Desalination and Water Treatment
www.deswater.com

doi: 10.5004/dwt.2019.23365

142 (2019) 82–89
February

Spatial and temporal variation of physicochemical and microbial quality of drinking water for the distribution network in Maku, Iran

Farzaneh Baghal Asghari[a], Manijeh Pakdel[b], Ali Akbar Mohammadi[c,*], Mahmood Yousefi[a,*]

[a]*Department of Environmental Health Engineering, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran, Tel. +9809147177871 emails: asgharifarzane@gmail.com (F.B. Asghari), Mahmood_yousefi70@yahoo.com (M. Yousefi)*
[b]*Students Research Committee, Neyshabur University of Medical Sciences, Neyshabur, Iran, email: pakdel.manizhe@gmail.com (M. Pakdel)*
[c]*Department of Environmental Health Engineering, Neyshabur University of Medical Sciences, Neyshabur, Iran, Tel. +985142632476; email: mohammadi.eng73@gmail.com (A.A. Mohammadi)*

Received 4 June 2018; Accepted 27 October 2018

ABSTRACT

The objectives of this research were to assess the chemical and microbial quality of drinking water in Maku, Iran, and compare it with the national standard, as well as determine the spatial distribution of the chemical quality parameters of drinking water for warm and cold seasons using the geographical information system software. In this study, 136 drinking water samples were collected from 36 points of the distribution network in two successive years of 2016 and 2017 in warm and cold seasons. Paired-samples and Pearson correlation tests were used to examine the correlation between residual chlorine values and microbial parameters. Based on the findings of this study, the average concentration of all parameters in Maku distribution network falls within the national standard, except for turbidity. According to the zoning maps of drinking water, turbidity and hardness concentration are greater in warm than cold seasons. Results revealed that the mean heterotrophic bacteria (HPC) of samples in cold and warm seasons equaled 7 ± 11 cfu/ml and 29 ± 61 cfu/ml, respectively. According to the results of the paired-samples test, there was a significant correlation between the HPC values measured in two cold seasons and years for the samples (p-value = 0.012). It is recommended that respective agencies ensure the availability of chlorine residual at the consumer end.

Keywords: Temporal and spatial variation; Hardness; Total dissolved solid; Geographic information system (GIS); Distribution network; Maku

1. Introduction

Most of the Earth's surface is covered with water, and aquatic environments provide a good setting for microorganism growth. The entry of organic matter contaminates water, making the environment more suitable for the growth of microorganisms [1,2]. Different types of bacteria, viruses, and parasites can easily enter hydrated networks and cause intestinal diseases [3]. The presence of some salts and chemicals in water is essential for human health, while some of these agents may be toxic at low concentrations, causing various diseases in the long run [4,5]. Currently, drinking water quality control in distribution networks means the determination of physical, chemical, and microbial characteristics of water [6–8] which is extensively researched worldwide.

Yidana et al. [9] conducted a study in Ghana on groundwater quality using multivariate and spatial analyses in the Keta basin. Results showed that, during dry seasons when the water table has a low level, saline water intrusion elevates the content of sodium in groundwater as reflected by sodium adsorption rate values in some of the wells sampled. In the Northern Arabian Sea along the Indian coast, Vase [10] reported that the values of physical and chemical variables

* Corresponding author.

are higher during summer, whereas nutrient concentrations are high during winter due to the maturity of intake nutrients post-monsoon and during winter convective mixing during the Northeast monsoon. Kumari et al. [11] also assessed the spatial distribution of groundwater quality in industrial areas of Ghaziabad, India, and concluded that the groundwater in the two blocks is unfit for drinking as per world health organization (WHO) guidelines. The presence of elements such as arsenic (As), selenium (Se), and uranium (U) in toxic amounts is a matter of serious concern. In India, the physicochemical parameters of the drinking water of Bhopal were investigated with reference to health impacts [12].

In Iran, Maleki et al. [13] examined the chemical quality of drinking water in rural areas of Qorveh. They showed that all the studied parameters have lower concentrations than the permitted limits, except for As and Se in some water resources. The As concentration was higher than the recommended standard in 20% of the studied resources. Moreover, in 2007–2008, Rajaei et al. [14] investigated the chemical quality of rural drinking water in Birjand and Cain plains and concluded that, due to the non-conformity of the remaining amounts of solids, hardness, sulfate, sodium, chloride, electrical conductivity, and fluoride to relevant standards, it is essential to plan for continuous monitoring of water resources. Furthermore, Sarposhi et al. [15] studied the microbial and chemical quality of drinking water in the villages covered by the Robot Sarposhi and concluded that sampling should be performed periodically from the end of the network due to the non-compliance of some parameters, such as hardness (11%), sulfate (39%), and chlorine (0.05%) in the samples with the relevant standards. Source of pollutant emissions in the distribution network for various reasons cause quality decline in water distribution lines including; transportation of organic materials to water supply lines due to fractures, reverse siphon, small leaks, or lack of disinfectant, creation and growth of biological layer (biofilm) in the wall pipes, water drainage, action and reaction to water and pipe and existence microorganisms and organic ingredients that are passed from treatment processes and factors like that, all of the conditions for the growth of microbial population changes in the chemical composition of water in distribution networks that is why water pollution in distribution networks with parabola 29% is the most important factor in the incidence of water borne diseases It is known [18,19]. In this regard, recognizing the physicochemical and microbial quality of drinking water and the possible sources of pollution is an issue requiring further attention.

