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A comparative study of various parameters of drinking water quality in Shahroud city, Iran: tap water, well water and bottled water

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ABSTRACT

The physical, chemical and microbial quality of bottled water, tap water and water supplied from wells in the city of Shahroud was compared. The results of the analysis showed that the measured parameters, except in minor cases, were of national and international standards. There was no significant difference between the quality of bottled water and tap water, as well as bottled water and water available in water supply resources in the city of Shahroud. Regardless of the area in which the study was conducted, it was found that there was no need for developing other types of water treatment systems such as bottled water and domestic water treatment systems. In many cases, since bottled water is exposed to intense sunlight during the transport process, there could be a leakage of plastic monomers from the bottle wall into the water in hot or cold conditions, which can endanger consumer health. Tap water supplied from the water supply resources in the city of Shahroud was found to be completely safe and posed no threat to consumer health.

Key words: Bottled water, Physico-chemical properties, Tap water, Water quality, Well water

HIGHLIGHTS

- The quality of three water groups in the city of Shahroud was compared.
- Tap water supplied from the water supply resources in the city of Shahroud was found to be completely safe and posed no threat to consumer health.
- There was no need for developing other types of water treatment systems such as bottled water and domestic water treatment systems for Shahroud water supply.

1. INTRODUCTION

Available freshwater resources account for less than 1% of the total water resources of the world (Cooper & Hiscock, 2019). It is anticipated that by the year 2050, two-thirds of the world's population will live in areas with low access to freshwater resources, and by 2100, this figure may touch 11.2 billion (Biswas & Tortajada, 2019; Ridzuan, 2021). Currently, many countries in the world are grappling with problems of water stress, water scarcity and poor drinking water quality (Biswas & Tortajada, 2019; Hourieh Fallah *et al.*, 2020; Javid *et al.*, 2020a). Accordingly, with an improvement in the general health conditions of the people on account of rapid technological advancements in the field of medicine, the need for an evaluation of the quality of various available drinking water resources, including well water, tap water, and even bottled water, may be necessary, especially in developing countries (van der Linden, 2015; Hourieh Fallah *et al.*, 2020; Javid *et al.*, 2020b; Ghanbarian *et al.*, 2021).

Following numerous reports about the detection of some chemical and microbiological pollutants in well water and even treated tap water, the consumption of bottled water is increasing on a daily basis (Rani & Prasad, 2012; van der Linden, 2015; Brei, 2018). Moreover, the chemical parameters of bottled water such as fluoride, calcium, magnesium, sodium and other additives are almost evident and visible for the consumer (Javid *et al.*, 2020b; Ghanbarian *et al.*, 2021). Hence, the consumption of bottled water as a reliable source of water is increasing day by day around the world.

For example, the consumption of bottled water in Italy in the year 2017, which is the leading market for bottled water, was about 188 L per person per day. In Germany, the second largest consumer of bottled water, it was 175 L per person per day. Moreover, the global average per capita consumption of bottled water stands at 82 L per person per day (Abtahi *et al.*, 2019).

Although manufacturers producing bottled water follow strict quality requirements, some studies have demonstrated that the chemical, physical and microbiological properties of some bottled water brands do not match national and international standards, especially in developing countries. For example, Momtaz *et al.* (2013) investigated the microbiological quality of tap water and five brands of bottled water in Iran. Based on their analysis, 2.63% of bottled water was infected with *Escherichia coli*. A study conducted by Shams *et al.* (2012) for the evaluation of bottled water quality in Gonabad province of Iran showed that the time and storage conditions of bottled water affected its bacteriological quality and reduced water quality. Ehya & Ghanavati (2019) investigated the case of a bottled water distribution in Kohgiluyeh and Boyer-Ahmad Province of Iran and reported that the concentration of calcium, magnesium, sodium and potassium minerals in the bottled water was not at the standard level required for daily supply of these minerals via water.

Against this background, the aim of the present study is to evaluate the chemical and microbiological properties of three forms of drinking water supply used by the residents of Shahroud city. Shahroud is one of the cities of Semnan Province, located in northern Iran, which is surrounded by very different climates. The population of Shahroud was estimated to be 150,129 people in 2016. Water supply in some rural areas of Shahroud is in the form of well water, including 22 wells that are scattered in various parts of the province, with pretreatment via chlorination. However, in urban areas, treated tap water and bottled water are the main forms of drinking water supply. Some physicochemical parameters including electrical conductivity (EC), pH, total dissolved solids (TDSs), fluoride, chloride, turbidity, nitrite, nitrate and total hardness are measured for each supply. Moreover, the microbiological quality is identified using the standard most probable number (MPN) experiments.

2. MATERIALS AND METHODS

2.1. Sampling

Sampling was performed as follows:

- Bottled water: The 10 most widely used brands of bottled water were purchased from supermarkets as samples and transferred to the laboratory for analysis.
- Tap water: Sampling was carried out in 10 sites of the city by considering the distribution of water valves.
- Well water: The samples were collected from 22 water supply wells of Shahroud in four seasons and, by preserving standard conditions of the sample transfer, they were transferred to the laboratory for experiments. Figure 1 shows the geographical location of the sampling points of well water of Shahroud.

