Archives of Hygiene Sciences
Qom University of Medical Sciences

https://jhygiene.muq.ac.ir/
10.34172/AHS.11.4.38.17
Vol. 11, No. 4, 2022, 248-257

Original Article

Investigating Water Quality Parameters of the Water of the Distribution Network, the Outlet Water of the Household Water Purification Device, and the Widely Consumed Bottled Waters Distributed in the City of Ardabil, and Comparing them with Drinking Water Standards in 2019

Zahra Pourakbar[1], Abdollah Dargahi[2,3], Ahmad Mokhtari[1], Mehdi Vosoughi[1,3], Hadi Sadeghi[1*]

[1]Department of Environmental Health Engineering, School of Health, Ardabil University of Medical Sciences, Ardabil, Iran
[2]Department of Environmental Health, Khalkhal University of Medical Sciences, Khalkhal, Iran
[3]Social Determinants of Health Research Center, Ardabil University of Medical Sciences, Ardabil, Iran

Abstract

Background & Aims: The quality of water consumed by individuals in a society will significantly affect the health of individuals of that society. Various substances that enter individuals' bodies through drinking water play a critical role in maintaining their health so that the lack or excess of some of these substances can cause many complications. Thus, this study aims to determine water quality parameters of the water of the distribution network, the outlet water of the household water purification device, and the widely consumed bottled waters distributed in the city of Ardabil, and compare them with drinking water standards in 2019.

Materials and Methods: This study is a descriptive cross-sectional type, in which 30 bottled waters from 10 most widely consumed brands of bottled water distributed in the city of Ardabil and also 30 samples of the water of the distribution network and the outlet water of the household water purification device were randomly selected. All samples were tested based on the method standard reference. The one-way analysis of variance (ANOVA) test was used to compare the brands of bottles, the one-sample *t* test was used to compare the mean of each parameter with the standard value, and the paired student t-test was used to compare the mean inlet and outlet of the water purification device.

Results: The results showed no microbial pollution in the investigated samples. The highest removal efficiency of the parameters by the household water purification device was 93.18% for sodium, and the lowest was 7.0% for nitrite.

Conclusion: In terms of chemical and microbial quality, the widely consumed bottled waters distributed in Ardabil had no health problems. In general, since the concentration of most urban physicochemical parameters is below the drinking water standard limit of 1053 in household water purification devices, the use of these devices is not necessary for the city of Ardabil.

Keywords: Water purification, Water quality, Drinking water, Bottled water

Received: Januray, 12, 2022, **Accepted**: February, 14, 2022, **ePublished**: December 29, 2022

1. Introduction

Water is the most abundant chemical substance on the earth's surface and the most important factor for creatures' survival. About 65% to 75% of the human body weight is made up of water. Water, as one of the three factors in the formation and survival of the environment, is more important than ever [1,2]. Water-related concerns are acute in arid and semi-arid regions, and many countries facing water crises rely on non-conventional water sources (purified sewage or desalinated seawater). Nowadays, people use bottled water for various reasons, including a lack of favorable drinking water quality of distribution systems, lack of drinking water, ease of access, and relatively low cost. According to the general public, bottled water is completely hygienic and safe, while it can sometimes not have the required quality. Bottled water has standards, rules, and regulations; however, if they are higher than the standard values, the product is unhealthy and may be dangerous for the consumer [3]. Bottled waters are divided into two categories: Mineral bottled waters and drinking bottled waters. Mineral water contains minerals, trace elements, and other ingredients and is obtained directly from the spring or the points excavated from the underground layers. Concerning the use of bottled waters, several aspects are taken into account, such as the water type, compounds, additives, price, quality control, environmental effects stemming from plastic bottles, and more energy consumption

***Corresponding Author:** Hadi Sadeghi, Email: hsadeghi1079@gmail.com

compared to the pipeline network, [4]. One of the parameters that may impact bottled water is the place of water extraction. The quality of extracted water depends on the environment of the groundwater table, which can culminate in the contact of the groundwater with the surrounding rocks and the dissolution of the minerals, and change the content of its minerals, which the bottled water samples may be different due to it [5]. According to the World Health Organization (WHO) report, more than 1.8 million people (mostly children) die annually in the world by water-borne diseases, and this issue has become one of the most leading and common causes of death [6]. There are various ways for entering chemical and microbial pollution into water sources in today's industrial societies, including the sewage from chemical industries, the waters that have passed through farmlands as drainage and are contaminated with pesticides or chemical fertilizers, and municipal sewage and chemical waste disposal areas, which are among serious sources of pollution [7]. In case of violation of the standards, some of the components in water (nitrate, nitrite, fluoride, etc.) may have unfavorable effects on water quality and reduce water quality [8]. One of the essential parameters in producing and consuming bottled waters, like other drinking waters, is controlling their physical, chemical, and microbial quality, which can lead to consumer dissatisfaction or complications for them [9]. Nowadays, with increasing the population, decreasing water resource reserves per capita, and increasing physical, chemical, and microbial water pollution, the water crisis has been proposed as one of the critical global problems so that main message in the second world water council in the Hague, the Netherlands in 2000, was the necessity of more rational water management, its fundamental reform and transformation, the coordinated participation of the beneficiary sectors of the society in water management, and the extension of international cooperations to solve the water crisis [10]. One of the most important health problems in backward and developing countries is the lack of healthy drinking water. Since the basis of sustainable development is a healthy human being and human health relies on benefiting from ideal drinking water, there is no place for the health and well-being of society without supplying healthy water [11]. Given the WHO policy, some factors in bottled waters receive more attention than waters of the distribution network, and stricter standards are applied to reduce their pollution [12]. Bottled waters must meet the drinking water quality standards of the Environmental Protection Agency, the WHO, and the Institute of Standards and Industrial Research. In many societies, water quality standards have been formulated separately [13]. Because of the pollution potential of urban water sources, people have turned to bottled waters and household water purification devices as alternative sources. In order to inhibit the incidence of health effects due to consuming improper and polluted water, awareness of drinking water quality becomes particularly important. Therefore, the current research was conducted to assess water quality parameters of the water of the distribution network, the outlet water of the household water purification devices, and the widely consumed bottled waters distributed in the city of Ardabil and compare them with drinking water standards in 2019.

