Evaluation of Drinking Water Quality From Water Coolers in Makkah, Saudi Arabia

Author: Ahmed, Omar B

Source: Environmental Health Insights, 17(1)

Published By: SAGE Publishing

URL: https://doi.org/10.1177/11786302231163676

Evaluation of Drinking Water Quality From Water Coolers in Makkah, Saudi Arabia

Environmental Health Insights
Volume 17: 1–5

DOI: 10.1177/11786302231163676
SAGE

Omar B Ahmed

Department of Environmental and Health Research, The Custodian of the Two Holy Mosques Institute for Hajj and Umrah Research, Umm Al-Qura University, Makkah, Saudi Arabia.

ABSTRACT: The quality of drinking water is an important health issue in crowded cities, so that an adequate drinking water with good quality must be provided, hence over hundreds of water coolers are distributed in Makkah city to cope with the increasing demand for drinking water. The present study aimed to determine the chemical and microbial quality of drinking water from coolers in Makkah city. Sixty-three samples from randomly selected water coolers were tested for chemical and bacteriological quality. For all samples, the mean value of physiochemical tests of pH (7.12), TDS (152.7 ppm), turbidity (2.56 NTU), free chlorine (0.312 ppm), fluoride (0.112 ppm), chloride (25.7 ppm), bromide (0.123 ppm), nitrate (0.616 ppm), sulfate (8.36 ppm), lithium (0.134 ppm), sodium (17.6 ppm), potassium (1.42 ppm), magnesium (1.95 ppm), calcium (19.2 ppm), chromium (0.025 ppm), cadmium (0.0026 ppm), and lead (0.0244 ppm) did not exceed the reference values of the drinking water regulations. The total coliform count was detected in 3.2% of the water samples. For total coliform count, the MPN in the majority of water samples (96.8%) was excellent while for *E. coli* count, the MPN in all water samples (100%) was excellent. Bacteriological quality has shown that no *Pseudomonas, Salmonellae*, or *Legionellae* species contamination detected. It was concluded that, the drinking waters in coolers in Makkah city were complied with international standards and within the acceptable limit. It is worth to continue periodic inspection and maintenance for the drinking water coolers during mass gatherings.

KEYWORDS: Drinking water, quality assessment, dispensers, physiochemical, bacteriological, Hajj

RECEIVED: January 19, 2023. **ACCEPTED:** February 27, 2023.

TYPE: Original Research Article

FUNDING: The author received no financial support for the research, authorship, and/or publication of this article.

DECLARATION OF CONFLICTING INTERESTS: The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

CORRESPONDING AUTHOR: Omar B Ahmed, Department of Environmental and Health Research, The Custodian of the Two Holy Mosques Institute for Hajj and Umrah Research, Umm Al-Qura University, Makkah 21955, Saudi Arabia. Email: abuaglah1@hotmail.com

Introduction

Water is an essential natural resource for the continuation of life on earth, but it can also become a source of undesired elements that are harmful to human health when it is contaminated.[1] Drinking water should not represent any significant risk to health over a lifetime of consumption as stated by world health organization (WHO).[2] In Makkah city, Kingdom of Saudi Arabia (KSA), the seasonal increase in the population size during Hajj seasons may raise challenges in providing sufficient and clean food, water, and sanitary facilities. The quality of drinking water during the mass gatherings (pilgrimage events) is an important health issue, as during this event, an adequate drinking water with good quality must be provided.[3]

During visit and Hajj (pilgrimage) events Makkah city is under pressure of a large number of mass gatherings, so it is difficult to maintain the drinking water quality in this period. Recently, hundreds of water coolers in Makkah and other holy sites were introduced to meet the growing demand for potable water, especially during Hajj (pilgrimage). A water cooler is a device that delivers water and frequently also uses a refrigeration unit to chill or heat the water with a drain connection into the sewage system is constructed for the water cooler.[4] One of the major concerns about water cooler challenges is the blocked spouts, bad water quality. Drinking water quality in coolers may be deteriorated by microbial and chemical contamination during transport, storage and handling before consumption. It has been reported that water dispensers can lead to infections of waterborne diseases, especially among immunocompromised people.[5] Bacterial growth and the coloring of water surfaces are caused by dissolved organic chemicals in drinking water, hence the drinking water in water coolers was may be more polluted than water newly supplied to the coolers.[5] Water quality is a term used to express the suitability of water to sustain various uses or processes and involves the routine testing of water quality to ensure compliance with national standards.[6] It refers to the chemical, physical, biological, emerging contaminants, and characteristics of water.[7,8] In addition, the carcinogenic and non-carcinogenic of some plasticizers (Phthalates) have been reported as health risks in drinking water.[9]