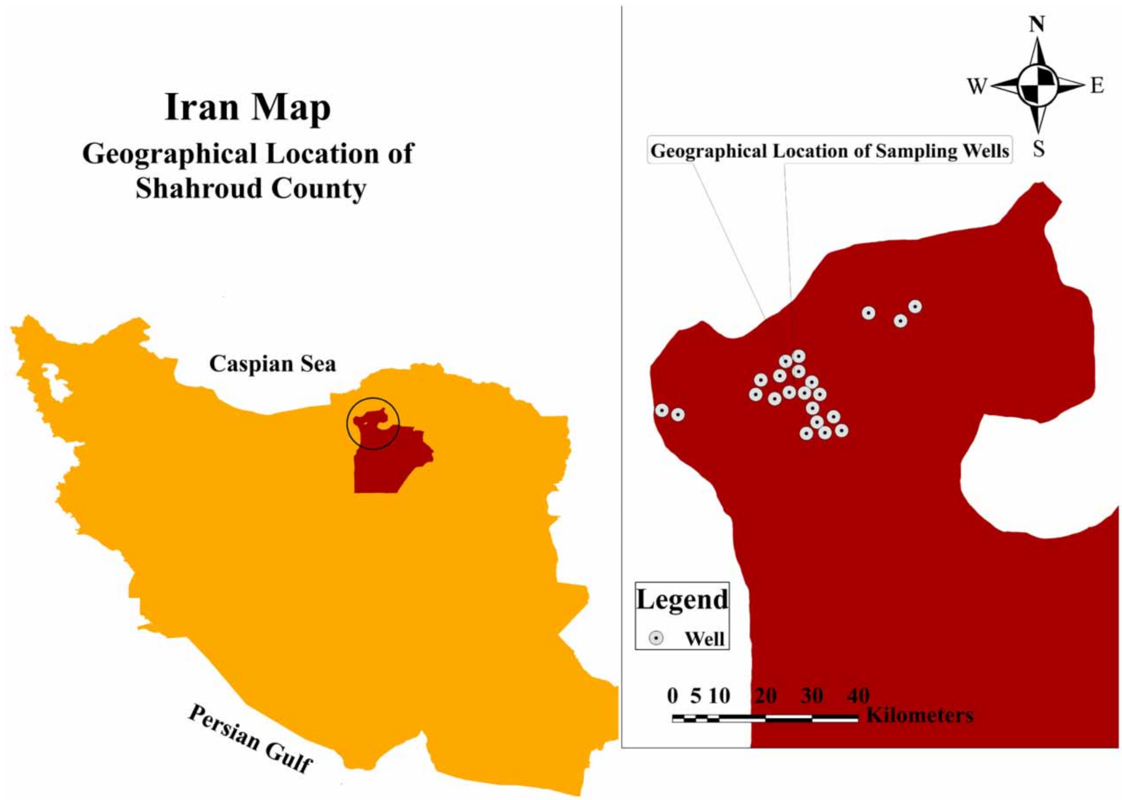

Fig. 1 | Geographical location of the sampling points of the well water of Shahroud.

2.2. Experimental procedures and analytical method

The water samples were analyzed on the basis of the procedure given in standard methods for the examination of water and wastewater (APHA) (APHA, AWWA, WEF, 2012). The selected samples were kept in an ice box at 4 °C and then transferred to the laboratory. Microbial experiments were performed in a clean laboratory room. All glass containers and other instruments in contact with the samples were completely cleansed with nitric acid and deionized water.

Some physicochemical parameters including EC, pH, TDSs, fluoride, chloride, turbidity, nitrite, nitrate and total hardness were examined for sampling the water. These parameters were chosen on the basis of their importance in water resources and specified on the labels of bottles. Hardness was determined by the standard titration method and pH was measured by using the pH meter (model PL-700PV). EC and TDSs were measured by using the TDS meter (model AZ8361). EC, TDS and pH were assessed at the sampling site. Turbidity was measured by using the turbidity meter (model AL250T-IR). Chlorine concentration was evaluated by the Mohr method. Fluoride was measured by the SPADNS method. Nitrite and nitrate were assessed by the standard colorimetric method using a spectrophotometer (Lambda 365 UV/Vis, Perkin Elmer). Moreover, microbial tests were performed using the MPN method. All chemicals used in this study were of high analytical grade and were obtained from the Merck Company. The concentration of dissolved solids, fluoride, chloride, nitrite, nitrate and hardness were reported as mg/L. EC was reported as μmho/cm and the number of coliforms was reported as count per 100 mL.

2.3. Data analysis

All experiments were performed in triplicate and the results were reported as the mean value ± SD (standard deviation). The obtained data were analyzed using Prism 2007 software, and analysis of variance (ANOVA) was used to determine the statistical significant difference between the physical, chemical and microbial quality of the three water groups. The Student–Newman–Keuls (SNK) test was used to investigate the significance of the mean difference between every two water groups. The measured values of each parameter were compared with the desired values in the instructions and standards for drinking water developed by the WHO, Institute of Standards and Industrial Research of Iran (ISIRI) and the International Bottled Water Association (IBWA), and these are represented in Table 1.

3. RESULTS AND DISCUSSION

3.1. Quality of well water

Table 2 presents the selected physical, chemical and microbial parameters of sampled well water. Moreover, the minimum, maximum, mean and SD of each measured parameter were also represented. Accordingly, the quality of the well water of Shahroud was compared with the ISIRI and WHO guidelines.

3.2. Tap water quality

The mean values of physical, chemical and microbial parameters in the tap water samples are presented in Table 3 and compared with the ISIRI and WHO guidelines. Moreover, the minimum, maximum, mean and SD of each parameter were assessed.

