Research Paper

Microbiological and physico-chemical properties of packaged, residential treatment device and tap water drinking water and their possible effects on human health

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ABSTRACT

The objective of this study was to examine the microbiological and physico-chemical properties of different types of drinking water used. The cross-sectional type study was carried out between January 1 and April 30, 2016. The samples acquired for the study from 50 packages, 50 tap water taps, and 50 residential treatment devices were examined both microbiologically and biochemically. The pH values varied between 5.57 and 8.26. pH values of tap and packaged waters were all determined to be proper, and improperly low pH values were determined in 25 of the samples acquired from the residential treatment devices. It was determined that amounts of fluoride, chloride, nitrate, nitrite, arsenic, and ammonium were all acceptable. Fluoride amounts were determined to be high at a statistically significant level in packaged and residential treatment device water ($p = 0.000$). *Escherichia coli* was determined in 10% of tap water and 2% of packaged water. Microbiological contaminations of the samples collected after the pump-faucet and water fountain were determined to be greater in comparison with those of samples collected directly from packaged waters. It was determined that the residential treatment process is applied more on drinkable waters. The purification of water causes significant physico-chemical changes.

Key words | drinking water, packaged water, sanitation, tap water, water analysis

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INTRODUCTION

The quality of drinking water is one of the strong indicators of environmental health. Guaranteeing safe drinking water is the basis for the control and prevention of water-based diseases. One of the most important public services is to provide clean and healthy drinkable water to society (WHO 2016).

It is desired with regard to drinkable water that the microbiological and physico-chemical parameter values for drinking waters remain inside the limits determined by national or international standardization institutions. In Turkey, TS 266 and Regulation for Waters Intended for Human Consumption are used for these purposes (İnsani Tüketim Amaçlı Sular Hakkında Yönetmelik T.C. Resmî Gazete 2005). Water quality is adversely affected as a result of increased population and, therefore, increased contamination of water by residential, industrial, and agricultural polluters has occurred. Hence, individuals may prefer other water sources such as a carboy (19 lt packaged water), PET bottle, or a residential treatment device. Today, drinking water has become a sector that provides a significant commercial income (Canik 1998).

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Most people in the world accept bottled water as being more natural, pure, and a healthier alternative to tap water because they do not like the taste, smell, or color of tap water or because of health concerns. For example, in the United States, it has been reported that the increase in outbreaks of water-borne diseases, due to problems in public water distribution systems, led the public to using bottled water. For these reasons, the ever-increasing demand for bottled water is a reality all over the world (Baba *et al.* 2008).

Branded and packaged water consumption in this sector is increasing. Recyclable polycarbonate packages that are used for this purpose have taken their place in the market for residential use as a healthy, light, unbreakable, and recyclable product with cost advantages (Çetin *et al.* 2013). However, packaged water is not necessarily safer than tap water. Many studies have reported the presence of heterotrophic bacteria along with coliforms in packaged water in counts exceeding national and international standards (Pant *et al.* 2016). The use of residential treatment devices as another option is gaining popularity. There are different types of residential treatment systems. Regular maintenance is required in order to ensure that all the residential treatment devices work effectively. Indeed, these maintenance costs can sometimes be very high. If the use of residential treatment devices is among the regular options in a society, then that society is under physico-chemical and biological influence (Güler 2008). The residential treatment systems must be well managed and replaced regularly because their effectiveness is eventually lost, depending upon the types of contaminating chemicals and their concentrations in the water. Reverse osmosis technologies have general applicability for removal of most organic and inorganic chemicals; however, there is some selectivity, and also there is a significant amount of water wastage when low-pressure units are used in small-volume applications (WHO 2011).

The objective of this study was to examine the microbiological and physico-chemical properties of tap water, packaged water, and residential treatment device water used for drinking purposes in Gaziantep city center. The effects of pump-faucet and water fountain use on microbiological quality were examined.

MATERIALS AND METHODS

The study is a cross-sectional type research study carried out by the Gaziantep University Faculty of Medicine Public Health Department and Gaziantep Directorate of Public Health. It was carried out at randomly selected homes and workplaces in Gaziantep city center during January 1, 2016 to April 30, 2016.

