the low-rain

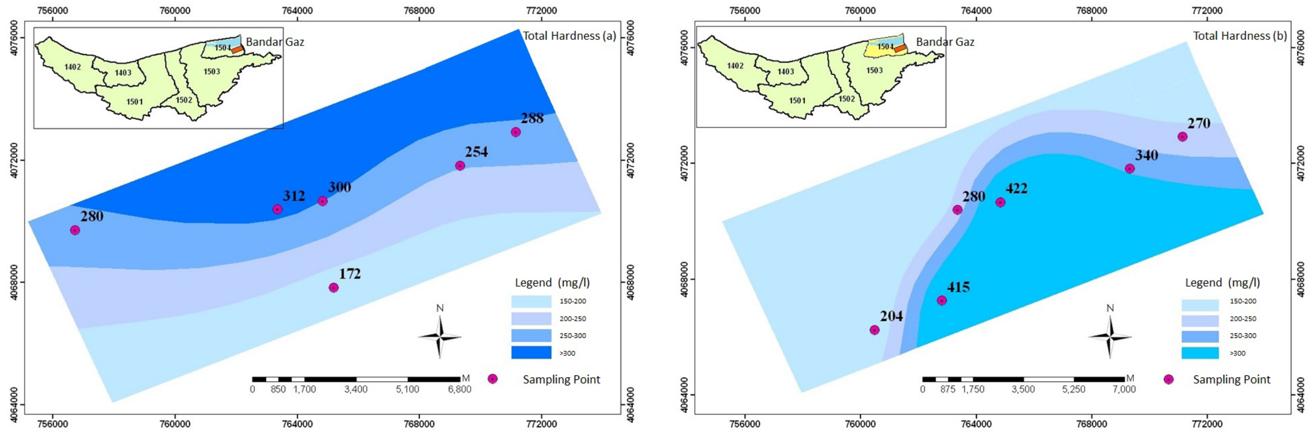

Fig. 6. Spatial distribution of TH in wet (a) and dry (b) season in 2012.

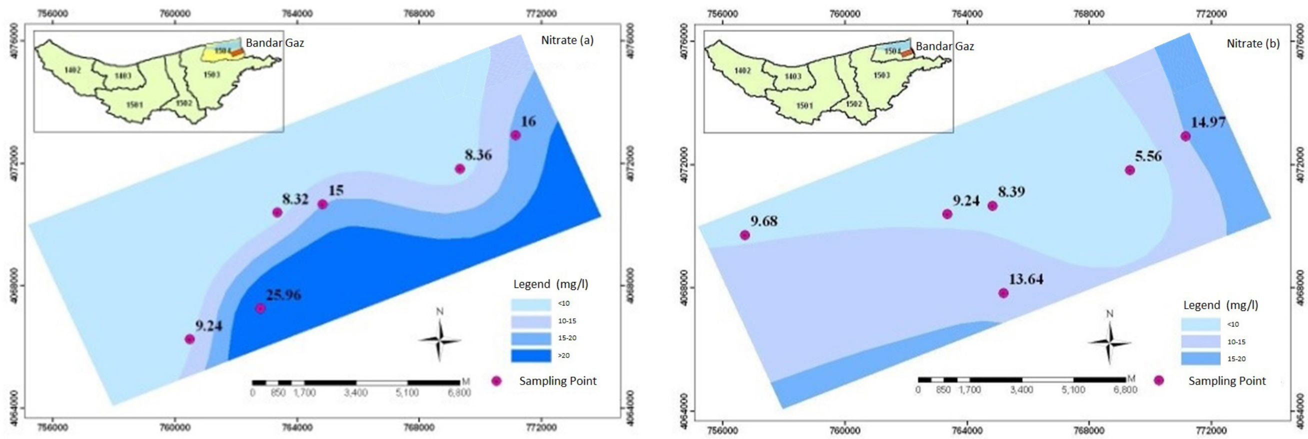

Fig .7. Spatial distribution of nitrate in wet (a) and dry (b) season in 2013.