By comparing the quality of parameters evaluated in the water supply resources (wells) of Shahroud and the quality of water at the point-of-use, it was revealed that, except for some samples, the parameters were not significantly different from the standard values provided by the WHO and ISIRI. The quality of well water and tap water was compatible with the standards and there was no problem with them. The inconsistencies in the water quality of some wells with the standards were as follows:

Wells 9, 18 and 19 in terms of EC, wells 9, 17, 18, 19 and 20 on TDS, well 10 on chloride, well 19 on turbidity and wells 18 and 19 on hardness level showed inconsistencies with the standards. However, the differences were not significant.

The water quality inconsistencies in some of the samples collected throughout the city with the standards were as follows:

In terms of pH, sample 3 had inconsistency with the standards, and in terms of nitrate content, samples 3 and 6 had a higher nitrate content than other samples. In sample 3, the nitrate content was considerable, equal to 89 mg/L, which was higher than the standard value of 50 mg/L; but sample 6 showed a value of 39 mg/L that was not higher than the standard but had a higher nitrate content than other sampling sites.

Table 1 | Some selected parameters of drinking water standards represented by the WHO, ISIRI, IBWA.

	Parameter									
Guideline or standard type	**EC**	**pH**	**TDS**	**F**	**Cl**	**NTU**	**Nitrite**	**Nitrate**	**Hardness**	**Coliform**
WHO	1,000	6.5–8	500	0.5–1.5	200	<1	3	50	350	0
ISIRI	1,000	7–8.5	500	0.5–1.5	200	1	3	50	150	<2
IBWA	1,000	6.5–8	500	<1.3	250	0.5	0	0	180	0

Table 2 | Mean and standard deviation of measured parameters in water supply wells.

Well No.	EC	pH	TDS	F	Cl	NTU	Nitrite	Nitrate	Hardness	Coliform
1	525 ± 0.12	7.8 ± 0.03	367 ± 2.3	0.57 ± 0.05	70.3 ± 4.1	0.24 ± 0.04	0	0.95 ± 0.01	175 ± 4.2	0
2	571 ± 0.05	7.4 ± 0.03	400 ± 4.5	0.5 ± 0.01	39.8 ± 1.7	0.56 ± 0.06	0	3.38 ± 0.1	185 ± 2.1	0
3	570 ± 0.43	7.6 ± 0.1	400 ± 0.9	0.51 ± 0.06	41.9 ± 0.05	0.76 ± 0.001	0	2.62 ± 0.1	190 ± 3	0
4	620 ± 0.67	7.8 ± 0.05	434 ± 1.8	0.47 ± 0.05	109 ± 1.1	0.18 ± 0.02	0.001	1.4 ± 0.01	200 ± 1.1	0
5	531 ± 0.94	7.8 ± 0.002	371 ± 3.1	0.5 ± 0.04	100 ± 0.09	0.58 ± 0.01	0.009	1.58 ± 0.02	175 ± 5.3	0
6	630 ± 0.05	7.6 ± 0.03	441 ± 2.7	0.45 ± 0.06	111.5 ± 1	0.19 ± 0.01	0.001	1.75 ± 0.01	200 ± 1.2	0
7	610 ± 0.03	7.8 ± 0.1	427 ± 1.5	0.35 ± 0.002	119.3 ± 0.4	0.16 ± 0.01	0.001	1.58 ± 0.01	200 ± 2.8	0
8	633 ± 0.06	7.8 ± 0.2	443 ± 0.06	0.47 ± 0.02	109.3 ± 0.1	0.17 ± 0.03	0.005	1.7 ± 0.02	195 ± 0.3	0
9	**1,815 ± 2**	7.6 ± 0.09	**1,270 ± 12**	0.48 ± 0.07	100.8 ± 1.6	0.12 ± 0.3	0.001	1.74 ± 0.2	185 ± 0.4	0
10	616 ± 0.06	7.8 ± 0.05	431 ± 1.3	1.05 ± 0.04	**295.5 ± 1.8**	0.44 ± 0.02	0.001	1.72 ± 0.05	255 ± 1.1	0
11	608 ± 0.03	7.8 ± 0.05	425 ± 1.2	0.48 ± 0.01	81.6 ± 2.8	0.19 ± 0.02	0.001	2.63 ± 0.03	215 ± 0.04	0
12	648 ± 0.1	7.8 ± 0.1	453 ± 0.01	0.52 ± 0.01	89.5 ± 0.08	0.11 ± 0.01	0.001	1.36 ± 0.03	195 ± 0.6	0
13	605 ± 0.08	7.8 ± 0.04	423 ± 4.6	0.52 ± 0.05	102.9 ± 1.7	0.12 ± 0.02	0.001	1.77 ± 0.06	195 ± 1.7	0
14	612 ± 0.02	7.8 ± 0.4	428 ± 4.5	0.31 ± 0.04	90.2 ± 2	0.87 ± 0.2	0.001	1.56 ± 0.04	215 ± 2.5	0
15	561 ± 0.02	7.8 ± 0.02	392 ± 0.3	0.48 ± 0.02	73.1 ± 0.04	0.32 ± 0.01	0	1.43 ± 0.02	170 ± 1.9	0
16	382 ± 0.3	8 ± 0.5	267 ± 2.3	0.52 ± 0.02	26.3 ± 1.09	0.31 ± 0.02	0	1.2 ± 0.001	120 ± 0.2	0
17	805 ± 0.09	7.6 ± 0.03	**563 ± 1.2**	0.55 ± 0.02	108.6 ± 2.1	0.12 ± 0.1	0.002	4.82 ± 0.02	225 ± 2.6	0
18	**1,114 ± 4**	7.1 ± 0.02	**779 ± 0.8**	0.6 ± 0.06	134.2 ± 0.6	0.29 ± 0.02	0.001	8.8 ± 0.04	**390 ± 6.9**	0
19	**1,418 ± 1.2**	6.8 ± 0.002	**992 ± 0.05**	0.54 ± 0.08	146.9 ± 0.9	**1.22 ± 0.5**	0.001	14.2 ± 0.1	**485 ± 7.3**	0
20	849 ± 2.3	7.4 ± 0.06	**594 ± 1.6**	0.51 ± 0.05	89.5 ± 0.03	0.26 ± 0.01	0.002	3.82 ± 0.06	325 ± 0.6	0
21	323 ± 1.2	8.1 ± 0.02	226 ± 1.2	0.38 ± 0.01	19.9 ± 0.1	0.23 ± 0.01	0	1.2 ± 0.03	150 ± 1.7	0
22	505 ± 4.5	8.1 ± 0.7	353 ± 0.5	0.65 ± 0.02	41.9 ± 0.5	0.7 ± 0.1	0.001	0.98 ± 0.03	130 ± 3.1	0
Min	323	6.8	226	0.31	19.9	0.11	0	0.95	120	0
Max	1,815	8.1	1,270	1.05	295.5	1.22	0.009	14.2	485	0
Mean	706.86	7.69	494.50	0.52	95.55	0.37	0	2.83	217.05	0
SD	339.08	0.30	237.25	0.14	56.23	0.29	0	3.08	83.73	0

