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Evaluation of physical and chemical quality of groundwater in the villages of Qom province and zoning them by GIS

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Abstract

Background: The aim of this study was to evaluate the physical and chemical quality of groundwater in the villages of Qom province during summer 2014, and to compare the results with Iran's Standard No. 1053.

Methods: This research is a descriptive sectional study. During the investigation, one step sampling with the necessary repetitions (if necessary) was performed of each well for evaluation of physical and chemical quality of groundwater in the villages of Qom province. SPSS version 16 and ARCGIS software were employed for data analysis and data zoning respectively.

Results: The average concentration of magnesium, sulfate and ammonia in wells water were higher than standard. The average concentration of fluoride was lower than the standard limit. pH and turbidity in all wells were within the standard limit but sulfate in 33.33%, ammonia in 13.33%, magnesium in 10.66%, sodium in 40%, calcium in 5.33%, nitrate in 17.33%, total dissolved solids (TDS) in 14.66% and electrical conductivity (EC) in 24% of wells were higher than the standard limit, and fluorine in 98.66% of wells was lower than the standard limit. The results of zoning in the villages of Qom province revealed that measured values at most wells were in the maximum amount in central and northeastern areas and minimum amount in southern and western areas.

Conclusion: This study indicated that most of the physicochemical parameters such as fluoride in almost all villages, and sulfates, chloride, magnesium, sodium, calcium, nitrate, TDS and EC in some of the wells did not fall within the permissible limit.