The province of Gaziantep is at the junction of the Mediterranean and the southeastern Anatolia Region. Gaziantep, with a population of 1,844,438, has a 2,045,000 m water distribution network. The water requirements of Gaziantep province is provided from three sources, the most important one being the Kartalkaya Dam, which is 40 km from the city. The water treatment plant is located in Hacıbaba. Tap water is provided to people after pre-disinfection, coagulation, clarification, filtration, and the final disinfection, respectively (GASKİ Gaziantep Su ve Kanalizasyon İdaresi Stratejik Plan 2015–2019).

A questionnaire form with questions related to sociodemographic properties, the properties of the used drinking water, the type of use and reasons for preference was issued to individuals after relevant information about the study was given and their verbal consents were taken.

The samples were taken from the drinking water used by the individuals for microbiological and biochemical parameters after the questionnaire form was completed. Fifty packaged (carboy; 19 lt packaged water), 50 tap water, and 50 residential treatment devices were included in the study taking into consideration the capacity of the laboratory. Two microbiological samples were taken from the packaged water in the packaged group, one from the closed package, and one after the pump-faucet was installed or the water was emptied into the water fountain. Two microbiological samples were taken from the group using residential treatment devices; one from the tap water prior to purification and one after the residential treatment was completed. The samples were taken on the same day to the Gaziantep Public Health Laboratory.

Six parameters were examined during the microbiological analysis (*Escherichia coli* (*E. coli*), coliform bacteria, *Pseudomonas aeruginosa* (*P. aeruginosa*), *Clostridium* *perfringens* (*C. perfringens*), colony count at 22 °C and colony count at 37 °C).

Color, odor, turbidity, conductivity, pH, ammonium (NH_4), fluoride (F), chloride (Cl), nitrite (NO_2), and nitrate (NO_3) were studied for all the biochemical samples. In addition, bromoform, bromate, and arsenic were examined in all the packaged samples; calcium (Ca), magnesium (Mg), and aluminum (Al) were studied in all tap water.

The parameters were evaluated according to both the World Health Organization Guidelines for Drinking-water Quality Regulation and the Turkish Regulation on waters for Human Consumption (published in the Official Gazette dated March 7, 2013, No. 28580) (WHO 2011; İnsani Tüketim Amaçlı Sular Hakkında Yönetmelikte Değişiklik Yapılmasına Dair Yönetmelik T.C. Resmî Gazete 2013).

Approval was taken from the Clinical Studies Ethics Council of Gaziantep University with decision number 2015/323.

The data were analyzed via the SPSS Version 22 statistical software package program. Descriptive statistics, chi square test, Student's *t*-test, analysis of variance (ANOVA), dependent groups *t*-test, McNemar, Mann–Whitney U, and Kruskal–Wallis tests were applied. The level of statistical significance was accepted as $p < 0.05$.

RESULTS

Fifty packaged, 50 tap, and 50 residential treatment device waters were included in the study. It was determined that 58% of the packaged water users use it with a water fountain, whereas 42% use it by installing a pump-faucet. The participants stated that they finished a package in an average of 4.97 ± 2.82 days. The longest duration of time for using the package was determined as 14 days.

28.6% of those who use the package with a pump-faucet stated that they did not visually inspect the pump cleanliness prior to use. It was determined that 23.8% of those who use a pump-faucet do not clean the pump-faucet, that 19% clean it less than once a month, 19% clean it once a month or more, and that 38.1% clean it during each package change. 93.8% of those who clean the pump-faucet stated that they washed it with water, whereas 6.2% stated that they cleaned it with vinegar. It was stated that the average pump use time was 13.14 ± 14.96 months and that the longest time of use was 72 months.

It was determined that the average water fountain use duration was 30.34 ± 25.90 months for those who use packaged water with a fountain. The longest time period for the water fountain use was determined as 120 months. 79.3% of the users stated that they did not check for odor, color change, and contamination in the device during the package change process. 51.7% of the water fountain users stated that they did not clean the water fountain. It was determined that 57.1% of those who clean the water fountain use water for cleaning, 21.4% use vinegar, 21.4% use chemical disinfectants, and they clean it every 3.28 ± 4.10 (1–12) months on average. The longest cleaning frequency was determined as once every 12 months. 92.9% stated that they cleaned the water fountain themselves, whereas 7.1% stated that the cleaning process was performed by the company personnel.