Bold values are higher than the standard value.

3.3. Bottled water quality

Table 4 shows an analysis of microbial, physical and chemical parameters in bottled drinking water samples. Except for some cases, the mean of all parameters in all brands was lower than the permissible levels of WHO, ISIRI and IBWA.

In terms of the bottled water quality inconsistency with the IBWA standard, the observations were as follows:

In terms of turbidity, brand 1 with turbidity 8 showed much higher turbidity than the standard. In terms of nitrite, brands 1, 2, 5, 6, 7 and 10 were above the IBWA standard for nitrite.

As for nitrate, all the brands had some nitrate, while according to the IBWA standard for bottled water, this parameter must be zero. In terms of hardness, brands 1, 2, 4, 6 and 7 had hardness values above the IBWA

Table 3 | Mean and standard deviation of measured parameters in tap water.

Sampling point	EC	pH	TDS	F	Cl	NTU	Nitrite	Nitrate	Hardness	Coliform
1	521 ± 1.2	7.8 ± 1.6	341.9 ± 0.06	0.4 ± 0.03	79 ± 1	0.35 ± 0.04	0	15.2 ± 0.09	170 ± 2.1	0
2	516 ± 2.3	7.8 ± 0.02	344 ± 0.02	0.87 ± 0.01	76 ± 1.3	0.15 ± 0.03	0.01	18.8 ± 0.01	140 ± 1.6	0
3	872 ± 3.8	**8.2 ± 0.12**	582 ± 0.04	0.96 ± 0.06	82 ± 2.4	0.46 ± 0.01	0.01	**84 ± 0.6**	258 ± 0.09	0
4	586 ± 2.4	7.85 ± 1	380.9 ± 1.6	0.85 ± 0.01	76 ± 3.5	0.33 ± 0.03	0	19.8 ± 1.5	145 ± 1.5	0
5	519.6 ± 0.4	7.8 ± 0.4	346.45 ± 0.09	0.89 ± 0.02	78 ± 0.5	0.21 ± 0.06	0.01	19.6 ± 0.9	160 ± 1.8	0
6	648 ± 0.67	7.9 ± 0.7	325 ± 2.3	0.92 ± 0.01	80 ± 2.8	0.31 ± 0.01	0.03	**39.2 ± 1.08**	180 ± 2.1	0
7	603 ± 1.3	7.8 ± 1.6	402 ± 0.1	0.98 ± 0.02	95 ± 1.2	0.35 ± 0.03	0	28.8 ± 0.02	220 ± 0.03	0
8	478.5 ± 2.8	7.8 ± 0.05	319 ± 0.7	0.64 ± 0.2	78 ± 0.05	0.28 ± 0.01	0	18.8 ± 0.01	160 ± 0.06	0
9	495 ± 1.7	7.8 ± 0.06	330 ± 1.5	0.85 ± 0.01	63 ± 1.05	0.28 ± 0.08	0	11.2 ± 0.01	215 ± 0.5	0
10	540 ± 4.3	7.8 ± 0.06	351 ± 1.6	0.8 ± 0.03	55 ± 0.06	0.27 ± 0.05	0	26.4 ± 1.6	200 ± 1.6	0
Min	478.50	7.80	319.00	0.4	55.00	0.15	0.00	11.20	140.00	0
Max	872.00	8.20	582.00	0.98	95.00	0.46	0.03	84.00	258.00	0
Mean	584.39	7.86	372.23	0.82	76.20	0.30	0.01	28.18	184.80	0
SD	120.93	0.13	77.92	0.17	10.75	0.08	0.01	21.13	37.72	0

Bold values are higher than the standard value.

Table 4 | Mean and standard deviation of measured parameters in bottled water.