Keywords: Physical and chemical quality, groundwater, Qom, zoning, GIS

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Introduction

Approximately, 65% of an organism's weight comprises water, and certainly it is a vital compound for all organisms on earth. Access to safe drinking water sources in many countries around the world is an important issue (1). According to the World Health Organization (WHO), drinking water is water that is suitable for human consumption and all home applications, and should be available in sufficient quantity and good quality for society. According to the viewpoint of the agency, the water utilized for human consumption must be free from microorganisms and chemicals that are dangerous to human health. The most important public preference attributes of public drinking water resources are that they have no turbidity and color, or unpleasant smell or taste. The absence of turbidity, color, odor or unpleasant taste of drinking water is the most important characteristics of drinking water public resources (2). Water does not exist in pure form in nature; it always contains levels of salts, suspended solids and dissolved gases. This causes the water in different regions to have different characteristics. For example, some salts in water are essential to human health, while levels of salts higher than the established standard limit would be dangerous for human health (3). The physical and chemical qualities of water in viewpoint of its acceptability for the consumer, protecting the health of consumers and for the maintenance of water network systems is necessary (4). Among the most important physical and chemical properties of drinking water are parameters like pH, electrical conductivity (EC), total dissolved solids (TDS), turbidity, alkalinity, hardness, chloride, calcium, magnesium, iron, sulfate, fluorine and phosphate (1). pH indicates the acidity or alkalinity property of water; so it depends on the consideration of H^+ or OH^- levels. pH is important in water treatment, disinfection and corrosion control. Corrosion control is dependent on the pH of water (5). Solids are one of the physical impurities of water. This parameter, involving protection from microorganisms via direct contact with disinfectants such as chlorine, can have an essential role in water pollution and may also cause an increase in the amount of disinfectant required to counteract the chemical action of the solids. Suspended materials can create tendencies for the adsorption of chemical and biological agents (4). High TDS in water can cause a salty taste and reduce the desire of consumers to utilize these waters. Drinking water with a TDS of less than 500 mg/L is considered very good water (1). One of the chemical characteristics of water is hardness (4). Hardness is caused by polyvalent metals cations. Sodium, potassium, calcium and magnesium are the most abundant type of polyvalent metal cations found in natural waters. Calcium and magnesium cause sedimentation of soap which decreases their cleaning performance. This reaction leads to the formation of layers of $CaCO_3$ and $MgOH_2$ in mainline water distribution channels and in hot water heaters. Water 'hardness' can be divided into 3 categories: slightly hard water, containing less than 50 mg/L TDS, moderately hard water, containing up to 150 mg/L TDS and very hard water, containing more than 300 mg/L TDS (6). Calcium and magnesium in excess amounts can have negative effects such as increased consumption of soap, creating stains on dishes, bleaching vegetables, and bursting boilers (4). Higher levels of sodium, potassium and magnesium compounds create taste in drinking water. Waters with large amounts of chloride are salty and waters containing large amounts of sodium sulfate and magnesium sulfate have a bitter taste. Sulfate in drinking water can substantially change the taste (7). Drinking water containing high concentrations of sulfate (200 ppm+), or ammonia levels of 100 ppm+, or calcium carbonate of over 300 ppm will cause dyspepsia in most people (8). High fluoride concentrations in drinking water can cause tooth enamel fluorosis, and low concentrations can cause tooth decay at an early age (2). Standards fluoride concentration in drinking water which provided by different organizations are different. These values in different standards are dependent on seasonal changes. The reason for this issue is a direct relationship between air temperature and water consumption. The amount of drinking water consume in warm months is higher than on cold months. Therefore, with the assumption of constant fluoride ion concentration in the water, the amount of fluoride is more in warmer months than other months (8). The fluoride concentration in drinking water should not be less than 0.5 mg/L (2). Nitrogen is a complex element. Different forms of nitrogen are found in natural waters that contain organic nitrogen, ammonia, nitrogen gas, nitrite and nitrate (9). In areas where rainfall is low and has little vegetation, groundwater pollution with nitrate is more than other areas (10). According to the Iran national standard (Standard No. 1053), the standard limits of nitrate and nitrite in drinking water are 50 mg/L in terms of NO_3^- and 3 mg/L in terms of NO_2^- respectively (11). The ill health effects of nitrate and nitrite are related to the occurrence of methemoglubinemia disease or blue baby syndrome, the production of carcinogenic nitrosamine compounds, and an increased risk of miscarriage (12). At present, many studies have been carried out on the physical and chemical quality of water in rural areas. In a study carried out in the city of Zahedan in 2008, it was found that the concentration of fluoride in the water of 6.48% of the villages were in optimal range, 87.3% were higher than optimal range, and 6.48% were lower than the optimal range (13). In Pourmoghadas' study, it was found that all groundwater of Lenjan city of Isfahan were very hard water (14). Dindarlo et al in assessing the quality of drinking water of Bandar Abbas concluded that the amount of sulfate, ammonia, sodium, total hardness, EC and TDS in groundwater sources are at the maximum standard limits (15). Sadeghi et al, in evaluating the physico-chemical indicators of drinking water in the city of Ardabil reported that sulfate in 9% of total samples, total hardness in 41% and phosphate in 71% of samples were higher than the standard limit, and fluorine is less than the minimum allowed in 57% of the samples (16). The results of investigating the chemical quality of drinking water in rural areas of the Boyer Ahmad's central part in 2009 revealed that the average concentration of chemical parameters (except fluoride and chlorine residual) are in the range of Iran's national and international standards (3).

The main purpose of reviewing water quality is to ensure the protection of public health. The aim of this study was to evaluate the physical and chemical quality of groundwater in the villages of Qom province during summer 2014 and the results were compared with the Iran's standard 1053 issue.

Methods

This research is a descriptive cross-sectional study carried out for the evaluation of physical and chemical quality of groundwater in the villages of Qom province (75 wells in 6 regions). Since there are no special guidelines for the evaluation of physico-chemical quality of water and due to the chemical water quality parameters not having significant changes in the short term; during the investigation, one step sampling with necessary repetitions (if necessary) was carried out on each well to evaluate the physical and chemical quality of groundwater in the villages of Qom province. A total number of 75 wells were evaluated. The areas studied were numbered from 1 to 6 and the studied wells were numbered from 101 to 606. The study areas included regions 1 (21 wells), 2 (23 wells), 3 (5 wells), 4 (6 wells), 5 (16 wells) and 6 (4 wells). The locations of studied wells are shown in Figure 1. Sampling was carried out in 3.5 L plastic containers. Before each sampling, bottles were washed with the well water. After recording characteristics (sampling places and sampling time), the samples were immediately sent to the laboratory to measure various parameters. Chemical and physical parameter measurements were carried out according to standard testing methods in Standard Methods for the Examination of