2. Materials and Methods

This research was a descriptive cross-sectional study conducted in 2019 in Ardabil. The statistical population included the water of the distribution network, the outlet water of the household water purification device, and the widely consumed bottled waters distributed in Ardabil. According to the investigations, 10 widely consumed brands of bottled water are distributed in Ardabil, which are predominant in the country, too. Out of these 10 brands, five are bottled mineral waters called Vata, Parmin, D.D., Atash, and Pana, which are packaged and supplied in Ardabil province. Five other brands are bottled drinking waters called Oxab, Purelife, Damavand, Desani, and Aquafina, which are packaged in other provinces. Three samples were collected from the ten bottled water brands (30 bottles) and 30 samples were collected from the inlets and outlets of household water purification devices. It should be noted that one sample of each brand of bottled waters also worked, but because of obtaining better results regarding statistical mean comparison, three samples of each brand (with the same production date) were prepared. The total number of samples was 60. In order to prepare samples of household water desalination devices, Ardabil was randomly divided into five regions, and water samples were randomly taken from each region. The samples were then transferred to the laboratory of Ardabil School of Health and tested. Totally, 780 samples were analyzed for 13 parameters investigated in this study according to the standard method of water and wastewater. In general, the tests were performed in two categories, including device tests and titration, on the basis of the method standard reference for water and wastewater tests. pH and electrical conductivity (EC) were measured using a portable pH meter and EC meter, respectively. Total hardness, calcium, and chloride were measured by the titration method, sulfate, fluoride, nitrate, and nitrite were measured using a spectrophotometer device, and sodium was measured using a flame photometer device; for measuring other factors, the instructions contained in the book of "Standard Methods" were used. The most portable number (MPN) method was also used for microbial testing [14].

2.1. Data analysis

The results were analyzed using Excel and SPSS version 22 software, and the mean concentrations obtained were compared with drinking water and bottled mineral water standards. The one-way analysis of variance (ANOVA) test was used to compare the brands of bottles, the one-sample *t* test was used to compare the mean of each parameter with the standard value, and the paired student t-test was used to compare the mean inlet and outlet of the water purification device.

3. Results

The results of investigating the water quality parameters of bottled waters, inlet and outlet waters of the household water purification device, data analysis, and the removal efficiency of parameters by household water purification devices are presented in Tables 1 and 2. The results of the minimum, maximum, mean, and standard deviation values of physicochemical parameters in bottled waters distributed in Ardabil in 2019 are presented in Table 1; the results of the minimum, maximum, mean, and standard deviation values of physicochemical parameters in the inlet and outlet waters of household water purification devices in Ardabil in 2019 and the comparison of their mean concentrations with the drinking water standard 1053 are presented in Table 2. Table 2 represents the removal efficiency results of physicochemical parameters by household water purification devices in Ardabil in 2019. The results of the one-sample t-test for comparing the mean values of physicochemical parameters in the inlet and outlet waters of household water purification devices with the drinking water standard 1053 revealed a significant relationship between the parameters investigated in the inlet and outlet waters of household water purification devices ($P<0.05$). In addition, the results of the ANOVA test for the physicochemical parameters of bottled waters showed a significant difference between all parameters investigated in this study (except for nitrite and pH).

4. Discussion

4.1. Nitrate

Nitrate is produced by nitrogen oxidation. Most metal nitrates are water-soluble and are present in small amounts in surface and underground water. Nitrate is detrimental to human health, and long-term contact with its high concentrations may cause disease. The standard amount of nitrate for drinking water and bottled water in Iran is less than 50 mg/L [15], and the amount of nitrate in the samples tested in the current study is less than this value. Although the entrance of small amounts of nitrate into the adult human body is not dangerous since nitrate is a natural part of the human diet, if nitrate concentration is high, especially above 45 mg/L, then consuming such water for children younger than six months old, especially for babies who eat infant formula, is dangerous and results in the occurrence of a disease called methemoglobinemia [16]. According to Iran's Standards and Industrial Research, if the amount of nitrate is more than 10 mg/L, the words "not suitable for babies" should be written on the bottled water label [17]. Among the brands investigated in the current study, the highest nitrate concentration was observed in the Pana brand, with a mean value of 1.14 mg/L, and the Aquafina brand had the lowest nitrate concentration, with a mean value of 1.29 mg/L. In the study of the inlets and outlets of household water purification devices in the current study, the highest amount of nitrate was related to inlet 4 with a mean value of 5.11 mg/L, and the lowest amount was related to inlet 1 with a mean value of 2.18 mg/L. The mean nitrate range at the inlets and outlets of household water purification devices was between 0.43 and 5.11 mg/L, which is below the standard limit. In the present study, nitrate removal efficiency by household water purification devices was 81.86%. The mean nitrate concentration was 3.94 mg/L at the inlets and 0.72 mg/L at the outlets of household water purification devices. None of the samples investigated in the present research were associated with nitrate

Table 1. The results of the minimum, maximum, mean, and standard deviation values of physicochemical parameters in bottled waters distributed in Ardabil in 2019