Brand	EC	pH	TDS	F	Cl	NTU	Nitrite	Nitrate	Hardness	Coliform
1	473 ± 2.3	7.65 ± 0.01	238 ± 1	0.5 ± 0.06	4.9 ± 0.1	**8 ± 2.1**	**0.02**	0.38 ± 0.08	**185 ± 1.3**	0
2	686 ± 1.7	7.25 ± 0.04	345 ± 1.2	0.3 ± 0.01	36 ± 2.1	0	**0.01**	2.5 ± 0.1	**225 ± 4.5**	0
3	656 ± 0.05	8.2 ± 0.02	327 ± 0.09	0.5 ± 0.09	46 ± 0.045	0	0	4 ± 0.07	170 ± 12	0
4	785 ± 3.1	7.5 ± 0.01	394 ± 0.4	0.55 ± 0.02	7.6 ± 0.06	0	0	2.14 ± 0.1	**220 ± 2.1**	0
5	371 ± 0.09	7.31 ± 0.02	184 ± 2.5	0.55 ± 0.01	10.5 ± 1.1	0	**0.01**	3.2 ± 0.07	70 ± 0.09	0
6	770 ± 1.09	7.59 ± 0.01	384 ± 5.3	0.65 ± 0.01	42 ± 1.4	0	**0.01**	7.8 ± 0.02	**215 ± 8.3**	0
7	541 ± 0.9	7.61 ± 0.9	271 ± 1.7	0.35 ± 0.02	5.3 ± 0.2	0	**0.02**	0.3 ± 0.08	**285 ± 1.05**	0
8	447 ± 1.1	7.12 ± 0.03	224 ± 6.3	0.2 ± 0.01	48 ± 0.09	0	0	0.54 ± 0.01	105 ± 0.9	0
9	266 ± 0.04	7.28 ± 0.03	133 ± 1.2	0.3 ± 0.03	3.4 ± 0.09	0	0	2.5 ± 0.1	110 ± 1.1	0
10	105 ± 0.01	7.15 ± 0.02	53 ± 2.1	0.5 ± 0.01	0.1 ± 0.03	0	**0.01**	1.04 ± 0.7	20 ± 1.7	0
Min	105	7.12	53	0.20	0.10	0	0.00	0.30	20.00	0
Max	785	8.20	394	0.65	48.00	8.00	0.02	7.80	285.00	0
Mean	510	7.47	255.3	0.44	20.38	0.80	0.01	2.44	160.50	0
SD	222.2	0.32	111.3	0.14	19.88	2.53	0.01	2.27	81.94	0

Bold values are higher than the standard value.

standard. Differences in the quality of various brands of bottled drinking water can be attributed to the quality of water purifiers or geographical differences in water resources, precipitation, mineralogy of aquifer rocks and regional topography, which provide water for bottled water companies (Mohammadi *et al.*, 2019).

In a study by Dindarloo in Bandar Abbas (Dindarloo *et al.*, 2016), it was revealed that the quality of some parameters, such as pH, in some brands was not consistent with the standard. But in terms of other parameters, the physicochemical and microbial quality was similar to the results of the present study.

Naddeo conducted a comparison between the quality of bottled water and standards provided for bottled water in Italy (Naddeo *et al.*, 2008). The results showed that several parameters were not consistent with these standards.

3.4. Comparative analysis

Using the statistical tests, the quality of parameters measured in three groups of drinking water suppliers in Shahroud (well water, tap water and bottled water) was compared. Supplementary Material 1 (SM1) and Table 5 show the results of one-way ANOVA and the SNK test, respectively. ANOVA explains the mean differences in the three groups and interprets the significance or non-significance of mean differences in three groups. The SNK test investigates the pairwise significance of the mean differences in groups.

According to the data of ANOVA analysis in SM1, except for EC, turbidity and hardness parameters, the mean of other parameters was significantly different in the three groups. Figure 2 shows the ANOVA analysis visually in which the comparison of the mean values of the parameters with the standard is shown.

Table 5 shows that the water quality of the two groups of bottled water and water available in urban water supply is not significantly different in terms of EC, turbidity, TDS, nitrite and hardness, which clearly shows a lack of need for bottled water, instead of tap water. A comparison of the quality of bottled water and well water demonstrated that, except for pH, TDS, chloride and nitrite, there was no significant difference between the quality of bottled water and well water.

An examination of Table 5, which compares the quality of well water and tap water, showed that, except for fluoride and nitrate, there was no significant difference between the quality of well water and tap water, which was obvious, because wells are the main water suppliers in the tap water system. The small difference between the quality of these two groups can be due to probable problems in the water distribution network or water storage tanks.

The results of the tables presented based on data analysis showed that the microbial quality was excellent in all three groups and no microbial problems were observed in any of the groups.

According to the WHO program for safety of water, the water safety plan (WSP) approach has been developed to organize and systematize a long history of management practices applied to drinking water and to ensure the applicability of these practices to the management of drinking water quality (WHO 2011).

Although Iran is one of the developing countries with WSP where the spread of waterborne diseases, especially cholera, has occurred in the past, it has now made significant progress in developing the microbial quality of

Table 5 | SNK test in three groups of water.

Group	EC	pH	TDS	F	Cl	NTU	Nitrite	Nitrate	Hardness
B vs. T	NS	S	NS	S	S	NS	NS	S	NS
B vs. W	NS	S	S	NS	S	NS	S	NS	NS
W vs. T	NS	NS	NS	S	NS	NS	NS	S	NS

Note: B, bottled water; T, tap water; W, well water; S, significant; NS, non-significant.