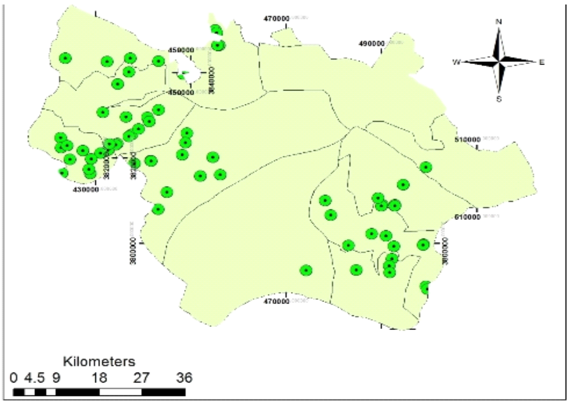

Figure 1. The location of sampled wells.

Water and Wastewater (17). SPSS version 16 and ARCGIS software were utilized for data analysis and data zoning respectively. In descriptive statistics, mean and standard deviation were calculated. Generally, experiments were carried out in two groups of test devices and titrimetric. Testing methods are listed in Table 1.

Results

According to Tables 2 and 3, the quality evaluation result of chemical and physico-chemical parameters of the quality of groundwater in the villages of Qom province at summer 2014 was determined and compared with standard 1053. The Standard No. 1053 is an instruction provided by industrial research and the Standard Institute of Iran for evaluating the quality of drinking water. The number and percentage of drinking water wells with concentration beyond Standard No. 1053 are shown in Table 4. Based on this study, the average concentration of magnesium, sulfate and ammonia in wells water were higher than Iran's Standard No. 1053. In addition, the average concentration of fluorine was lower than the standard limit. Sulfate in 33.33% of wells, ammonia in 13.33% of wells, magnesium in 10.66% of wells, sodium in 40% of wells, calcium in 5.33% of wells, nitrate in 17.33% of wells, TDS in 14.66% of wells and EC in 24% of wells were higher than the standard limit, and fluorine in 98.66% of wells was lower than the standard limit.

Figures 2 to 4 present geographical distributions of fluoride, total hardness, magnesium, calcium, electrical conductivity, total solid solution, chloride, potassium, nitrite, sulfate and total alkalinity in water tables in the villages of Qom province.

Villages

Summarized results of zoning parameters are shown in Table 5. Chemical and physical parameters of zoning results in well water in the villages of Qom province showed that the wells' content levels measured in the central and northeast regions had the higher content and the south and east had lower content.

Table 1. Testing methods

Parameter	Test method	Model	Parameter	Test method	Model
Chloride	Argenometric Method	-	Calcium	EDTA Titration Method	-
Fluoride	Spectrophotometric method	USA– Hack-DR4000	Magnesium	MgB. Calculation Method	-
pH	Electreometric Methods	USA– Hack- HQ	Sodium	Flame Emission Photometric Method	JENWAY,PFP7/C
Total solids	Total Dissolved Solids Dried at 180°C	-	Potassium	Flame Emission Photometric Method	JENWAY,PFP7/C
Electrical conductivity	Laboratory Method	Hach 50161/co150	Bicarbonate	Titration Method	-
Total hardness	EDTA Titration Method	-	Sulfate	Turbidomethric Method	HACH,2100QIS01
Total alkalinity	Titration Method	-	Turbidity	Nephlometric Method	USA– Hack-P2100
Nitrite	Spectrophotometric method	USA– Hack-DR4000	Nitrate	Spectrophotometric method	USA– Hack-DR4000