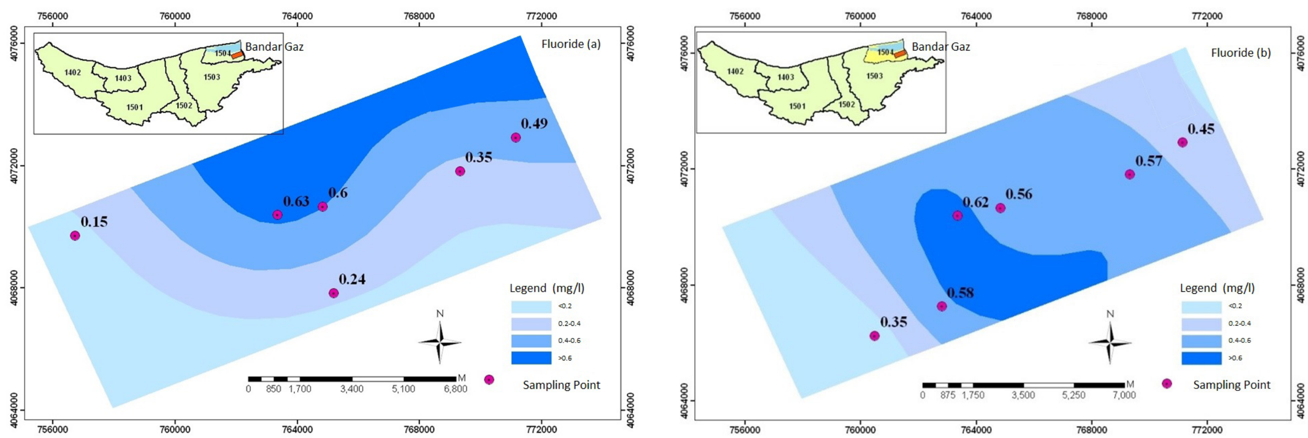

Fig. 8. Spatial distribution of fluoride in wet (a) and dry (b) season in 2013.

season [15,16]. The results indicate that only 20% of water samples were within the range of the Iran national standard and 80% were lower than the standard range for the rainy season. Statistical analysis (Wilcoxon test) demonstrated that there was no significant difference between the fluoride concentrations of samples collected in the rainy and low-rain seasons (p > 0.01). These results are similar to findings by other researchers [20,21]. Amouei found that the concentra-

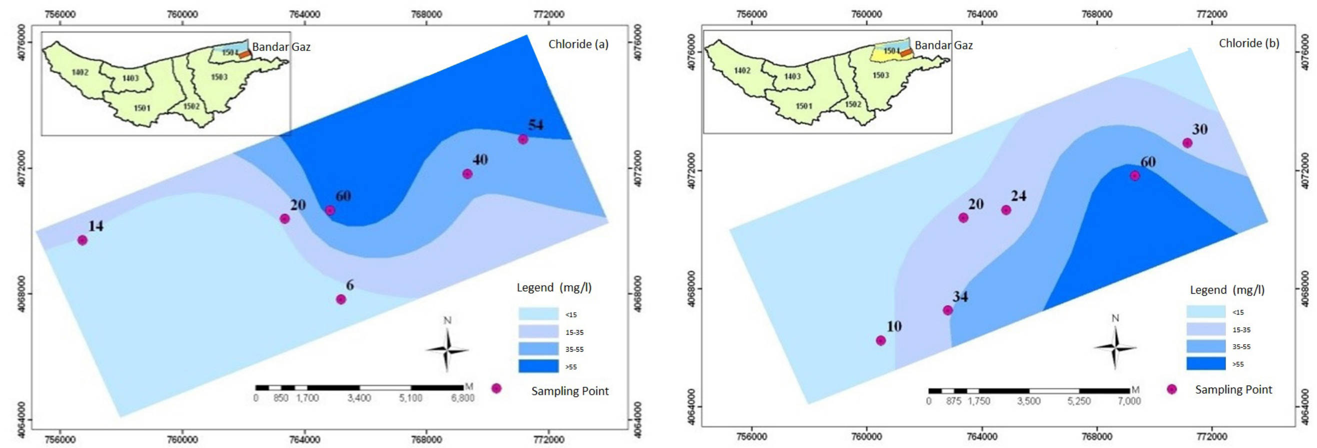

Fig. 9. Spatial distribution of chloride in wet (a) and dry (b) season in 2013.

tion of fluoride in rural areas of Khaf was 0.11 to 3.59 mg/l. He reported that the fluoride concentration in 31% of the samples was less than the standard, 4% was above the standard and 64% were within standard range [22].