Parameters	Minimum Values	Maximum Values	Mean Values	Standard Deviation Values
Nitrate	1.29	14.1	5.713	3.793
Nitrite	0.0002	0.004	0.0007	0.0017
Fluoride	0.15	0.87	0.4073	0.9943
Chloride	0.16	13.82	3.41	4.621
Total hardness	25.2	165.6	78.048	54.831
Calcium	0.0	56.45	17.712	17.973
Sodium	1.3	19.96	7.532	6.132
Sulfate	2.84	78.45	33.998	26.1
EC	122.25	794.42	324.9137	168.32
TDS	85.58	556.13	227.44	117.827
pH	7.23	8.03	7.628	0.575

EC, electrical conductivity; TDS, total dissolved solids

Table 2. The results of the physicochemical parameters in the inlet and outlet waters of household water purification devices

Parameters		Minimum Values	Maximum Values	Mean Values	Standard Deviation Values	Mean Removal Efficiency	Maximum Standard	Maximum Permissible Amount
Nitrate	Inlet	2.18	5.11	3.944		81.86	-	50
	Outlet	0.43	1	0.7153				
Nitrite	Inlet	0.0052	0.0086	0.0073		7.0	-	3
	Outlet	0.0	0.0077	0.0066				
Fluoride	Inlet	0.0	0.87	0.4113		60.78	0.5	1.5
	Outlet	0.0	0.36	0.1613				
Chloride	Inlet	12.49	66.98	44.95		77.7	25.	400
	Outlet	3.99	22.49	10.02				
Total hardness	Inlet	64.8	101.52	76.03		88.71	200	500
	Outlet	2.88	15.12	8.58				
Calcium	Inlet	37.88	83.81	52.36		90.22	300	-
	Outlet	0.86	21.6	5.12				
Sodium	Inlet	40.25	95.57	79.96		93.18	200	200
	Outlet	2.05	8.13	5.45				
Sulfate	Inlet	32.01	163.2	71.85		87.12	250	400
	Outlet	0.0	124.11	9.25				
EC	Inlet	122.25	1144.55	1324.91		89.95	-	-
	Outlet	38.63	794.42	125.92				
TDS	Inlet	85.58	801.18	500.44		89.95	1000	1500
	Outlet	27.04	556.13	54.14				
pH	Inlet	7.23	8.03	7.62		-	5.6-5.8	5.6-0.9
	Outlet	5.5	7.93	6.59				
Total coliform	Inlet	0.0	0.0	-		-	Zero	Zero
	Outlet	0.0	0.0	-				
Fecal coliform	Inlet	0.0	0.0	-		-	Zero	Zero
	Outlet	0.0	0.0	-				

Note: Concentrations with the drinking water standard 1053.
EC, electrical conductivity; TDS, total dissolved solids.

concerning pathogenicity and all are in appropriate health conditions. The results of Orooji and colleagues' study to assess the quality of bottled waters consumed in Iran showed that the mean nitrate concentration in all investigated bottled waters was within the standard range of bottled drinking waters and lower than the maximum permissible amount for drinking. Also, there was a significant difference in a number of samples between the measured values and those listed on the bottled water label [18], which is consistent with the results of the present study. The results of a study on bottled mineral waters in Italy indicated that the amount of nitrate was within the standard limit [19]. A study on inorganic ions, including nitrate in bottled drinking waters in Japan, concluded that nitrate concentration was within the standard limit [20]. A study conducted in Finland showed that the devices' efficiency in reducing nitrate was 91.75% [21], which is almost consistent with the results of the present study. Numerous studies have indicated the association of the presence of nitrate in drinking water with the risk of cancers such as gastric cancer [22].

4.2. Nitrite

Nitrite is the regenerated form of nitrate, which can create health problems of methemoglobinemia, liver injury, and carcinogenic nitrosamines in the body because of the possibility of bonding with blood hemoglobin. Thus, its presence in drinking water is worrying and should be eliminated [23]. Iran's national standard 1053 has not stated any optimal limit for nitrite and has suggested the maximum permissible amount of nitrite as 3 mg/L. Standard 2441 of Iran's Institute of Standards and Industrial Research for nitrite in bottled waters has stated 0.02 mg/L as the permissible limit. In the investigated bottled water brands, the amount of nitrite had not been included only on the label of the Desani brand bottled water. In all investigated samples, nitrite was lower than the permissible limit. In examining the amounts of nitrite in bottled mineral waters in the city of Babol, nitrite concentration was reported to be within 0.003 to 0.05

mg/L [24]. The results of Orooji and colleagues' study to assess the quality of bottled waters consumed in Iran revealed that the mean concentration of the chemical parameter of nitrite in all investigated bottled waters was within the standard range of bottled drinking waters and lower than the maximum permissible amount for drinking [18]. The evaluation of the efficiency of household water purification devices by Sadigh et al showed that the outlet nitrite amount of two three-filter and six-filter household water purification devices had significant changes compared to each other [25]. Investigating the drinking water quality of the city of Bardsir showed that the amount of nitrite in all samples was lower than the permissible limit of the Iranian standard and the WHO guidelines [26]. The results of the current research regarding the 60 investigated water samples indicated that the mean nitrite concentration was 0.0038 mg/L and the standard deviation was 0.00378. According to the results of the present study, the nitrite concentration of all samples was lower than the standard limit.