Table 2. Results of chemical examination parameters of drinking water in the villages of Qom province in summer 2014

Parameter (mg/L)	Ca	Mg	Na	K	CO_3^{2-}	HCO_3^-	NO_3^-	NO_2^-	SO_4^{2-}	Cl^-	F^-
Mean	120.72	24.06	199	1.2	0	259.19	30.28	0.012	317	187	0.55
Maximum	646.40	221.49	1920	11.5	0	528	91.52	0.03	1500	2872	1.84
Minimum	32	1.97	2	0.2	0	28.80	4.84	0.006	8	12	0.03
Standard deviation	±91.31	±28.64	±267	±1.51	0	±89.46	±19.21	±0.005	±322	±366	±0.32
Standard	250	50	200	-	-	-	50	3	400	400	0.8-1.8

Table 3. Result of chemical and physico-chemical parameters quality of groundwater in the villages of Qom province at summer 2014

Parameter (mg/L)	Turbidity (NTU)	pH	TDS (mg/L)	EC (Mmho/cm)	Total Hardness (mg/L as $CaCO_3$)	Total alkalinity (mg/Las $CaCO_3$)
Mean	0.42	7.6	1040	1598	401	213
Maximum	3.5	8.38	6971	13500	1836	440
Minimum	0.12	6.39	123	210	88	24
Standard deviation	±0.36	±0.32	±1011	±1722	±303	±73.5
Standard	5	6.5-9	1500	2000	500	-

Table 4. Number and percentage of wells' drinking water with concentration higher than the standard limit in the villages of Qom province in 2014

Parameter	SO_4^{2-} (mg/L)	Cl^- (mg/L)	F^-(mg/L) Lower than the permissible limit	Higher than permissible limit	NO_3^- (mg/L)	NO_2^- (mg/L)	Mg (mg/L)	Na (mg/L)	Ca (mg/L)	TH (mg/L)	EC (Mmoh/cm)	TDS (mg/L)	pH	Turbidity (NTU)
Standard	400	400	0.8	1.8	50	3	50	200	250	500	2000	1500	6.5-9	5
No. of well	25	10	74	1	13	0	8	30	4	23	18	11	0	0
%	33.33	13.33	98.66	1.33	17.33	0	10.66	40	5.33	30.66	24	14.66	0	0