Sixteen percent of those who use water residential treatment devices stated that they signed a maintenance agreement with the company from where they made the purchase, and 90% stated that they believed the residential treatment device water to be clean and reliable. 68% of the users stated that they considered the brand when purchasing a residential treatment device, 60% stated that they check its cheapness, 20% considered the company having a wide service network, 16% considered the suggestions of their acquaintances, 10% were influenced by advertisements and introductions, 10% were impressed by the fact that the device is multi-filtered, and 4% checked whether the device was certified by institutions such as Water Quality (WQ), NSF, FDA.

All the sampled water was determined to be in accordance with the regulations in terms of color and odor. 22% of the packaged water samples, 2% of the tap water samples, and 6% of the water residential treatment device samples were not determined to be appropriate in terms of turbidity. The pH values were determined to be different at statistically significant levels among the samples ($p = 0.000$). The pH values of all the tap and packaged water were determined to be appropriate, and inappropriate pH values were determined for 50% of the water residential treatment device samples. All the samples were determined to be appropriate with regard to fluoride, chloride, nitrate, nitrite, arsenic, and ammonium values. Two percent of the packaged water was not determined to be appropriate in terms of bromate.

The fluoride, chloride, and nitrate values of the tap water were determined to be greater at a statistically significant value in comparison with the values of the other samples ($p = 0.000$). Nitrite was determined in none of the samples. Arsenic and bromoform values were all determined to be acceptable for drinking purposes in the packaged water. The average values of the physico-chemical parameters of the samples are given in Table 1.

It was determined that 4% of the packaged water, 10% of the tap water, and 8% of the residential treatment device water was not appropriate in terms of *E. coli*. No statistically significant difference was determined in the examined samples in terms of appropriateness of the microbiological parameters and the average bacteria count.

The microbiological parameters and their appropriateness are given in Table 2 according to the packaged water use, and their distribution according to the microorganism count is given in Table 3.

Statistically significant differences were determined for *E. coli* ($p = 0.014$), coliform bacteria ($p = 0.041$), total colony count at 22 °C ($p = 0.019$), and total colony count at 37 °C ($p = 0.002$) values in the packaged water samples before and after the use of pump-faucet or water fountain. Microbiological contamination of the samples obtained from the pump-faucet and water fountain was determined to be greater in comparison with

Table 1 | Physico-chemical parameters of the samples

Parameters	Bottled water mean ± SD (min–max)	Tap water mean ± SD (min–max)	Filtered water mean ± SD (min–max)	*p*
Conductivity	159.41 ± 81.03 (37.40–490.30)	576.12 ± 73.81 (436.0–880.0)	108.13 ± 144.34 (3.0–583.0)	0.000
pH	7.68 ± 0.37 (6.95–8.25)	7.47 ± 0.13 (7.14–7.88)	6.54 ± 0.52 (5.57–8.26)	0.000
Aluminum (Al)	Not tested	0.29 ± 2.06 (0–14.60)	0	
Fluoride (F)	0.04 ± 0.05 (0–0.29)	0.19 ± 0.2 (0–0.87)	0.04 ± 0.05 (0–0.16)	0.000
Chloride (Cl)	4.08 ± 4.33 (0–22.80)	11.55 ± 4.95 (4.95–55.67)	2.03 ± 2.58 (0–12.45)	0.000
Nitrate (NO_3)	3.13 ± 3.52 (0.20–16.43)	15.84 ± 5.44 (5.56–32.20)	5.31 ± 6.17 (0–38.93)	0.000
Nitrite (NO_2)	Not detected	Not detected	Not detected	
Bromate ($HBRO_3$)	2.28 ± 3.15 (0–15.27)	Not tested	Not tested	
Arsenic	0.33 ± 0.39 (0–1.18)	Not tested	Not tested	
Ammonium (NH_4)	<0.04	Not tested	Not tested	

Table 2 | The distribution of the samples with regard to their microbiological accordance