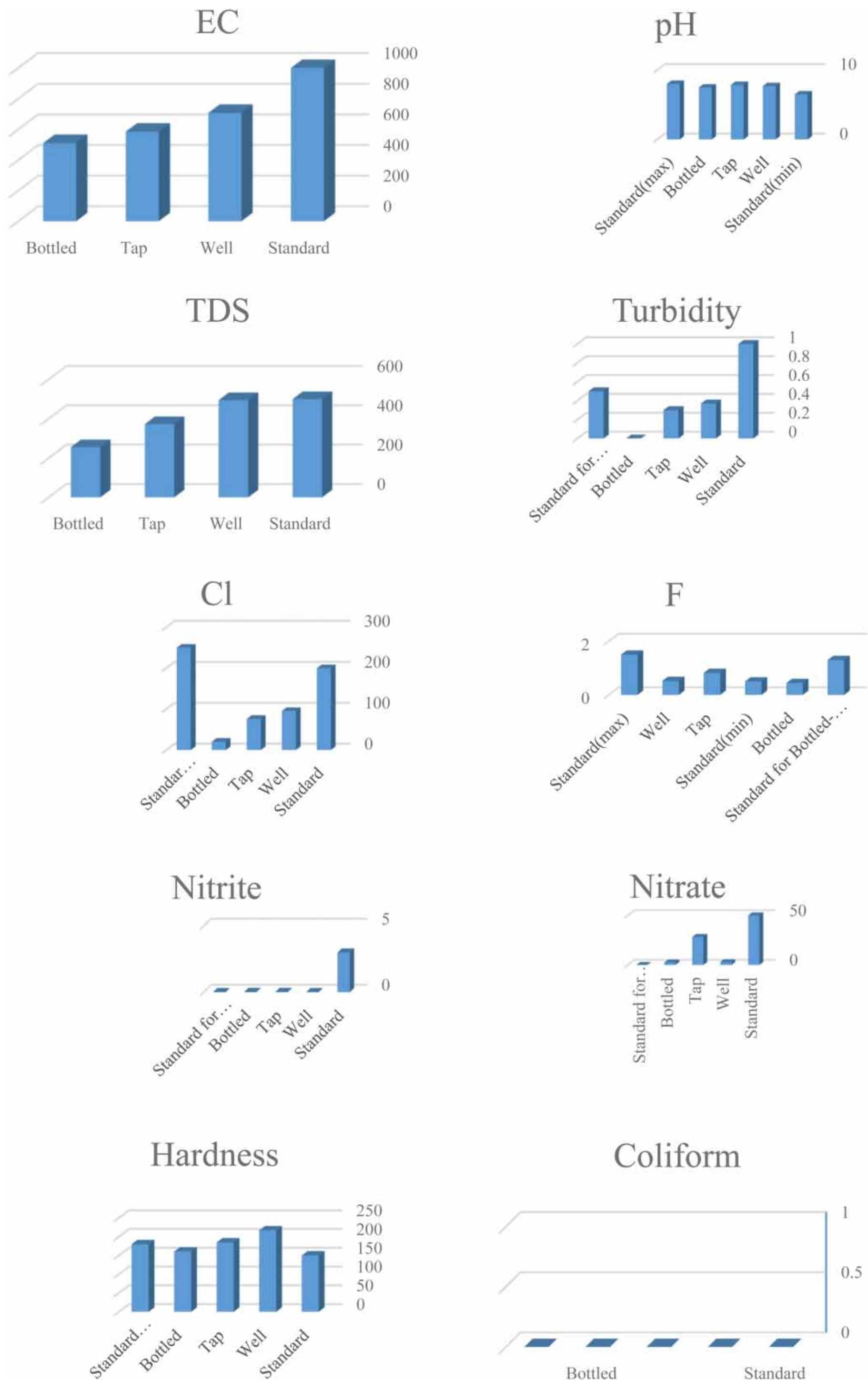

Fig. 2 | Comparison of the mean values of the parameters with the standard.

water, as the results of the present study show (Gundry *et al.*, 2004). This research is part of the WSP program implemented in Iran in the city of Shahroud. Like many WSP programs running in developing countries such as Nepal, Philippines and South-East Asia (WHO, 2016a, 2016b; Sutherland, 2017), this program in different cities of Iran is ongoing based on the instructions of WHO and has achieved significant success in water management.

In a study of the water resources of some developing countries, in different seasons, between 80 and 95% of water resources do not meet the physicochemical and bacteriological quality standards (Pritchard *et al.*, 2016). However, in the present study, as can be seen in Tables 2–4, the microbial and physicochemical quality of all three water sources used in Shahroud is in accordance with national and international standards.

A study conducted two seasons before the rainy season and the rainy season on the physicochemical and microbial quality of drinking water in Pakistan's urban areas shows that, as in the present study, the pH does not contradict the standards, but in the case of turbidity in the rainy season, the turbidity was higher than the WHO limit.

In terms of fecal coliforms, 50% of the samples before the rainy season and 75% of the samples in the rainy season showed coliform pollution (Haydar *et al.*, 2009).

Also, based on a broader study in Pakistan, which is one of Iran's neighbors, 33% of deaths were due to waterborne diseases (Daud *et al.*, 2017; Chandio *et al.*, 2019). However, in the present study, no bacteriological contamination was observed in any of the water resources of Shahroud.

In 2010, Ikem performed a study on the concentration of volatiles in bottles and tap water and showed that 97% of all types of tap water were safe and healthy for human use and that there was no need for bottled water (Ikem, 2010).

Cidu published a paper in which organic compounds were compared in bottled water and tap water in Italy. The results showed there were several compounds in many bottled water samples, which was inconsistent with Italian legislation on water and WHO guidelines (Cidu *et al.*, 2011).