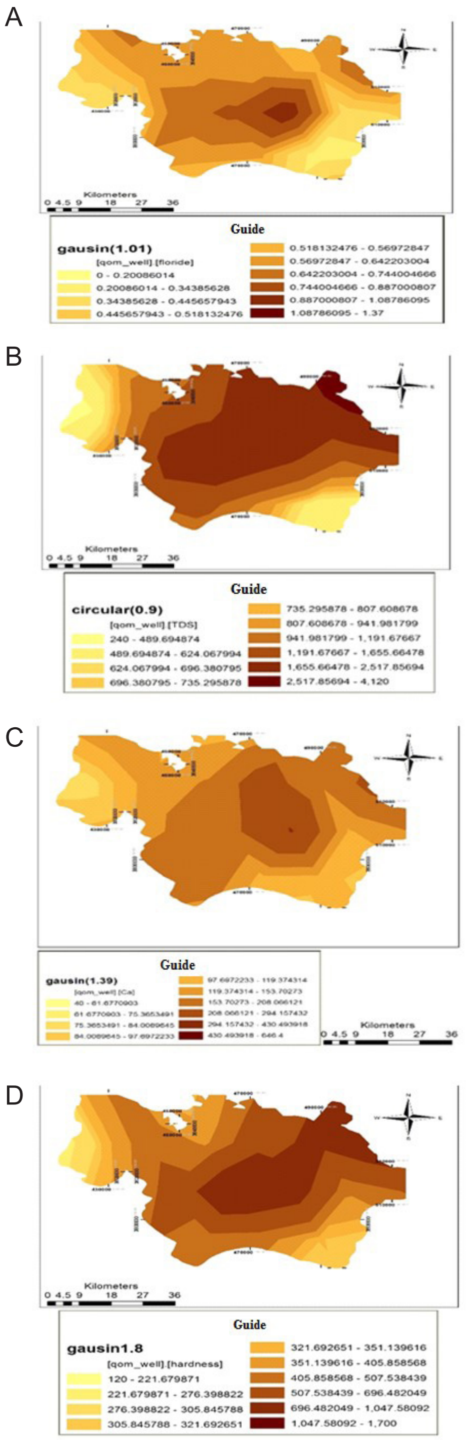

Figure 2. Geographical distribution of drinking water resources in the villages of Qom province: (A) Fluoride, (B) Water hardness, (C) dissolved solids, (D) Calcium.

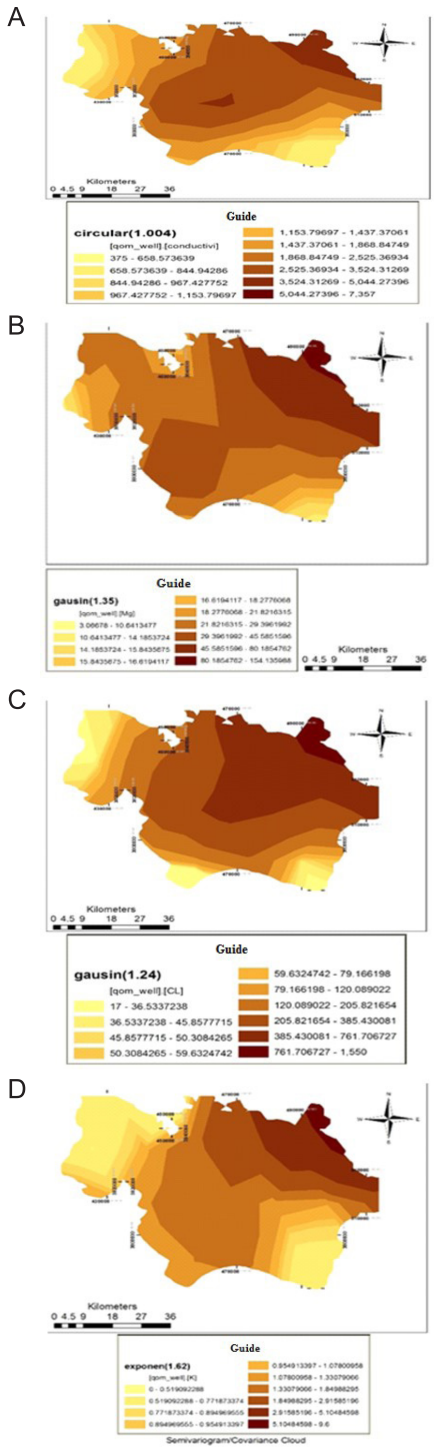

Figure 3. Geographical distribution of drinking water resources in the villages of Qom Province: (A EC, (B) Magnesium, (C) Chloride, (D) Potassium