Parameters		Bottled water	Tap water	Filtered water	*p*
Escherichia coli	Acceptable (0)	48	45	46	0.503
	Unacceptable	2	5	4	
Coliform bacteria	Acceptable (0)	48	46	47	0.701
	Unacceptable	2	4	3	
Pseudomonas aeruginosa	Acceptable (0)	50	47	45	0.810
	Unacceptable	0	3	5	
Clostridium perfringens	Acceptable (0)	50	48	50	0.132
	Unacceptable	0	2	0	
22 °C CFU	Acceptable (0–1,000)	50	50	50	All acceptable
37 °C CFU	Acceptable (0–200)	47	47	47	1.000
	Unacceptable	3	3	3	

CFU: colony forming unit.

Table 3 | The distribution of the samples with regard to average microorganism count

Parameters	Bottled water mean ± SD (min–max)	Tap water mean ± SD (min–max)	Filtered water mean ± SD (min–max)	*p*
Escherichia coli	0.64 ± 4.24 (0–30)	18.7 ± 89.5 (0–500)	0.48 ± 1.89 (0–9)	0.131
Coliform bacteria	0.64 ± 4.24 (0–30)	26.5 ± 128.9 (0–700)	0.46 ± 1.89 (0–9)	0.136
Pseudomonas aeruginosa	0	1.2 ± 5.2 (0–30)	1.7 ± 7.5 (0–50)	0.231
Clostridium perfringens	0	1.54 ± 9.92 (0–70)	0	0.303
22 °C CFU	30.7 ± 96.74 (0–600)	28.0 ± 86.6 (0–400)	42.4 ± 158.9 (0–1,000)	0.811
37 °C CFU	40.3 ± 154.5 (0–1,000)	26.2 ± 104.5 (0–500)	52.7 ± 167.4 (0–1,000)	0.659

the samples collected directly from the package. However, even though all the samples were suitable for drinking purposes in terms of *Pseudomonas* prior to pump-faucet or water fountain use, it was determined that 10% of the samples collected afterwards was not acceptable for drinking. *C. perfringens* was determined in none of the packaged water samples.

The distribution of the suitability of the microbiological parameters according to the packaged water use is given in Table 4, and the distribution according to the average microorganism count is given in Table 5. No statistically significant difference was determined for the microbiological parameters of *E. coli*, coliform bacteria, *C. perfringens*, total colony count at 22 °C, total colony count at 37 °C in respect to the packaged water use, and a statistically significant difference was determined in *Pseudomonas* ($p = 0.006$). *P. aeruginosa* was not determined in the 29 samples collected from the water fountains, and five of the 21 samples (23.8%) collected from the pump-faucets were determined to be not suitable for drinking purposes.

Table 4 | The microbiological parameters for packages prior to the use of pump-faucet or water fountain

Parameters		Before	After	*p*
Escherichia coli	Acceptable (0)	48	38	0.02
	Unacceptable	2	12	
Coliform bacteria	Acceptable (0)	48	42	0.031
	Unacceptable	2	8	
Pseudomonas aeruginosa	Acceptable (0)	50	45	
	Unacceptable	0	5	
Clostridium perfringens	Acceptable (0)	50	50	All acceptable
22 °C CFU	Acceptable (0–1,000)	50	48	
	Unacceptable	0	2	
37 °C CFU	Acceptable (0–200)	47	37	0.006
	Unacceptable	3	13	

Table 5 | Microbiological distribution according to microorganism count before and after pump-faucet or water fountain

Parameters	Before mean ± SD (min–max)	After mean ± SD (min–max)	*p*
Escherichia coli	0.64 ± 4.24 (0–30)	11.0 ± 28.5 (0–150)	0.014
Coliform bacteria	0.64 ± 4.24 (0–30)	9.0 ± 28.0 (0–150)	0.041
Pseudomonas aeruginosa	0	1.74 ± 7.66 (0–50)	0.115
22 °C CFU	30.7 ± 96.74 (0–600)	150.8 ± 348.2 (0–1,500)	0.019
37 °C CFU	40.3 ± 154.5 (0–1,000)	238 ± 421.4 (0–2,000)	0.002

Microbiological parameters before and after purification are given in Tables 6 and 7 for the samples collected from the residential treatment device water, whereas the microbiological parameters and the physico-chemical properties are summarized in Tables 8 and 9.