The physiochemical quality of water for example, turbidity, color, taste, and odor may affect its acceptability to consumers.[10,11] The pH of drinking water is often considered to be one of the most important parameters, although it usually has no direct impact on the consumer.[12] Failure to control pH of the water can result in the contamination of drinking-water and in adverse effects on its taste, odor, and appearance. Turbidity (cloudiness) of water is higher when water hardness is higher, and is reported in nephelometric turbidity units (NTU), and can also be reported in other units such as Jackson turbidity units (JTU). Turbidity is formed from a number of substances such as sand, dead plant, Mud, algae, organisms, silt, and precipitates.[13] Conductivity is a measure of the conductance of an electric current in water. This is an easy measurement to make and relates closely to the total dissolved solids

(TDS) content of water. TDS is the term used to describe the inorganic salts and small amounts of organic matter present in solution in water. The main constituents of TDS are usually calcium, magnesium, sodium, and potassium cations and carbonate, hydrogencarbonate, chloride, sulfate, and nitrate anions.[14] Nitrate ($NO3-$), is usually formed from organic matter decomposition and from atmospheric nitrogen fixation.[15] The concentrations of other inorganic and organic substances in drinking water may affect its safety and acceptability for use.[16] Some of these elements are: Fluoride (F), Chloride (Cl), Bromide (Br), sulfate ($SO42-$), lithium (Li), sodium (Na), potassium (K), magnesium (Mg), calcium (Ca), chromium (Cr), cadmium (Cd), arsenic (As), and lead (Pb).[12,15,17-19] Finding the number of coliforms and fecal coliform in the water is one of the most crucial factors in determining the quality of coolers' water. *Escherichia coli (E. coli)* bacteria are considered to be the species of coliform bacteria that is the best indicator of fecal pollution and the possible presence of pathogens.[6,20] One of the most way of transmission of infectious diseases is contamination of drinking water which can lead to serious illnesses and high mortality rate.[21-23] Hussain et al[24] found that the *Pseudomonas, E. coli*, *Enterobacter*, *Bacillus, Salmonella, Enterococcus*, and *Staphylococcus* species were the common bacterial types occurring in drinking water. The present study aimed to determine the chemical and microbial quality of drinking water from water coolers in Makkah city, Saudi Arabia.

Material and Methods

Sixty-three bottles representing randomly selected water coolers were collected over a 3-month period in 2019 (May to August) from randomly selected coolers in hotels and pilgrims' buildings from different districts in Makkah city, Saudi Arabia, were tested for chemical and bacteriological quality. Sample size selection was based on the desire to obtain the highest number of samples during period of crowd (pilgrimage) which extended to 3 months, depending on the availability of water coolers and the cooperation of the owners of refrigerators. The water samples were collected from 63 water coolers hotels located in Makkah town. The districts were selected on the basis of the water cooler distribution in the districts, the characteristics of the buildings, and hotel cooperation. Two water samples were taken from each cooler, depending on the number of coolers. Most of the selected coolers were from Tysser and Zahir districts (15.9%) followed by Nassem (12.7%), Misfallah (11.1%), Jarwal (9.5%), Shuhada (6.3%), Shougia (6.3%), Aziziah (6.3%), Shisha (4.8%), Kaakiah (3.2%), Otaibia (3.2%), Kudai (3.2%), and Nuzha (1.6%) districts. Samples were collected in 1-liter sterile polypropylene bottles directly from 63 water coolers located in different zones in Makkah; each sample is consisting of 2 sampling bottles (500 ml), one bottle for microbiological testing (with Sodium Thiosulfate), the second bottle for chemical testing (without Sodium Thiosulfate). Collected samples were transferred in an ice box to the Microbiology Laboratory in Department of Environmental and Health Research at Umm Al Qura University. Samples were stored at 4°C till further investigation of water-quality parameters to be carried out.