4.3. Fluoride

One of the water quality indices that can provide beneficial information about water drinkability and its content of minerals is the amount of fluoride in water, which is essential as one of the anions of water concerning health aspects and its effect on dental health [27]. According to Iran's drinking water standard, the ideal concentration of fluoride in drinking water is 0.7 mg/L in hot months and 1.2 mg/L in cold months. Based on the results of the current study, the outlet fluoride amount of the household water purification device is significantly lower than the minimum standard values in municipal water. The reduction of fluoride by these devices is one of the principal disadvantages of these devices and may have health effects on humans. Of course, similar studies carried out in other places have confirmed the removal of fluoride by these devices and its reduction below the drinking water standard. In a study conducted in Bojnoord, the efficiency of water purification devices in fluoride reduction was found to be 68.8% [28]; another research in Qeshm showed the efficiency of these devices in fluoride reduction at 99.3% [29], all confirming the results of the present research. The efficiency of the devices in the current study to reduce fluoride is 60.78%. Investigations carried out by different researchers, including Matloob's study on investigating the amount of fluoride in Euphrates River water and bottled waters in the city of Babel, Iraq [30] and Dianati and colleagues' [31] study in the city of Savadkooh, showed that the amount of fluoride in the investigated water samples was lower than the WHO standard and Iran's national standard 1053 of drinking water, which have declared the amount of fluoride to be 0.5 to 1.5 mg/L; this result is consistent with our results regarding the amount of fluoride in the water samples investigated in the city of Ardabil. In the investigation of bottled waters in the present study, the amount of fluoride had not been mentioned on the bottles' labels for four brands, Aquafina, Pana, Parmin, and Damavand. The comparison of the analysis results of the present study was not consistent with the values listed on the bottles' labels. Thus, it is necessary to monitor and supervise the places of producing these bottled waters continuously, and the information about the actual water quality and the bottles' labels should coincide. The results of the current study on the mean fluoride value of bottled waters showed that only two brands of the investigated bottled waters, that is, Atash mineral water with a mean fluoride value of 0.53 mg/L and Damavand drinking water with a mean fluoride value of 0.76 mg/L, were within the standard limit and other bottled waters were below the standard limit. The results of Cochrane and colleagues' study, indicated that the amount of fluoride in five out of ten water samples was 0.03 mg/L and less than the standard limit [32]. The results of Shabankareh Fard and colleagues' study on investigating the amount of fluoride in drinking water of the distribution network of Bushehr showed that the mean fluoride value was 0.48 mg/L [33], which is consistent with the findings of the present research. The results of the present study on the 60 investigated water samples showed that the minimum fluoride concentration was zero, the maximum fluoride concentration was 0.87 mg/L, the mean value was 0.35, and the standard deviation was 0.226. The results of the statistical analysis indicated a significant difference between the investigated groups regarding fluoride concentration, which may be due to fluoride reduction by the household water purification device and the difference in water sources. According to the results of the present study, the amount of fluoride concentration in most of the samples was lower than the standard limit. Since the most important way to receive fluoride is through drinking water and the absorption of fluoride about 0.5 to 1.5 mg/d is useful for the growth of teeth and bones, the amount of fluoride in the investigated drinking water network of Ardabil and bottled waters should be increased.

4.4. Chloride

Chloride is a mineral that is very helpful in creating taste in water. The presence of chloride anion can be one of the reasons for unfavorable drinking water [34]. Iran's national standard 1053 has stated the ideal amount of chloride as 250 and its maximum permissible amount as 400 mg/L. The WHO guideline standard for chloride is 250 mg/L. The mean chloride concentration in all investigated samples was lower than the optimal standard. In Jahed Khaniki and colleagues' study in Tehran, the amount of chloride in all investigated samples was determined within the standard limit and much lower than the optimal level [15], which is consistent with the results of the present study. In Amouei and colleagues' study on the water quality of Khaaf, the chloride parameter was higher than the standard limit in 10% of cases [35]. The results of Azarpira and colleagues' study in the city of Saveh indicated that the mean chloride concentration exceeded the permissible limits, and water non-quality conditions were totally obvious [36]. In the study conducted in Kashan, the mean inlet and outlet chloride of household water purification devices were about 204 and 68 mg/L, and the device efficiency in reducing the amount of chloride was reported to be 66.5% [37]. The mean inlet and outlet chloride of household water purification devices in Bojnoord have been found to be 167 and 37 mg/L, respectively, and the efficiency of the devices in reducing chloride has been 77.8% [28]. The results of the present study on 60 investigated water samples showed that the total mean chloride concentration was 15.44 mg/L and the standard deviation was 19.01. The results of statistical analysis indicated a significant difference between the investigated groups in terms of chlorine concentration. According to the results of the present study, the amount of chlorine concentration in all samples was lower than the standard limit. The mean chlorine concentration at the inlets of household water purification devices in Ardabil in the current research was 44.95 mg/L, and considering that the chlorine concentration in the water of the distribution network of Ardabil is less than the optimal level, the use of the household water purification device with reduced efficiency of 77.7% causes the taste of water to disappear because based on the recommendations of relevant organizations, the presence of minerals such as chloride is necessary for proper drinking taste.