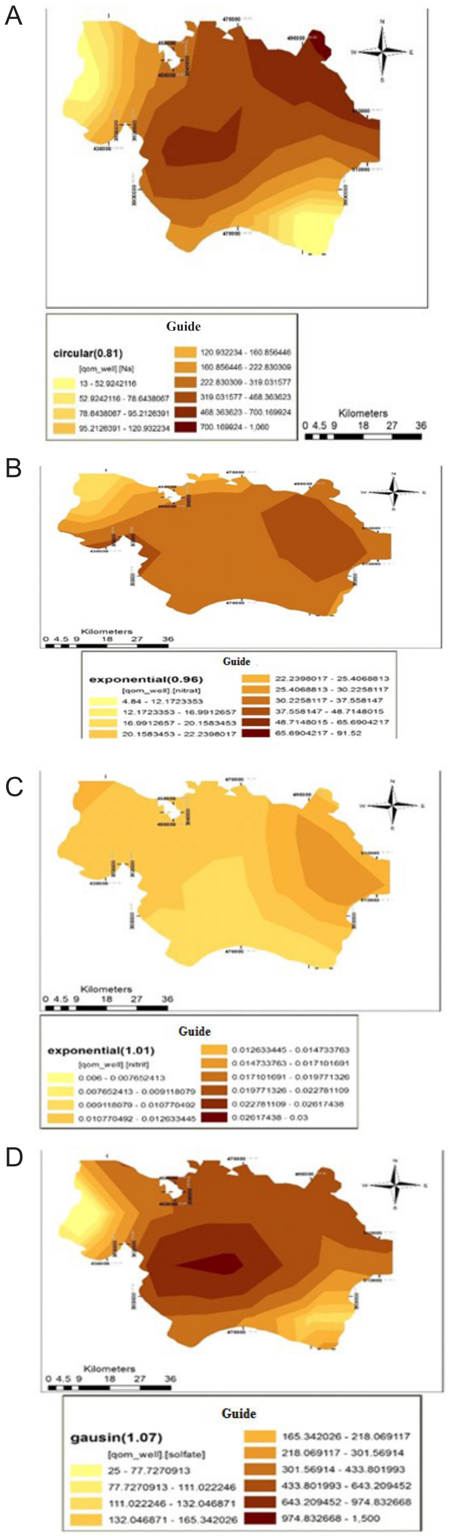

Figure 4. Geographical distribution of drinking water resources in the villages of Qom Province: (A) Sodium, (B) Nitrate, (C) Nitrite, (D) Total alkalinity

Discussion

In this study, minimum, average and maximum turbidity was 0.12, 0.42 and 3.5 NTU respectively. The authorized range of NTU by Iranian national standard is 5 NTU. In a study carried out in 2012 by Rezai et al, corrosion and scaling potential in drinking water resources in the villages of Qom province were investigated. Average turbidity in Rezai et al study was 0.78 NTU (18). In a study carried out by Fahiminia et al in 2012, the average turbidity in the water wells of the Qom city were 0.58 NTU (19). The results of this study are in line with the studies of Fahiminia et al and Rezai et al.

In this study, maximum and minimum pH was 8.38 and 6.39, respectively. Average pH was 7.6. The accepted range of pH by Iranian national standard is 7-8.5 and the maximum is 6.5-9. pH of samples when compared with national standards were in the authorized range (20). The study of Fahiminia et al demonstrated that the average pH values in Qom city groundwater is 7.4 (19). The average pH values in the study of Rezai et al was 7.27 (18). The results of this study are in line with the studies of Fahiminia et al and Rezaei et al.

Minimum and maximum chloride concentration was 12 and 2872 mg/L respectively, in groundwater resources in the villages of Qom province. Average chloride concentration was 187 mg/L. Chloride concentrations higher than 250 mg/L can make a distinguishable effect on water taste (18). Based on national standards, the maximum chloride concentration in drinking water should not be more than 400 mg/L (11). Chloride levels in 13.33% of wells sampled were higher than the national standard. The average amount of chloride in the study of Rezaei et al was 230.83 (18), which is higher than those obtained in the present study.

In this study, the variations sulfate content ranged between 8 to 1500 mg/L. In studied wells, the average sulfate was 317 mg/L. Sulfate concentrations between 300-400 mg/L can create a distinguishable taste in water. Diarrhea is often the result of high sulfate concentrations. Sulfate can also cause water hardness and foam in steam boilers (21). The Iranian national standard for sulfate concentration is 400 mg/L (11). According to the study of Rezaei et al, sulfate levels in water wells in the villages of Qom province were obtained as 309 mg/L (18) which is in line with the current study. In the present study, the amount of sulfate in 33.33% of wells was higher than the national standard. The study of Miranzadeh et al showed that the sulfate content in 5.3% of drinking water samples in the villages of Kashan city were higher than the national standard (2). In a study carried out by Rajaei et al, amounts of sulfate in drinking water samples of Birjand and Qaen plain at 33% were higher than national standards (8). The results of this study were not in line with those of Miranzadeh et al but are similar to the study of Rezaei et al (18).