Chemical Analysis

The pH, conductivity, and TDS were measured by advanced electrochemical meter Orion Star Benchtop Meter, by Thermo Scientific (USA). Residual free chlorine in water was determined by photometric test using a commercial test kit (VISOCOLOR Powder Pillows Free Chlorine, MACHEREY-NAGEL, Düren, Germany). Turbidity was measured using by using NANOCOLOR Compact photometer PF-12Plus (MACHEREY-NAGEL, Düren, Germany). Chemical examination such F−, Cl−, Br−, $NO3-$, $PO43-$, $SO42-$, Li, Na, K, Mg, Ca were carried out by ionic chromatography (IC) analyzer (850 professional, metRohm, Swaziland). Metals like Cr, Cd, and Pb were carried out by atomic absorption spectrophotometer (AAS) (ice 3000 series, Thermo Scientific, USA).

Bacteriological Tests

To evaluate bacteriological quality of drinking water, 2 bacteriological examinations were done; presumptive coliform count and differential coliform count.

Presumptive coliform count: *E. coli* and Coliforms count were determined in the samples, by using most probable number (MPN) per 100 ml using Colilert test kit Procedure (IDEXX Laboratories, Inc., USA). Briefly, 1 packet of powder was added to the 100 ml water sample in a vessel which was shaken after being capped till to dissolve the powder. The mixture was poured directly into a Quanti-Tray which was sealed and incubated. The number of yellow and blue-fluorescent wells were counted and then MPN/100 ml was determined using the table provided with the Quanti-Tray (according to manufacturer instructions). The standards used to for interpretation of MPN were as follows: 0 (excellent), 1 to 3 (satisfactory), 4 to 10 (suspicious), and ⩾10 (unsatisfactory).[25]

Differential coliform count: When samples show elevated levels of indicator bacteria, further analysis was performed to look for specific pathogenic bacteria such as *Pseudomonas aeruginosa*, *legionella*, and *salmonellae* spp using standard microbiological methods.

Results

The quality of water samples from water coolers was evaluated by using both physiochemical and microbiological procedures. The results of these parameters were shown in Tables 1 and 2. The results showed that the pH was ranged between (6.10 and 8.30) with a mean of 7.1079, the TDS were ranged between (58.0 and 276.0) with a mean of 152.7 ppm, turbidity (1.2-3.10) with a mean of 2.5556 NTU, free Cl2 (0.03-2.14) with mean 0.312 ppm, F− range (0.04-0.19) with mean 0.112 ppm,

Table 1. Chemical parameters results.

TEST	MIN.	MAX.	MEAN	WHO LIMIT[26]
pH	6.10	8.30	7.1079	6.50-8.50
Conductivity	91.00	432.00	238.9206	400
TDS (ppm)	58.00	276.00	152.6984	500
Turbidity, (NTU)	1.20	3.10	2.5556	5.00
Free CL2 (ppm)	0.03	2.14	0.3117	5.00
F (ppm)	0.04	0.19	0.1116	1.50
Cl– (ppm)	10.6	66.6	25.6873	200
Br– (ppm)	0.02	0.37	0.1268	0.50
NO3– (ppm)	0.10	8.10	0.6159	10
SO42– (ppm)	0.70	27.40	8.3556	250
Li (ppm)	0.09	0.19	0.1357	0.70
Na (ppm)	9.30	37.10	17.6032	60
K (ppm)	0.00	6.60	1.4159	20
Mg (ppm)	0.40	5.10	1.9460	50
Ca (ppm)	6.40	43.70	19.2159	75
Cr (ppm)	0.00	0.06	0.0247	0.05
Cd (ppm)	0.00	0.01	0.0026	0.03
Pb (ppm)	0.01	0.04	0.0244	0.05

Table 2. Microbiological parameters results.

MICROBIOLOGICAL INDICATORS (COLIFORM)					PATHOGENS					
RESULTS	*COLIFORM*		*E.COLI*		*SALMONELLAE SPP*		*PSEUDOMONAS SPP*		*LEGIONELLAE SPP*	
	NO	%	NO	%	NO	%	NO	%	NO	%
Negative	61	96.8	63	100	63	100	63	100	63	100
Positive	2	3.2	0	0.0	0	0.0	0	0.0	0	0.0
Total	63	100.0	63	100.0	63	100.0	63	100.0	63	100.0