Even though there was a difference in the average microorganism count in the samples collected from the residential treatment device users before and after purification, no statistically significant difference was determined in regard to their suitability for use. A statistically significant difference was determined between the average levels of conductivity, pH, fluoride, chloride, nitrate, calcium, and magnesium in the samples collected before and after the purification from the residential

Table 6 | Distribution of the suitability of microbiological parameters according to packaged water use

Parameters		Pump-faucet	Water fountain	*p*
Escherichia coli	Acceptable (0)	16	22	0.979
	Unacceptable	5	7	
Coliform bacteria	Acceptable (0)	16	26	0.200
	Unacceptable	5	3	
Pseudomonas	Acceptable (0)	16	29	0.006
	Unacceptable	5	0	
Clostridium perfringers	Acceptable (0)	21	29	All acceptable
22 °C CFU	Acceptable (0–1,000)	20	28	0.815
	Unacceptable	1	1	
37 °C CFU	Acceptable (0–200)	16	21	0.764
	Unacceptable	5	8	

Table 7 | Distribution of average microorganism count according to packaged water use

Parameters	Pump-faucet mean ± SD (min–max)	Water fountain mean ± SD (min–max)	*p*
Escherichia coli	11.10 ± 26.46 (0–104)	10.93 ± 30.37 (0–150)	0.969
Coliform bacteria	11.10 ± 26.46 (0–104)	7.48 ± 29.60 (0–150)	0.218
Pseudomonas	4.14 ± 11.55 (0–50)	0	0.006
Clostridium perfringens	0	0	1.000
22 °C CFU	150.05 ± 333.44 (0–1,500)	151.34 ± 364.44 (0–1,500)	0.187
37 °C CFU	272.14 ± 485.31 (0–2,000)	213.69 ± 375.65 (0–1,400)	0.459

Table 8 | Microbiological parameters for samples before and after purification collected from residential treatment device water

Parameters	Before mean ± SD (min–max)	After mean ± SD (min–max)	*p*
Escherichia coli	18.7 ± 89.5 (0–500)	0.48 ± 1.89 (0–9)	0.156
Coliform bacteria	26.5 ± 128.9 (0–700)	0.46 ± 1.89 (0–9)	0.160
Pseudomonas	1.2 ± 5.2 (0–30)	1.7 ± 7.5 (0–50)	0.664
Clostridium perfringens	1.54 ± 9.92 (0–70)	0	0.539
22 °C CFU	28.0 ± 86.6 (0–400)	42.4 ± 158.9 (0–1,000)	0.363
37 °C CFU	26.2 ± 104.5 (0–500)	52.7 ± 167.4 (0–1,000)	0.278

Table 9 | Physico-chemical properties for samples before and after purification collected from residential treatment device water

Parameters	Before mean ± SD (min–max)	After mean ± SD (min–max)	p
Conductivity	576.12 ± 73.81 (436.0–880.0)	108.13 ± 144.34 (3.0–583.0)	0.000
pH	7.47 ± 0.13 (7.14–7.88)	6.54 ± 0.52 (5.57–8.26)	0.000
Aluminum (Al)	0.29 ± 2.06 (0–14.60)	0	0.320
Fluoride (F)	0.19 ± 0.2 (0–0.87)	0.04 ± 0.05 (0–0.16)	0.000
Chloride (Cl)	11.55 ± 4.95 (4.95–55.67)	2.03 ± 2.58 (0–12.45)	0.000
Nitrate (NO_3)	15.84 ± 5.44 (5.56–32.20)	5.31 ± 6.17 (0–38.93)	0.000
Nitrite (NO_2)	Not detected	Not detected	
Ammonium (NH_4)	<0.04	<0.04	
Calcium (Ca)	86.11 ± 17.04 (49.94–133.90)	13.84 ± 20.62 (0.05–94.20)	0.000
Magnesium (Mg)	16.98 ± 7.77 (6.58–29.60)	3.22 ± 5.99 (0.03–27.42)	0.000

treatment device users ($p = 0.000$). However, the values for both cases were determined to be in accordance with the regulations. No statistically significant difference was determined in regard to color, odor, turbidity, aluminum, nitrite, and ammonium.