Amini assessed the mean concentrations of fluoride for the 8-y period in the study area were 1.6 and 2.0 mg/l, respectively and Spatial, temporal, and spatiotemporal variability of fluoride in overall groundwater resources were relatively constant over the years [22].

Statistical analysis (Wilcoxon test) demonstrated that there was no significant difference between the chloride concentrations of samples collected in rainy and low-rain seasons ($p > 0.01$). The chloride concentration was 6 to 62 and 10 to 60 mg/l in the low-rain and rainy seasons, respectively. Maximum and minimum values were recorded for wells 3 and 4, respectively. According to the national standard range of 250–500 mg/l, all samples fell within the WHO standard range. The increase in chloride in the low-rain season was the result of the entrance of Caspian Sea water into the water resources. These results are similar to findings by other researchers [23,16]. Fytianos, Christophoridis studied rural water resources of Greece for nitrate, arsenic and chloride content using GIS. Their results indicated that the high application of nitrogen fertilizer in northwestern agricultural land resulted in a nitrogen concentration in 7.7% of groundwater samples that was higher than 50 mg/l. The chloride concentration in 70% of coastal area samples was more than 80 mg/l, but the percentage in non-coastal areas was 32.7%, which is an indication of sea water entrance to groundwater resources [24]. Nas et al. assessed the quality of groundwater resources of Konya City in Turkey using GIS and revealed that the final map shows the southwest of the city has optimum groundwater quality, and, in general, the groundwater quality decreases south to north of the city [17]. Water hardness is related to the presence of dissolved minerals in the water. TH consists of carbonated hardness or temporary hardness and non-carbonated hardness or permanent hardness. Permanent hardness is due to the presence of elements such as magnesium or calcium sulfate and chloride that do not precipitate by boiling heat. The hardness values of samples in the low-rain and rainy seasons were 172 to 312 and 204 to 422 mg/l, respectively. By comparison with Iranian standards and those of WHO, it can be understood that all samples are in the permitted range and can be classified as hard water. Wells 1 and 2 had the minimum and maximum hardness at 415 and 422 mg/l, respectively. These concentrations are not harmful to human health, but are problematic for industrial use [16].

Evaluation of groundwater quality for irrigation and drinking using GIS and geo statistics in a peri-urban area of Delhi, India indicated that water hardness of 362.65–2,763.45 mg/l with a mean value of 1,351.14 mg/l can be classified as very hard and that this hardness was the result of high concentrations of magnesium and calcium in the water resources and The study found that, out of the total study area have a severe problem of water hardness [25].

In Badee, Nezhad studied the quality of drinking water of Shiraz plain using GIS and found that the sulfate concentration and pH of all samples were within the desirable range. Nevertheless, groundwater in this area was classified as very hard. In addition, an increase in nitrate concentration was observed in the eastern part of Shiraz plain [26].

5. Conclusion

The results of this study showed that the parameters measured were compatible with Iranian national standards and, in terms of health considerations, were desirable, except for fluoride. Fluoride deficiency in the drinking water can weaken resistance of tooth enamel, especially in children. The best and most cost-efficient way to prevent the harmful effect of fluoride deficiency is to add fluoride to the drinking water, so facilities should be prepared for application of fluoride in Bandar Gaz. Operation management and groundwater conservation must be a basic principle of urban planning to maintain the desired quality of the groundwater resources of Bandar Gaz. Appropriate management includes prevention of human and agriculture activities in the buffer zones of wells, construction of a wastewater collection system and a wastewater treatment plant.

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