Cl– (10.6-66.6) with a mean 25.7 ppm, Br– (0.02-0.37) with a mean of 0.123 ppm, NO3– (0.10-8.10) with a mean of 0.616 ppm, SO42– (0.70-27.40) with a mean of 8.36 ppm, li (0.09-0.19) with a mean of 0.134 ppm, Na (9.30-37.10) with a mean of 17.6 ppm, K (0.00-6.60) with a mean of 1.42 ppm, Mg (0.40-5.10) with a mean of 1.95 ppm, Ca (6.4-43.7) with a mean of 19.2 ppm, Cr (0.00-0.06) with a mean of 0.025 ppm, Cd (0.00-0.01) with a mean of 0.0026 ppm, and Pb (0.01-0.04) with a mean of 0.0244 of ppm. The total coliform count was detected in 2 (3.2%) of water samples, the MPN in the majority of water samples (96.8%) was excellent, however, one sample (1.6%) was suspicious and other sample (1.6%) was unsatisfactory as shown in Table 3. The *E. coli* count was not detected any water sample, the MPN in all water samples (100%) was excellent (Table 3). *Pseudomonas, Salmonellae*, or *Legionellae* species were not detected in any of the water samples.

Table 3. The interpretation of MPN/100 ml for total coliform and *E. coli*.

MPN	*COLIFORM*	*E.COLI*
Excellent (0)	61 (96.8%)	63 (100%)
Satisfactory (1-3)	0 (0.0%)	0 (0.0%)
suspicious (4-10)	1 (1.6%)	0 (0.0%)
Unsatisfactory(⩾10)	1 (1.6%)	0 (0.0%)
Total	63 (100%)	63 (100%)

Discussion

The drinking water from coolers is increasingly popular in Makkah and other Saudi cities. In addition to its basic necessity for all known forms of life, water can play a central and important role in human health and nutrition.[27] The present study evaluated the quality of drinking water from water coolers and found that the mean value of physiochemical results did not exceed the reference values of the drinking water regulations. The results of the present study showed that the mean value of physiochemical tests of pH (7.12), TDS (152.7 ppm) turbidity (2.56 NTU), free Cl2 (0.312 ppm), F– (0.112 ppm), Cl– (25.7 ppm), Br– (0.123 ppm), NO3– (0.616 ppm), SO42– (8.36 ppm), li (0.134 ppm), Na (17.6 ppm), K (1.42 ppm), Mg (1.95 ppm), Ca (19.2 ppm), Cr (0.025 ppm), Cd (0.0026 ppm), and Pb (0.0244 ppm) did not exceed the reference values of the national drinking water regulations.[28] It has been recommended that the pH level of drinking water should be within the range 6.5 to 8.56.[27,29] The pH in all samples was within limits recommended by WHO guidelines.[10] Drinking water should be colorless, tasteless, and odorless and should have turbidity less than 5 NTU. Therefore, the changes in color and the presence of any taste and odor indicates water pollution.[11] The According to Khater et al,[30] the TDS value should be within the range of 100 to 600 ppm. A maximal TDS concentration of 500 ppm is recommended by the USEPA.[29] High concentration of chloride ion gives salty taste and also corrodes pipelines of water. Normally 150 ppm of chloride ion is harmless. Maximum permissible limit of chloride ion in drinking water is 200 ppm. In the vast majority of cases residual chlorine is less than adequate. According to legislation on water systems in Saudi Arabia, the residual active chlorine concentration of water supplied from the faucet is required to be above 0.1 mg/l. A leading advantage of chlorination is that it has proven effective against bacteria and viruses. It has long been recognized that trace elements content of drinking water can have either adverse or beneficial effects on human health depending on concentrations.[31] For total coliform count, the MPN in the majority of water samples (96.8%) was excellent, however, one sample (1.6%) was suspicious and other sample (1.6%) was unsatisfactory. For *E. coli* count, the MPN in all water samples (100%) was excellent. Coliform bacteria can be found in the environment and feces of all warm-blooded animals and humans and do not cause illness, but when found in drinking water, it is an indication that disease-causing organisms (pathogens) could be in the water system. Our results have shown that no *Pseudomonas, Salmonellae*, or *Legionellae* species contamination detected in present study. Similarly, previous studies reported the absence of *E. coli* in any of the studied sample.[32-34] In contrast, previous studies reported high count of total coliform bacteria and *E. coli* were enumerated.[5,35] A positive total coliform test would indicate unsanitary conditions and the possible presence of disease-causing organisms. In another similar study, Baumgartner and Grand[36] detected no *E. coli* from coolers samples, however they identified *P. aeruginosa* in 21.6% of water from coolers suggesting potential growth of *P. aeruginosa* in the water coolers. In a study, carried out to isolate Legionella species from water systems in healthcare facilities, Rivera et al[37] identified Legionella species with higher isolation rates in potable water systems.