4.5. Total hardness

Water hardness is one of the influencing factors in water tastiness, which is caused due to the existence of calcium and magnesium in water. In assessing widely consumed bottled waters distributed in Ardabil, the Damavand brand bottled water was determined as hard water, the Purelife and Oxab brands were determined as semi-hard waters, and other brands were determined as light waters. The results of investigating bottled water samples available in Ilam revealed that the investigated samples were within the permissible limit regarding total hardness [38], which is consistent with the results of the current research. The results of investigating bottled water samples in Hamedan province showed that the total hardness level of 40 out of 56 samples was less than the optimal maximum, and 16 samples had a total hardness level higher than the optimal maximum [39]. The results of investigating the drinking water sources of Saveh [36] showed that the mean concentration of total hardness exceeded the maximum permissible limit. In the examination of the water quality of Bushehr, the mean total hardness was obtained at 458 mg/L regarding calcium carbonate, which is determined as very hard water according to the classification [33]. According to Iran's national drinking water standard, the optimum level of total hardness is 200, and the maximum permissible amount is 500 mg/L regarding calcium carbonate. Hence, the drinking water hardness of Ardabil, with a mean concentration of 76.03, will cause no health problems for consumers. Considering that the drinking water hardness of Ardabil is classified as semi-hard water according to the WHO classification [40], after being purified by household water purification devices, it is placed in the class of light waters, and since light waters cause cardiovascular diseases [41], the reduction of this amount of hardness by household water purification devices may have health effects; therefore, this issue is considered a disadvantage of these devices [41]. The hardness removal efficiency in the current study was 88.71%, which is consistent with the study conducted in Qeshm, in which the hardness removal efficiency by the household water purification device was 99.5% [29].

4.6. Calcium

Calcium is mostly present in bones and teeth, and its shortage results in osteoporosis. Only 1% of it is available in other parts of the body, and this amount performs many actions; for example, the contraction of our muscles relies on the existence of calcium. Considering that most food we consume during the day is water, the reason for the importance of calcium in drinking water is evident. Calcium can be absorbed in drinking water. Therefore, water can have a critical role in supplying the calcium needed by the body. Calcium is present in all waters that originate from rocks, and its amount depends on the type of bedrock through which the water passes. Calcium is often seen as carbonate, bicarbonate, and sulfate [42]. The main characteristic of calcium shortage in children is rickets and structural transformation in growing bones, while in adults, it contributes to osteoporosis. Standard 1053 has stated the optimum calcium level as 300 mg/L and has not specified a permissible level. In the present study, the mean inlet calcium concentration of household water purification devices was obtained at 52.36 mg/L. The removal efficiency of the investigated devices was estimated at 90.22%, which is consistent with the results of Rajaei and colleagues' study suggesting the calcium reduction efficiency as 85.5% [43]. In the present study, investigating the mean calcium concentration of widely consumed bottled waters distributed in Ardabil was measured at 17.71 mg/L, which is inconsistent with the results of Orooji et al. In Orooji's study, the mean calcium concentration in bottled waters was within the standard limit of bottled drinking waters [18].

4.7. Sodium

In the current research, all investigated samples had sodium levels lower than 200 mg/L. Examining Iran's bottled water quality by Orooji et al in 2015 showed that the amount of sodium in all investigated samples was within the determined standard limit and much lower than the optimal standard, which is consistent with the results of the current research. The investigation of the bottled mineral water quality in Kerman in 2009 indicated that 46% of the samples had higher sodium amounts than the recommended limit [44].

4.8. Sulfate

In the present study, the mean sulfate concentration at the inlets of household water purification devices was obtained at 71.85 mg/L. Investigating the mean sulfate concentration of water in Ardabil by Sadigh et al showed its mean sulfate concentration as 70.4 mg/L, which is consistent with the results of the present study [25]. The mean outlet sulfate concentration of the devices is equal to 9.25 mg/L, indicating a sharp decrease in the outlet sulfate concentration of these devices. Considering that the concentration of minerals in water is essential in small amounts to create taste in drinking water, this reduction may largely remove the taste of water, which can be considered one of the disadvantages of these devices. On the other hand, because of sulfate's laxative effects, this reduction can be helpful in some cases [45]. In Rezaei and colleagues' study on bottled water samples, the amount of sulfate in all samples was within the standard limit. In the current research, the mean sulfate concentration for widely consumed bottled waters distributed in Ardabil was much lower than the optimal level [17]. The results of Rajaei and colleagues' study showed that the mean outlet sulfate concentration of household water purification devices was 5 mg/L, which is to some extent in line with the results of the current research [43]. The results of Amouei and colleagues' study regarding the water quality of Khaaf showed that the amount of sulfate was 20% higher than the standard limit [35]. Shabankareh Fard and colleagues' study on the drinking water quality of the distribution network of Bushehr reported the mean sulfate as 728.38 mg/L and higher than the drinking water standard, which does not meet any of the standards and is not consistent with the results of the current study [33].

4.9. Electrical conductivity

Considering that EC is directly associated with TDS and water-soluble salts, its measurement is essential to control water quality. The EC drinking water standard is directly associated with the TDS value of drinking water, which can be considered less than 1500 µS/cm. In the current study, the EC limit in bottled waters was obtained at 678.97-199.77 µS/cm. The highest amount is related to the Damavand brand bottled water, and the lowest is related to the D.D. brand bottled water. The drinking water EC sin Ardabil is in the range of 854.33-1518.2 µS/cm. The mean EC level at the inlet of household water purification devices is 1254/911 and more than the optimal maximum European standard. The mean EC level at the outlets was estimated to be 735.419 µS/cm. The highest amount was obtained in inlet 3 and the lowest in inlet 4. The removal efficiency of household water purification devices was estimated to be 82.95%. In Nourmoradi and colleagues study, the EC removal efficiency by household water purification devices was reported to be 70.44%, which is, to some extent, consistent with the results of the present study [46]. In Sadigh and colleagues' study, the mean EC level at the inlets of household water purification devices was reported to be 875.84, and that at the outlets it was reported to be 83.03 µS/cm, which is not consistent with the results of the present study [25]. When examining drinking water quality in Saveh, the EC level was higher than the maximum permissible limit [36].