EC, or EC of water, represents the ionic strength of a solution to conduct an electric current. Its unit is microsiemens per centimeter (µs/cm) or micromhos per centimeter (µmho/cm). Since ions carry electric current, the EC is directly related to TDS. Therefore, EC increases as TDS does and consequently, the corrosive effects of TDS in affected water increases. Water EC is 56 µmho/cm (9). In fact, TDS is total dissolved solids in the water; that is, the sum of the concentrations of all ions present in the water. TDS is an important parameter that could cause some

Table 5. Chemical and physical zoning parameter results

Parameter	Region with the most content	Region with the fewest content
F^-	Central	East and West
Total Hardness	Central and East	West and South
TDS	Central and East north	West and South
Ca	Central point	West and South
EC	Central and East North	West and South
Mg, Cl^-, K, Na	Central and East North	West and South
NO_3^-	East	West
NO_2^-	East	Central and West
SO_4^{2-}	Central point	West and South
Total Alkalinity	South and South West	East

adverse effects of water quality and can have a direct or indirect important effect on other quality characteristics of water. We can calculate the corrosion of metals in water and the leakage of metals (18). In this study, TDS content and EC were 123 to 6971 mg/L and 210 to 13500 µmho/cm, and the mean was 1040 mg/L and 1598 µmho/cm, respectively. The national standard range for TDS is 1500 mg/L and for EC 2000 µmho/cm (11). Water from wells with TDS of more than 1500 mg/L are non-drinkable (1). If water EC is more than 1500 µmho/cm, it can have a corrosive effect on any iron structures within a water distribution network (1). According to this issue, the amount of TDS in 14.66% of wells and the amount of EC in 24% of wells was higher than the national standard. In the study of Rezai et al, mean values of TDS in drinking water wells of villages in Qom province equal 1205 mg/L (18) which is in line with the current study.

Results of groundwater analysis in villages of Qom province have shown that the fluoride range is between 0.03-1.84 mg/L and the fluoride's mean is 0.55 mg/L, which is lower than the national standard. Based on Iranian national standards, the best of fluoride concentration in warm months is 0.7 mg/L, and in cold months is 1.2 mg/L (11). Results of the study of Rezaei et al showed that the fluoride concentration in drinking water wells in the villages of Qom province is equal to 0.6 mg/L (18). The results of this study corresponded to those of Rezai et al. In the present study, fluoride content in 98.66% of wells was below the authorized range and in 1.33% of wells was higher than authorized range. The study of Rajaei et al showed that the fluoride content in 92% of drinking water samples in the Birjand and Qaen plain is lower than the permissible limit (8) which is in line with the current study. The important issue about the chemical quality of water in the villages of Qom province is the low fluoride concentration. Most general hygiene agencies suggest the addition of fluoride in water as an effective way to prevent caries in populations with low fluoride levels in water (2). The range of sodium and potassium's content in studied wells were 2-1920 and 0.2-11.5 mg/L, respectively. Average sodium and potassium in wells were 199 and 1.2 mg/L, respectively. The national standard range for sodium is 200 mg/L (11). In 40% of studied wells, sodium was above the national standard. In a study carried out by Miranzadeh et al, sodium and potassium in drinking water in Kashan city were equal to 110.4 and 2.5 mg/L respectively (2). The average of sodium and potassium in the study of Rezaei et al were 245 and 1.76 mg/L, respectively (18). The values obtained in the above studies are higher than those obtained in the present study.