Limitation

The size of the samples during short period (pilgrimage or visit time) time was one of the limitations in this study. Also some problems were encountered in analyzing some of chemical and biological parameters such as hardness, dissolved oxygen, and biological oxygen demand, viruses, and protozoa, which could be not done.

Conclusions

The drinking waters in coolers and dispensers distributed in Makkah city were complied with international standards and within the acceptable limit. The mean value of physiochemical tests of pH, TDS, turbidity, free Cl2, F–, Cl–, Br–, NO3–, SO42–, li, Na, K, Mg, Ca, Cr, Cd, and Pb did not exceed the reference values of the drinking water regulations. Bacteriological quality has shown that no *Pseudomonas, Salmonellae*, or *Legionellae* species contamination detected. For total coliform count, the MPN in the majority of water samples (96.8%) was excellent while for *E. coli* count, the MPN in all water samples (100%) was excellent. Therefore, it must take into consideration microbial examination of water quality, in addition, it is worth to continue periodic inspection, maintenance for water coolers in Makkah, especially during mass gatherings. The study recommends future research that addressing water quality index (WQI) for supplied water in hotels and residential buildings at Makkah city.

REFERENCES

1. Karbasdehi VN, Dobaradaran S, Soleimani F, et al. The role of decentralized municipal desalination plants in removal of physical, chemical and microbial parameters from drinking water: a case study in Bushehr, Iran. *J Water Sanit Hyg Dev*. 2018;8:325-339.
2. World Health Organization. *Guidelines for Drinking-Water Quality: First Addendum to the Fourth Edition*. World Health Organization; 2017.
3. Othman A, Ahmed OB, Abotalib AZ, Sayqal A, Assaggaf H, Zeb J. Assessment of supplied water quality during mass gatherings in arid environments. *J King Saud Univ Sci*. 2022;34:101918.
4. Ananthakrishnan K, Bijarniya JP, Sarkar J. Energy, exergy, economic and ecological analyses of a diurnal radiative water cooler. *Renew Sustain Energ Rev*. 2021;152:111676.
5. Boonhok R, Borisut S, Chuklin N, Katzenmeier G, Srisuphanunt M. Drinking water quality assessment from water dispensers in an educational institution. *Water Supply*. 2021;21:4457-4464.
6. Poonam T, Tanushree B, Sukalyan C. Water quality indices-important tools for water quality assessment: a review. *Int J Adv Chem*. 2013;1:15-28.
7. Mohammadi A, Dobaradaran S, Schmidt TC, Malakootian M, Spitz J. Emerging contaminants migration from pipes used in drinking water distribution systems: a review of the scientific literature. *Environ Sci Pollut Res Int*. 2022;29: 75134-75160.
8. Akhbarizadeh R, Dobaradaran S, Schmidt TC, Nabipour I, Spitz J. Worldwide bottled water occurrence of emerging contaminants: a review of the recent scientific literature. *J Hazard Mater.* 2020;392:122271.
9. Abtahi M, Dobaradaran S, Torabbeigi M, et al. 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*. 2019;173:469-479.
10. World Health Organization. *Guidelines for Drinking-Water Quality: Second Addendum*. Vol. 1. Recommendations. World Health Organization; 2008.
11. Oyem HH, Oyem IM, Ezeweali D. Temperature, pH, electrical conductivity, total dissolved solids and chemical oxygen demand of groundwater in Boji-Boji-Agbor/Owa area and immediate suburbs. *Res J Environ Sci*. 2014;8:444-450.
12. Mohsin M, Safdar S, Asghar F, Jamal F. Assessment of drinking water quality and its impact on residents health in Bahawalpur city. *Int J Humanit Soc Sci*. 2013;3:114-128.
13. Myre E, Shaw R. The turbidity tube: simple and accurate measurement of turbidity in the field. *Mich Technol Univ*. 2006;15:1-17.
14. Salman SA, Shahid S, Mohsenipour M, Asgari H. Impact of landuse on groundwater quality of Bangladesh. *Sustain Water Resour Manag*. 2018;4:1031-1036.
15. Kruawal K, Sacher F, Werner A, Müller J, Knepper TP. Chemical water quality in Thailand and its impacts on the drinking water production in Thailand. *Sci Total Environ*. 2005;340:57-70.