4.10. Total dissolved solids

In the present study, the mean TDSs in all investigated samples were lower than the recommended standards in Iran and more than the value recommended by the US Environmental Protection Agency. The results of the current study were consistent with the results of Godini et al [38] and Orooji et al [18] studies. In Shabankareh Fard and colleagues' study on the water distribution network of Bushehr, the mean TDS value was reported as 577.7 mg/L [33]. In the current research, the amount of TDS in the inlet water of the household water purification device meets the national standard but is higher than the amount recommended by the US Environmental Protection Agency standard. This amount of TDS can cause problems regarding the taste in the drinking water of the distribution network of Ardabil and consequently lead to consumer dissatisfaction. The TDS reduction efficiency by household water purification devices was estimated at 82.95%, which is to some extent consistent with the results of the study conducted in Ilam, indicating the efficiency of household water purification devices in TDSs reduction to be 70.44% [38].

4.11. pH

pH is one of water's most important physicochemical properties because most water purification methods depend on pH. The pH levels at the inlets of household water purification devices in the present study were in the range of 7.2-8.37 and at the outlets were in the range of 5.5-7.93. Forty percent of the pH of the outlet samples of the household water purification device was lower than the permissible limit of 6.5, which can be one of the disadvantages of household water purification devices. The results of the present study show that household water purification devices have the least impact on pH, which is consistent with Nourmoradi and colleagues study [46]. In Shabankareh Fard and colleagues' study, the pH level of water in Bushehr's water distribution network was reported to be in the range of 7.04-7.22, which was in the normal and permissible range compared to the standards and is consistent with the results of the current study [33]. Alimohammadi and colleagues' study on bottled water quality in Iran showed that the 6% pH of Iran's mineral waters is outside the standard range [47].

4.12. Fecal coliform and total coliform

According to Iran's national standards and the WHO standard, the number of total coliforms should be zero in 95% of samples and, at most, 3 in the remaining 5%. Also, fecal coliform should be zero in drinking water [48]. In this study, all the results of total coliform and fecal coliform tests were negative, indicating that the water of the distribution network and the widely consumed bottled waters distributed in Ardabil are healthy from a microbial perspective. The results of the study are consistent with the results of the studies conducted in Ilam [38] and Kerman [44]. Information regarding the microbial quality of water produced by household water purification devices is minimal, and the function of these systems can be different. In Deghani and colleagues' study on the outlet water of desalination devices with reverse osmosis process, no cases of pollution with total coliform and fecal coliform were observed [29], which is consistent with the results of the present study. The results of investigating the effect of the household water purification device on the drinking water quality in Ilam showed that the household water purification device does not have an acceptable efficiency in removing microbial pollution, and in most cases, it has increased microbial pollution [38].

5. Conclusion

This study investigated the physicochemical and microbial parameters of widely consumed bottled waters distributed in the city of Ardabil and the physicochemical and microbial parameters of the inlet and outlet waters of household water purification devices. In general, it can be concluded that the widely consumed bottled waters distributed in Ardabil have no health problems in terms of chemical and microbial quality. Household water purification devices are highly efficient in decreasing physical and chemical parameters of water. Given that most of the physicochemical parameters of the drinking water distribution network of Ardabil are below the drinking water standard 1053, using these devices is not necessary for this city because such devices often reduce the concentration of the parameters to below the standard limit and somehow reduce the taste of water. In addition, they cause high removal of useful minerals; thus, the users of household water purification devices should be aware of the low intake of minerals from the purified water.

Acknowledgments

The authors wish to acknowledge the financial support of carrying out this project, Ardabil University of medical sciences.

Author Contributions

Conceptualization, methodology, validation, formal analysis, investigation, supervision, funding acquisition: Hadi Sadeghi and Abdollah Dargahi; Resources, writing - original draft, writing-review & editing: Mehdi Vosoughi and Ahmad Mokhtari; Formal analysis, investigation, resources: Zahra Pourakbar.

Conflict of Interests

The authors declared no conflict of interest.

Ethical Approval

The study protocol was approved by the Ethics Committee of Ardabil University of Medical Sciences (Code: IR.ARUMS.REC.1398.065).

Funding

This research was supported by the research project, Funded by the Ardabil University of Medical Sciences.

References

1. Morgan CE, Bowling JM, Bartram J, Kayser GL. Attributes of drinking water, sanitation, and hygiene associated with microbiological water quality of stored drinking water in rural schools in Mozambique and Uganda. Int J Hyg Environ Health. 2021;236:113804. doi: 10.1016/j.ijheh.2021.113804.
2. Timmers PHA, Slootweg T, Knezev A, van der Schans M, Zandvliet L, Reus A, et al. Improved drinking water quality after adding advanced oxidation for organic micropollutant removal to pretreatment of river water undergoing dune infiltration near The Hague, Netherlands. J Hazard Mater. 2022;429:128346. doi: 10.1016/j.jhazmat.2022.128346.
3. Hu G, Mian HR, Abedin Z, Li J, Hewage K, Sadiq R. Integrated probabilistic-fuzzy synthetic evaluation of drinking water quality in rural and remote communities. J Environ Manage. 2022;301:113937. doi: 10.1016/j.jenvman.2021.113937.
4. Praveena SM, Laohaprapanon S. Quality assessment for methodological aspects of microplastics analysis in bottled water–a critical review. Food Control. 2021;130:108285. doi: 10.1016/j.foodcont.2021.108285.
5. Cerna-Cortes JF, Cortes-Cueto AL, Villegas-Martínez D, Leon-Montes N, Salas-Rangel LP, Rivera-Gutierrez S, et al. Bacteriological quality of bottled water obtained from Mexico City small water purification plants: Incidence and identification of potentially pathogenic nontuberculous mycobacteria species. Int J Food Microbiol. 2019;306:108260. doi: 10.1016/j.ijfoodmicro.2019.108260.
6. Farid-ul-Hasnain S, Johansson E, Krantz G. What do young adults know about the HIV/AIDS epidemic? Findings from a population based study in Karachi, Pakistan. BMC Infect Dis. 2009;9:38. doi: 10.1186/1471-2334-9-38.
7. Shams M, Qasemi M, Afsharnia M, Mohammadzadeh A, Zarei A. Chemical and microbial quality of bottled drinking water in Gonabad city, Iran: effect of time and storage conditions on microbial quality of bottled waters. MethodsX. 2019;6:273-7. doi: 10.1016/j.mex.2019.02.001.
8. Cidu R, Frau F, Tore P. Drinking water quality: comparing inorganic components in bottled water and Italian tap water. J Food Compost Anal. 2011;24(2):184-93. doi: 10.1016/j.jfca.2010.08.005.
9. Ighalo JO, Adeniyi AG. A comprehensive review of water quality monitoring and assessment in Nigeria. Chemosphere. 2020;260:127569. doi: 10.1016/j.chemosphere.2020.127569.
10. Remoundou K, Koundouri P. Environmental effects on public health: an economic perspective. Int J Environ Res Public