DISCUSSION

In this study, samples collected from residential treatment devices and tap water were compared in regard to the physico-chemical and microbiological parameters.

Turbid water should always be considered as suspicious. Turbid water does not look good in appearance, in addition to having adverse effects on health. It was determined in our study that 22% of the packaged water samples, 2% of the tap water samples, and 6% of the residential treatment device samples were not suitable in regard to turbidity values. Turbidity was not determined in any of the samples collected from the tap water in the city of Kilis (Yelekçi *et al.* 2012). It was reported in a study carried out in Iran that turbidity was determined in 3.1% of the samples (Nikaeen *et al.* 2016). The differences in turbidity may be related to the location that the sample was taken from. The turbidity observed, especially in packaged water samples, may be related to the repeated use of the bottles and their storage conditions.

The pH values in our study varied between 5.57 and 8.26. The pH values for all the tap and packaged water were determined to be in accordance with the national standards and World Health Organization guidelines, and improper and low pH values were determined in 25 of the samples collected from the residential treatment devices. The pH values were determined to vary between different intervals, but they were all in accordance with the standards in studies carried out with different sources at different locations in Turkey (Tepe & Mutlu 2004; Süphandağ *et al.* 2007; WHO 2011). Similarly, studies have shown that residential treatment devices cause decreased pH (Singh *et al.* 2015; Perez-Vidal *et al.* 2016).

The fluoride levels in all of our samples in the study were determined to be suited for drinking according to the regulations. In addition, the fluoride amount of the tap water was determined to be greater at a statistically significant level in comparison with the samples from the packaged water and residential treatment devices. The fluoride levels were determined to be lower than the standard values in all the samples collected from the tap water in Kilis (Yelekçi *et al.* 2012). Similar to our study, it was determined in studies carried out with residential treatment devices that fluoride levels decreased after purification (Jaafari-Ashkavandi & Kheirmand 2013). In addition, there are studies where fluoride levels were high and that these high levels cause dental problems (Singh *et al.* 2015; Nikaeen *et al.* 2016; Taghipour *et al.* 2016; Yeşilnaçar *et al.* 2016; Atasoy & Yesilnacar 2017). Fluoride is found in the bones and teeth. It is known that low amounts of fluoride prevent tooth decay and that increased fluoride causes fluorosis

(Adler 1970; Yeşilnaçar *et al.* 2016; Atasoy & Yesilnacar 2017). The fluoride concentration in drinking water has a wide range depending on factors such as the geological, physical, and chemical properties of the area, and the pH, temperature, and soil content. The incidence of fluorosis is higher in people living in rural areas, especially those areas providing drinking water from underground water. In the world, approximately 30 countries including Turkey, and more than 200 million people, are being damaged and harmed due to emerging excess fluoride in drinking water. High fluoride waters have been identified in China, India, Sri Lanka, northern Mexico, western United States, Argentina, and many parts of Africa (Atasoy & Yesilnacar 2017). Even though the fluoride amount was determined to be acceptable after purification, the fact that it has decreased is an undesirable situation. The fact that the fluoride amount has decreased in tap water may have adverse effects on dental health in the region.

All natural water contains chloride. In addition, chloride is added to tap water for disinfection purposes because it is cheap and practical. It was determined in our study that chloride amounts were greater in tap water at a statistically significant level in comparison with the packaged water and residential treatment device samples. However, the chloride values were determined to be suited for drinking purposes in all the samples. There are national and international studies in which chloride levels have been determined to be greater than the standard levels (Yelekçi *et al.* 2012; Singh *et al.* 2015; Nikaeen *et al.* 2016). The reason for these high values should be examined.