4. CONCLUSIONS

Regardless of the area in which this study was conducted, a question arises: Is it necessary to use bottled water when regional water quality is excellent? The results of the analysis of the parameters evaluated in this study indicated that the microbial, chemical and physical quality of well water and tap water was highly compatible with the national and international standards and did not pose a threat to consumer health. Therefore, there is no need for developing other types of water treatment systems such as bottled water and domestic water treatment systems. Since bottled water is exposed to intense sunlight during the transport process, in many cases, there could be a leakage of plastic monomers from the bottle wall into the water in hot or cold conditions (Bach *et al.*, 2012; Mason *et al.*, 2018; Filella, 2020), which can endanger consumer health. The quality of tap water in the water supply network of Shahroud was at an appropriate level, which did not threaten consumer health. However, many people resort to domestic water treatment, and any lack of attention in cleaning the filters in this treatment system could lead to a mixing of organic matter or microorganisms and their toxins into the water consumed, which many people are unaware of.

Bottled water imposes high costs on families because the price of bottled water is several times higher than that of other types of urban drinking water in the distribution network (Qian, 2018). The results of studies on urban drinking water quality show that there is no need for consuming bottled water. Increased public awareness on the quality of water available in the urban water network, the sensitivity of drinking water suppliers, and the environmental hazards of plastic pollution caused by bottled water can help decrease household costs and help the family economy (Doria, 2006; Saylor *et al.*, 2011; Bach *et al.*, 2012; Mason *et al.*, 2018; Qian, 2018; Filella, 2020). However, providing a more accurate report on a comparison of the chemical and radiological quality of different water supply groups entails higher costs and requires more time.

AUTHOR CONTRIBUTIONS

M.G. and A.R. contributed to the writing and conceptualization of the research, S.N. and A.-B.J. contributed to the experimental works and the preparation of the methodology, and M.G. contributed in terms of software application and analysis of data.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

REFERENCES

Abtahi, M., Dobaradaran, S., Torabbeigi, M., Jorfi, S., Gholamnia, R., Koolivand, A., Darabi, H., Kavousi, A. & Saeedi, R. (2019). Health risk of phthalates in water environment: occurrence in water resources, bottled water, and tap water, and burden of disease from exposure through drinking water in Tehran, Iran. *Environ. Res. 173*, 469–479. https://doi.org/10.1016/j.envres.2019.03.071.

APHA, AWWA, WEF (2012). *Standard Methods for Examination of Water and Wastewater*, 22nd edn. American Public Health Association, Washington. https://doi.org/ISBN 978-087553-013-0.

Bach, C., Dauchy, X., Chagnon, M.-C. & Etienne, S. (2012). Chemical compounds and toxicological assessments of drinking water stored in polyethylene terephthalate (PET) bottles: a source of controversy reviewed. *Water Res. 46*, 571–583. https://doi.org/https://doi.org/10.1016/j.watres.2011.11.062.

Biswas, A. K. & Tortajada, C. (2019). Water crisis and water wars: myths and realities. *Int. J. Water Resour. Dev. 35*, 727–731. https://doi.org/10.1080/07900627.2019.1636502.

Brei, V. A. (2018). How is a bottled water market created? *Wiley Interdiscip. Rev. Water 5*, e1220. https://doi.org/10.1002/wat2.1220.

Chandio, S. H., Ahmed, S. M., Saleem, W. & Naeem, S. (2019). Assessment of physical-chemical parameters of water along the catchment areas of Rawal Dam Islamabad, Pakistan. *Eurasian J. Sci. Eng. 4*, 1–13. https://doi.org/10.23918/eajse.v4i4p1.

Cidu, R., Frau, F. & Tore, P. (2011). Drinking water quality: comparing inorganic components in bottled water and Italian tap water. *J. Food Compos. Anal. 24*, 184–193. https://doi.org/10.1016/j.jfca.2010.08.005.

Cooper, R. J. & Hiscock, K. M. (2019). Catchment water resources. In *Landsc. Plan. with Ecosyst. Serv*. pp. 153–178. https://doi.org/10.1007/978-94-024-1681-7_11.

Daud, M. K., Nafees, M., Ali, S., Rizwan, M., Bajwa, R. A., Shakoor, M. B., Arshad, M. U., Chatha, S. A. S., Deeba, F., Murad, W., Malook, I. & Zhu, S. J. (2017). Drinking water quality status and contamination in Pakistan. *Biomed Res. Int. 2017*. https://doi.org/10.1155/2017/7908183.

Dindarloo, K., Ghaffari, H. R., Kheradpisheh, Z., Alipour, V., Ghanbarnejad, A., Fakhri, Y. & Goodarzi, B. (2016). Drinking water quality: comparative study of tap water, drinking bottled water and point of use (PoU) treated water in Bandar-e-Abbas, Iran. *Desalin. Water Treat. 57*, 4487–4493. https://doi.org/10.1080/19443994.2014.992975.

Doria, M. F. (2006). Bottled water versus tap water: understanding consumer's preferences. *J. Water Health. 4*, 271–276. https://doi.org/10.2166/wh.2006.008.

Ehya, F. & Ghanavati, Z. (2019). Chemical characterization and quality assessment of some bottled water brands from the Kohgiluyeh-va-Boyer Ahmad province market, SW Iran. *Toxin Rev. 38*, 77–85. https://doi.org/10.1080/15569543.2017.1403929.

Filella, M. (2020). Antimony and PET bottles: checking facts. *Chemosphere 261*, 127732. https://doi.org/10.1016/j.chemosphere.2020.127732.