Health. 2009;6(8):2160-78. doi: 10.3390/ijerph6082160.
11. Soltanian M, Dargahi A, Asadi F, Ivani A, Setareh P, Saleh E. Variation of physicochemical quality of groundwater watershed in Gharehsou during 2003-2012. J Mazandaran Univ Med Sci. 2015;24(121):275-87. [Persian].
12. Shams Khorramabadi G, Dargahi A, Tabandeh L, Godini H, Mostafaee P. Survey of heavy metal pollution (copper, lead, zinc, cadmium, iron and manganese) in drinking water resources of Nurabad city, Lorestan, Iran 2013. Yafteh. 2016;18(2):13-22. [Persian].
13. Hamad AA, Sharaf M, Hamza MA, Selim S, Hetta HF, El-Kazzaz W. Investigation of the bacterial contamination and antibiotic susceptibility profile of bacteria isolated from bottled drinking water. Microbiol Spectr. 2022;10(1):e0151621. doi: 10.1128/spectrum.01516-21.
14. American Public Health Association (APHA). Standard Methods for the Examination of Water and Wastewater. 19th ed. Washington DC, USA: APHA; 1995.
15. Jahed Khaniki G, Mahdavi M, Ghasri A, Saeednia S. Investigation of nitrate concentrations in some bottled water available in Tehran. Iran J Health Environ. 2008;1(1):45-50. [Persian].
16. El-Sofany EA. Removal of lanthanum and gadolinium from nitrate medium using Aliquat-336 impregnated onto Amberlite XAD-4. J Hazard Mater. 2008;153(3):948-54. doi: 10.1016/j.jhazmat.2007.09.046.
17. Adesakin TA, Oyewale AT, Bayero U, Mohammed AN, Aduwo IA, Ahmed PZ, et al. Assessment of bacteriological quality and physico-chemical parameters of domestic water sources in Samaru community, Zaria, Northwest Nigeria. Heliyon. 2020;6(8):e04773. doi: 10.1016/j.heliyon.2020.e04773.
18. Orooji N, Takdastan A, Noori Sepehr M, Raeesi GR. Evaluation the quality of bottled waters consumption in Iran in 2015. J Environ Health Eng. 2017;4(1):70-81. doi: 10.18869/acadpub.jehe.4.1.70. [Persian].
19. Cicchella D, Albanese S, De Vivo B, Dinelli E, Giaccio L, Lima A, et al. Trace elements and ions in Italian bottled mineral waters: identification of anomalous values and human health related effects. J Geochem Explor. 2010;107(3):336-49. doi: 10.1016/j.gexplo.2010.04.004.
20. Abouleish MY. Concentration of selected anions in bottled water in the United Arab Emirates. Water. 2012;4(2):496-509. doi: 10.3390/w4020496.
21. Sehn P. Fluoride removal with extra low energy reverse osmosis membranes: three years of large scale field experience in Finland. Desalination. 2008;223(1-3):73-84. doi: 10.1016/j.desal.2007.02.077.
22. Catling LA, Abubakar I, Lake IR, Swift L, Hunter PR. A systematic review of analytical observational studies investigating the association between cardiovascular disease and drinking water hardness. J Water Health. 2008;6(4):433-42. doi: 10.2166/wh.2008.054.
23. Choe S, Liljestrand HM, Khim J. Nitrate reduction by zero-valent iron under different pH regimes. Appl Geochem. 2004;19(3):335-42. doi: 10.1016/j.apgeochem.2003.08.001.
24. Aghalari Z, Jafarian S. Survey of nitrite and nitrate in mineral water available in the city of Babol in 2015. J Environ Health Eng. 2017;5(1):65-72. doi: 10.29252/jehe.5.1.65. [Persian].
25. Sadigh A, Nasehi F, Fataei E, Aligadri M. Investigating the efficiency of home water treatment systems to reduce or eliminate water quality parameters in the city of Ardabil in 1392. J Health. 2015;6(4):458-69. [Persian].
26. Malakootian M, Momeni J. Quality survey of drinking water in Bardsir, Iran 2009-2010. J Rafsanjan Univ Med Sci. 2012;11(4):403-10. [Persian].
27. UNICEF. Position on Water Fluoridation. Fluoride in Water: An Overview. UNICEF; 2009.
28. Tavangar A, Naimi N, Alizade H, Tavakoli Ghochani H, Ghorbanpour R. Evaluation of water treatment systems' performance available in Bojnurd ciry during 2013. J North Khorasan Univ Med Sci. 2014;5(5):1107-19. doi: 10.29252/jnkums.5.5.S5.1107. [Persian].
29. Deghani M, Doleh M, Hashemi H, Shamsaddini N. The quality of raw and treated water of desalination plants by reverse osmosis in Qeshm. Health and Development Journal. 2013;2(1):33-43. [Persian].
30. Matloob MH. Fluoride concentration of drinking water in Babil-Iraq. J Appl Sci. 2011;11(18):3315-21. doi: 10.3923/jas.2011.3315.3321.
31. Dianati Tilaki R, Rasouli Z. Reviewing the chemical quality (nitrate, fluoride, hardness, electrical conductivity) and bacteriological assessment of drinking water in Savadkuh, Iran, during 2010-2011. J Mazandaran Univ Med Sci. 2013;23(104):51-5. [Persian].
32. Cochrane NJ, Saranathan S, Morgan MV, Dashper SG. Fluoride content of still bottled water in Australia. Aust Dent J. 2006;51(3):242-4. doi: 10.1111/j.1834-7819.2006.tb00436.x.
33. Shabankareh Fard E, Hayati R, Dobaradaran S. Evaluation of physical, chemical and microbial quality of distribution network drinking water in Bushehr, Iran. Iran South Med J. 2015;17(6):1223-35. [Persian].
34. Ghaffari HR, Kamari Z, Ranaei V, Pilevar Z, Akbari M, Moridi M, et al. The concentration of potentially hazardous elements (PHEs) in drinking water and non-carcinogenic risk assessment: a case study in Bandar Abbas, Iran. Environ Res. 2021;201:111567. doi: 10.1016/j.envres.2021.111567.
35. Amouei A, Mohammadi AA, Koshki Z, Asgharnia HA, Fallah SH, Tabarinia H. Nitrate and nitrite in available bottled water in Babol (Mazandaran; Iran) in summer 2010. J Babol Univ Med Sci. 2011;14(1):64-70. [Persian].
36. Azarpira H, Rasolevandi T, Aali R, Mahvi A, Ghorbanpour MA, Moradi h, et al. Investigation of nitrate and nitrite concentration and other physicochemical parameters of drinking water sources in Saveh city during the year of 2018. J Res Environ Health. 2018;4(2):140-5. doi: 10.22038/jreh.2018.33436.1232. [Persian].
37. Khaung T, Iwai CB, Chuasavathi T. Water quality monitoring in Inle Lake, Myanmar from the floating garden activity. Malaysian Journal of Fundamental and Applied Sciences. 2021;17(5):593-608. doi: 10.11113/mjfas.v17n5.2330.
38. Godini K, Sayehmiri K, Alyan G, Alavi S, Rostami R. Investigation of microbial and chemical quality of bottled waters distributed in Ilam (western Iran) 2009-10. J Ilam Univ Med Sci. 2012;20(2):33-7. [Persian].
39. Riahi Khoram M, Khoshshoar M, Hashemi M. Chemical and microbiological properties of bottled water in Hamedan province. J Food Hyg. 2014;4(13):69-96. [Persian].
40. United States Environmental Protection Agency, Office of Water. 2004 Edition of the Drinking Water Standards and Health Advisories. United States Environmental Protection Agency, Office of Water; 2004.
41. Ziv-El MC, Rittmann BE. Systematic evaluation of nitrate and perchlorate bioreduction kinetics in groundwater using a hydrogen-based membrane biofilm reactor. Water Res. 2009;43(1):173-81. doi: 10.1016/j.watres.2008.09.035.
42. Nkamare MB, Ofili AN, Adeleke AJ. Physico-chemical and microbiological assessment of borehole water in Okutukutu, Bayelsa State, Nigeria. Adv Appl Sci Res. 2012;3(5):2549-52.
43. Rajaei MS, Salemi Z, Karimi B, Ghanadzadeh MJ, Mashayekhi M. Effect of household water treatment systems on the physical and chemical quality of water in 2011-2012. J Arak Uni Med