The nitrate values of the tap water samples collected in our study were determined to be greater in comparison with those of the packaged water and residential treatment device samples ($p < 0.05$). However, the nitrite and nitrate values of all the samples were determined to be in accordance with the regulations. Nitrite was determined in none of the samples. In addition to the studies indicating that spring and well water used for drinking and as utility water contain nitrate at levels that might be dangerous for human health, there are studies in which these values have been determined to be in accordance with the standard values (Cammack *et al.* 1999; Ağaoğlu *et al.* 2007). It has been determined in various studies that 11–12.3% of the samples have high nitrate levels (Ander *et al.* 2016; Nikaeen *et al.* 2016). In a study assessing the groundwater quality of the Harran Plain, Turkey, nitrate concentrations, the most common pollutants in groundwater, were found to be above the maximum allowable concentration of 50 mg/L. Nitrate pollution is thought to be caused by intensive farming practices and excessive use of artificial fertilizers (Yesilnacar *et al.* 2008).

Since nitrate level is an indication of pollution in the spring, the reasons for these high levels should be examined at these locations and officials should be advised to take the necessary precautions.

E. coli was determined in 10% of the tap water in our study whereas coliform bacteria were determined in 8%. *E. coli* was determined in 5–8% of the tap water in studies carried out in different cities (Köksal *et al.* 2007a; Alemdar *et al.* 2009; Yelekçi *et al.* 2012). It was determined in a study carried out in India that 28% of tap water contains microbiological contamination. This ratio was determined as 4% for filtered water (Singh *et al.* 2015). This finding supports the fact that using a filter suited to the type of water might be effective. *E. coli* was determined in 2% of the packaged water in our study, whereas coliform bacteria were determined in 2%. Coliform was determined in 54% of the packaged water samples in Istanbul during 2005–2006, whereas excrement-related *E. coli* was determined in 3%. In addition, 23% *Aeromonas* and 38% *Pseudomonas* sp. were determined (Köksal *et al.* 2007b). In another study, physical contamination was determined in 19.8% of the packages at a packaged water filling facility with coliform group bacteria in 23.5%, *E. coli* in 2.1%, and *S. aureus* in 9.5% (Çetin *at al.* 2013). In conclusion, it has been determined that the physical contaminations where the packages which will be reused after being filled with drinking water increase the microorganism levels of packaged water at a certain level; that the hygienic quality of the drinking water sold for consumption is closely related to package cleanliness and that one of the most important contamination sources is polycarbonate packages. It was determined in a study carried out in Nepal that 55.3% of tap water contains coliform bacteria, whereas this ratio was determined as 25% for bottled waters and bottled waters were indicated to be safer (Pant *et al.* 2016). The quality might have increased in Turkey, especially in recent years due to the increased number of inspections carried out at packaged water sales locations.

It was determined in our study that of the microbiological parameters examined for packaged water, *E. coli*, coliform bacteria, microbiological contamination of samples collected from pump-faucet and water fountain were determined to be greater in comparison with those of the samples collected directly from the package. In addition, *P. aeruginosa* was detected in 23.8% of the samples collected after installing the pump-faucet. Thus, the water that was clean in packages might be contaminated after the pump-faucet or the water fountain stage. This points out the importance of the cleanliness of the pump or the water fountain.

Even though no statistically significant difference was determined in our study with regard to microorganism content after the residential treatment device, an increase was observed in the average number of *Pseudomonas*. Although it was observed that the average *E. coli* and coliform bacteria counts decreased, the change was not determined to be statistically significant. The residential treatment device requires cleaning and maintenance no matter what the system is. If proper cleaning is not carried out, microorganisms in that water that cause diseases may increase and form colonies in parts of the filter, purification chamber, pump, etc. (Tekbas & Ogur 2009).

According to the study results, each water spring has advantages and disadvantages. When we take into account the studies carried out to have access to clean and reliable water, which is a fundamental necessity, it is apparent that more comprehensive studies should be carried out. In addition, studies should be carried out to eliminate the distrust towards tap water.

CONCLUSIONS

As a conclusion, statistically significant differences were determined between the samples collected after purification in the physicochemical parameters of conductivity, pH, fluoride, chlorine, nitrate, calcium, and magnesium. It was determined in our study that the residential treatment process is carried out more on water which is already suitable for drinking. However, residential treatment can be necessary only in certain situations. It is the task of local administrations to provide clean, healthy, and reliable water to the public. In addition, this should be explained clearly to the public to ensure trust.

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