16. Pourfadakari S, Dobaradaran S, De-la-Torre GE, Mohammadi A, Saeedi R, Spitz J. Evaluation of occurrence of organic, inorganic, and microbial contaminants in bottled drinking water and comparison with international guidelines: a worldwide review. *Environ Sci Pollut Res Int*. 2022;29:55400-55414.
17. Reyes-Toscano CA, Alfaro-Cuevas-Villanueva R, Cortés-Martínez R, et al. Hydrogeochemical characteristics and assessment of drinking water quality in the urban area of Zamora, Mexico. *Water*. 2020;12:556.
18. World Health Organization. *Hardness in Drinking-Water: Background Document for Development of WHO Guidelines for Drinking-Water Quality*. World Health Organization; 2010.
19. Abtahi M, Dobaradaran S, Koolivand A, Jorfi S, Saeedi R. Assessment of cause-specific mortality and disability-adjusted life years (DALYs) induced by exposure to inorganic arsenic through drinking water and foodstuffs in Iran. *Sci Total Environ*. 2023;856:159118.
20. Pandey PK, Kass PH, Soupir ML, Biswas S, Singh VP. Contamination of water resources by pathogenic bacteria. *AMB Express*. 2014;4:51.
21. Blasi M, Carere M, Funari E. National surveillance capacity of water-related diseases in the WHO European region. *J Water Health*. 2011;9:752-762.
22. Jones AQ, Majowicz SE, Edge VL, et al. Drinking water consumption patterns in British Columbia: an investigation of associations with demographic factors and acute gastrointestinal illness. *Sci Total Environ*. 2007;388:54-65.
23. Liguori G, Cavallotti I, Arnese A, Amiranda C, Anastasi D, Angelillo IF. Microbiological quality of drinking water from dispensers in Italy. *BMC Microbiol*. 2010;10:19.
24. Hussain T, Roohi A, Munir S, et al. Biochemical characterization and identification of bacterial strains isolated from drinking water sources of Kohat, Pakistan. *Afr J Microbiol Res*. 2013;7:1579-1590.
25. Mosi L, Adadey SM, Sowah SA, Yeboah C. Microbiological assessment of sachet water "pure water" from five regions in Ghana. *AAS Open Res*. 2018;1:12.
26. WHO. *Guidelines for Drinking-Water Quality*. World Health Organization; 2011.
27. WHO. *Desalination for Safe Water Supply: Guidance for the Health and Environmental Aspects Applicable to Desalination*. World Health Organization; 2007.
28. Saudi Arabian Standards Organization (SASO). *Un-Bottled Drinking Water. SASO 701 and mkg 149*. Saudi Arabian Standards Organization (SASO); 2000. (in Arabic)
29. US EP. Drinking Water Standards and Health Advisories, EPA 822-R-04-005. 2004.
30. Khater AEM, Al-Jaloud A, El-Taher A. Quality level of bottled drinking water consumed in Saudi Arabia. *J Environ Sci Technol*. 2014;7:90-106.
31. Cannas D, Loi E, Serra M, Firinu D, Valera P, Zavattari P. Relevance of essential trace elements in nutrition and drinking water for human health and autoimmune disease risk. *Nutrients*. 2020;12:2074.
32. Pratum C, Khananthai N. Assessment of factors affecting drinking water quality from free water dispenser in the higher education institution. *IJESE*. 2017;12:787-797.
33. Yongyod R. Drinking water quality and evaluation of environmental conditions of water vending machines. *Asia J Sci Technol*. 2018;23:1-6.
34. Wibuloutai J, Thanomsangad P, Benjawanit K, Mahaweerawat U. Microbial risk assessment of drinking water filtration dispenser toll machines (DFTMs) in Mahasarakham province of Thailand. *Water Supply*. 2019;19:1438-1445.
35. Schillinger J, Du Vall Knorr S. Drinking-water quality and issues associated with water vending machines in the city of Los Angeles. *J Environ Health*. 2004;66:25-31, 43; quiz 45.
36. Baumgartner A, Grand M. Bacteriological quality of drinking water from dispensers (coolers) and possible control measures. *J Food Prot*. 2006;69:3043-3046.
37. Rivera JM, Aguilar L, Granizo JJ, et al. Isolation of Legionella species/serogroups from water cooling systems compared with potable water systems in Spanish healthcare facilities. *J Hosp Infect*. 2007;67:360-366.