Hardness is caused by polyvalent metals cations such as calcium and magnesium (6). In this study, the concentration variations for calcium and magnesium range from 32-646.40 and 1.97-221.49 and their mean were 120.72 and 24.06 mg/L respectively. Also, the total hardness variation ranges from 88-1836 mg/L while $CaCO_3$ average content was 401 mg/L. The national standard for calcium, magnesium and total hardness is 250, 50 and 500 mg/L respectively (11). Calcium, magnesium and total hardness were higher than national standard in 5.33%, 10.66% and 30.66% of wells, respectively. A high concentration of magnesium creates an unpleasant taste in water. Magnesium can also cause diarrhea, but the most harmful effect is on pipelines transporting water and thermal installation; therefore, it is expensive for thermal and water treatment facilities (1). Sadeghi and Rohollahi in assessing the physico-chemical indicators of drinking water in the city of Ardabil reported that 41% of the samples exceeded the limit allowed (16). In the study of Rezaei et al, mean values of calcium, magnesium and total hardness in drinking water wells in the villages of Qom province was 132, 25 and 435 mg, respectively (18), which corresponded to the current study.

Based on the national standard, the standard limit of nitrate and nitrite in the water are 50 and 3 mg/L, respectively (11). The average concentrations of nitrate and nitrite in wells in the villages of Qom province were 34.73 and 0.01 mg/L, respectively. Izanloo et al examined the trend in nitrate concentrations in drinking water resources in the villages of Qom province and its zoning by GIS software (22). The results showed that the average nitrate concentration in studied wells was 23.12 mg/L between the years 2006 to 2016. This study showed more concentration of nitrate than in the study of Izanloo et al but it is still in the authorized range. In another study carried out by Izanloo et al, average nitrate in Jiroft groundwater resources was 10.5 mg/L (23). The average amount of nitrate in the present study is the higher of the two studies above; however, it is within the standard range. The study shows that in 17.33% of well samples, nitrate levels were higher than the national standard. Generally, chemical and physical parameters of zoning results in water wells in the villages of Qom province showed that the wells' content levels measured in the central and northeast regions had the higher content and the south and east had lower content. The nitrate concentration distribution map shows that the villages in Qom province have different concentrations of nitrate. Nitrate and nitrite have the highest concentration in the eastern region. Nitrate has less concentration in the western region and nitrite has less concentration in the central and eastern regions. Zoning nitrate concentration in drinking water in villages of Qom province during 2006 to 2012 has been studied with GIS software by Izanloo et al (22). Nitrate has the highest concentration in the south-east. These results are in line with the study of Izanloo et al.

Conclusion

Chemical and physical parameters are important specifications in determining the quality of drinking water, which should be of concern in ensuring the health and development of society, and some rules should be enacted to achieve these purposes. Undesirable drinking water, besides having chemical, physical and microbial problems, also has unacceptable appearance and taste, and consequently the water distribution network will not be trusted by consumers, and they will use other sources of water instead. Results of this study showed the average concentration of fluoride in most villages was lower than the standard limit. The average concentration of magnesium, sulfate and ammonia in the wells water were higher than Iran's Standard No. 1053. Also, the average concentration of fluoride was lower than the standard limit. pH and turbidity in all wells were within the standard limit, but sulfate in 33.33% of wells, ammonia in 13.33% of wells, magnesium in 10.66% of wells, sodium in 40% of wells, calcium in 5.33% of wells, nitrate in 17.33% of wells, TDS in 14.66% of wells and EC in 24% of wells were higher than the standard limit, and fluorine in 98.66% of wells was lower than the standard limit. The results of physical and chemical parameters zoning of waters in the villages of Qom province showed that measured values at most wells were in the maximum amount in the central and northeastern areas and minimum amount in the southern and western areas.

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Ethical issues

The authors certify that all data collected during the study are presented in this manuscript, and no data from the study have been or will be published separately.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

Ahmadreza Yari and Ali Sayfouri designed the study. Gharib Majidi, Hossein Jafari Mansoorian and Sharam Nazari performed the literature search and wrote the manuscript. Ghazal Yazdanpanah provided significant English translation. All authors participated in data acquisition, analysis, and interpretation. All authors critically reviewed, refined, and approved the manuscript.

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