Ghanbarian, M., Ghanbarian, M., Tabatabaie, T., Ghanbarian, M. & Ghadiri, S. -K. (2021). Distributing and assessing fluoride health risk in urban drinking water resources in Fars Province, Iran, using the geographical information system. *Environ. Geochem. Health*. https://doi.org/10.1007/s10653-021-00982-3.

Gundry, S., Wright, J. & Conroy, R. (2004). A systematic review of the health outcomes related to household water quality in developing countries. *J. Water Health 2*, 1–13. https://doi.org/10.2166/wh.2004.0001.

Haydar, J. A., Arshad, S. & Aziz, M. (2009). Evaluation of drinking water quality in urban areas of Pakistan: a case study of Southern Lahore. *Eng. Appl. Sci. 5*, 16–23. https://doi.org/10.1016/B978-008044910-4.01017-8.

Hourieh Fallah, S., Bakaeian, M., Parsian, H., Amouei, A., Asgharnia, H., Ghanbarian, M., Mousapour, A., Tabarinai, H., Oskoei, V. & Miri, S. A. (2020). Potentially harmful heavy metal contamination in Babolrood river: evaluation for risk assessment in the Mazandaran province, Iran. *Int. J. Environ. Anal. Chem. 0*, 1–15. https://doi.org/10.1080/03067319.2020.1828386.

Ikem, A. (2010). Measurement of volatile organic compounds in bottled and tap waters by purge and trap GC-MS: are drinking water types different? *J. Food Compos. Anal. 23*, 70–77. https://doi.org/10.1016/j.jfca.2009.05.005.

Javid, A., Roudbari, A., Yousefi, N., Fard, M. A., Barkdoll, B., Talebi, S. S., Nazemi, S., Ghanbarian, M. & Ghadiri, S. K. (2020a). Modeling of chromium (VI) removal from aqueous solution using modified green-Graphene: RSM-CCD approach, optimization, isotherm, and kinetic studies. *J. Environ. Heal. Sci. Eng. 18*, 515–529. https://doi.org/10.1007/s40201-020-00479-8.

Javid, A., Roudbari, A. A., Mashayekh-Salehi, A., Ghanbarian, M. & Ghanbarian, M. (2020b). The effect of conventional water disinfection methods on nitrate level. *Int. J. Water. 14*, 1–13. https://doi.org/10.1504/IJW.2020.112710.

Mason, S. A., Welch, V. G. & Neratko, J. (2018). Synthetic polymer contamination in bottled water. *Front. Chem. 6*. https://doi.org/10.3389/fchem.2018.00407.

Mohammadi, A. M., Vafakhah, M. & Javadi, M. R. (2019). The relationship between surface water quality and watershed characteristics. *J. Civ. Eng. Constr. 8*, 107–111. https://doi.org/10.32732/jcec.2019.8.3.107.

Momtaz, H., Dehkordi, F. S., Rahimi, E. & Asgarifar, A. (2013). Detection of Escherichia coli, Salmonella species, and Vibrio cholerae in tap water and bottled drinking water in Isfahan, Iran. *BMC Public Health 13*. https://doi.org/10.1186/1471-2458-13-556.

Naddeo, V., Zarra, T. & Belgiorno, V. (2008). A comparative approach to the variation of natural elements in Italian bottled waters according to the national and international standard limits. *J. Food Compos. Anal. 21*, 505–514. https://doi.org/10.1016/j.jfca.2008.02.010.

Pritchard, M., Edmondson, A., Craven, T. & Mkandawire, T. (2016). Sustainable ecological engineering design. *Sustainable Ecol. Eng. Des.*, 259–277. https://doi.org/10.1007/978-3-319-32646-7.

Qian, N. (2018). Bottled water or tap water? A comparative study of drinking water choices on university campuses. *Water (Switzerland) 10*. https://doi.org/10.3390/w10010059.

Rani, B. & Prasad, M. (2012). Bottled water-a global market overview. *Adv. Biores.* 1–4. www.bepls.com (accessed November 24, 2019).

Ridzuan, S. (2021). Inequality and water pollution in India. *Water Policy*. https://doi.org/https://doi.org/10.2166/wp.2021.057.

Saylor, A., Prokopy, L. S. & Amberg, S. (2011). What's wrong with the tap? examining perceptions of tap water and bottled water at Purdue University. *Environ. Manage. 48*, 588–601. https://doi.org/10.1007/s00267-011-9692-6.

Shams, M., Dobaradaran, S., Mazloomi, S., Afsharnia, M., Ghasemi, M. & Bahreini, M. (2012). Drinking water in Gonabad, Iran: fluoride levels in bottled, distribution network, point of use desalinator, and decentralized municipal desalination plant water. *Fluoride 45*, 138–141.

Sutherland, D. (2017). Observations and lessons learnt from more than a decade of water safety planning in South-East Asia. *WHO South-East Asia J. Public Health 6*, 27–33. https://doi.org/10.4103/2224-3151.213788.

van der Linden, S. (2015). Exploring beliefs about bottled water and intentions to reduce consumption: the dual-effect of social norm activation and persuasive information. *Environ. Behav. 47*, 526–550. https://doi.org/10.1177/0013916513515239.

WHO (2011). Chapter 4: Guidelines for Drinking-Water Quality. pp. 45–76. Available from: https://apps.who.int/iris/bitstream/handle/10665/44584/9789241548151_eng.pdf?sequence=1.

WHO (2016a). *Keeping Drinking-Water Safe in the Philippines*. https://www.who.inthttps://www.who.int/philippines/news/feature-stories/detail/keeping-drinking-water-safe-in-the-philippines.

WHO (2016b). *Review of WSP Implementation Process in Nepal*.

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