Sci. 2013;16(72):26-36. [Persian].

44. Loloei M, Zolala F. Survey on the quality of mineral bottled waters in Kerman city in 2009. J Rafsanjan Univ Med Sci. 2011;10(3):183-92. [Persian].
45. Nouri A, Sadeghnezhad R, Soori MM, Mozaffari P, Sadeghi S, Ebrahemzadih M, et al. Physical, chemical, and microbial quality of drinking water in Sanandaj, Iran. J Adv Environ Health Res. 2018;6(4):210-6. doi: 10.22102/jaehr.2018.121023.1066.
46. Nourmoradi H, Karami N, Karami S, Mazloomi S. Investigation on the effect of household water treatment plants on the drinking water quality of Ilam city. J Environ Health Eng. 2017;5(1):57-64. doi: 10.29252/jehe.5.1.57. [Persian].
47. Alimohammadi M, Askari M, Aminizadeh S, Dehghanifard E, Rezazadeh M. Evaluation of microbial quality of bottled water in Iran. J Environ Health Eng. 2014;1(2):137-45. doi: 10.18869/acadpub.jehe.1.2.137. [Persian].
48. Mwabi JK, Mamba BB, Momba MN. Removal of *Escherichia coli* and faecal coliforms from surface water and groundwater by household water treatment devices/systems: a sustainable solution for improving water quality in rural communities of the Southern African development community region. Int J Environ Res Public Health. 2012;9(1):139-70. doi: 10.3390/ijerph9010139.