The city of Maku is located 39°17′ to 39°18′ North latitude and 44°26′ to 44°31′ East along the Northern West Azerbaijan Province and lies in the main link between Iran and Turkey. The source of drinking water in Maku is surface water supplied from the Baron Dam [18]. The geographical location and map of the distribution network of drinking water in Maku are presented in Fig. 1. Regarding the role of water quality in residents' health and the necessity of constant measurement of its various parameters, this study was conducted to determine the physical, chemical, and bacteriological quality of drinking water in Maku during warm and cold seasons in 2016–2017.

2. Materials and methods

The present study was a cross-sectional descriptive study conducted in warm and cold season of 2016–2017 on the drinking water network of Maku. The sampling sites in the distribution network and their number were selected based on the population density covered by the city water map and after scientific and statistical consultation. Fig. 1 depicts the sampling points.

In this cross-sectional study, 136 drinking water samples were collected from 34 points of the distribution network in two successive years of 2016–2017 in warm and cold seasons. The number and location of sampling points were determined based on the population covered by the water mains and the extension of pipes. The number of samples was calculated based on formula $N = \frac{Z^2 S^2}{d^2}$ and the final number of samples equaled 136 samples taking into account repeat sampling from each location in two seasons.

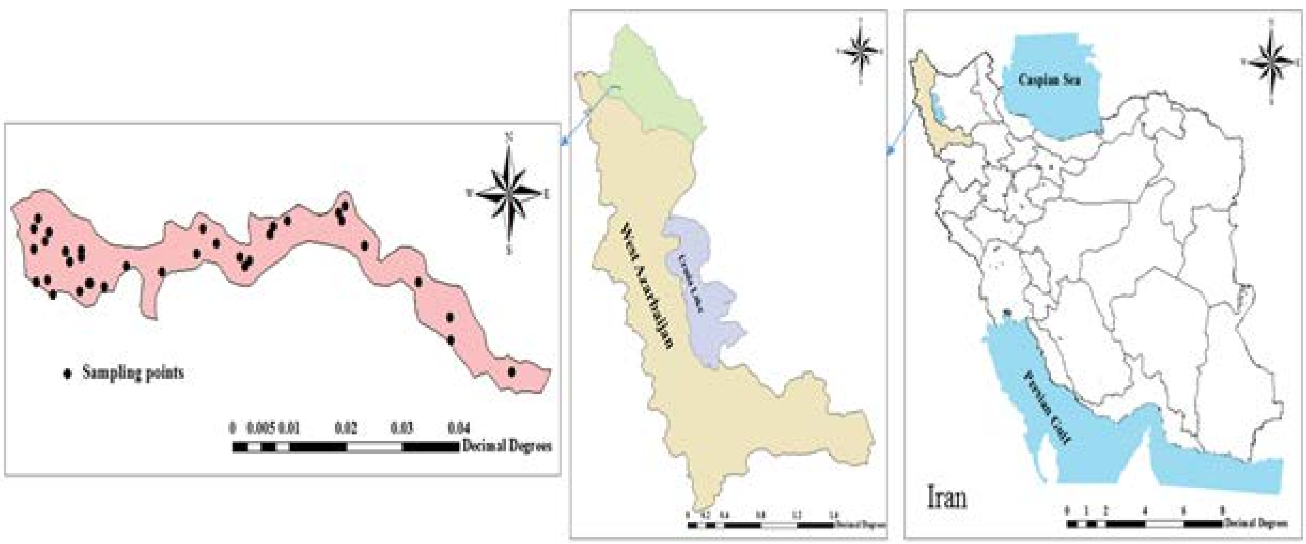

Fig. 1. Sampling points of drinking water distribution network.

Samples were taken from the distribution network in accordance with the guidelines in the reference book 'Standard Methods for the Examination of Water and Wastewater' using a standard volume of 2–3 L and analyzed according to the methods described in the book 'Standard Method' [19].

2.1. Physicochemical experiments

For physicochemical experiments, the parameters of pH, temperature, turbidity, hardness, alkalinity, total soluble solids, electrical conductivity, sodium, potassium, sulfate, chloride, and dissolved oxygen were analyzed. Weights were measured to determine the soluble solids and the titration method was employed to determine hardness, alkalinity, and chloride. The concentration of sulfate ion was measured by the turbidity method at 420 nm using a 5000 DR Spectrophotometer. A flame photometer was utilized to measure sodium and potassium in water. Also, residual chlorine was measured via a laboratory kit, temperature, and pH at the sampling site. The dissolved oxygen content was measured using a 340i/SET OXi portable DO meter, and turbidity was modeled with an IR 550 Turb Turbidity Sensor. All the chemicals were purchased from Merck Company (Germany) [19–23].

2.2. Microbial tests

In this study, samples were examined for microbial contamination by microbial indices of total coliforms as well as the plate count of heterotrophic bacteria (HPC) by the standard method.

2.3. GIS

Geochemical analysis using the geochemical quality of water is one of the best approaches for defining water concentrations and is essential for a comprehensive chemical survey of spatial and temporal quality of water. One of the most common methodologies for assessing variations in water geochemistry is geographic information system (GIS) which is a computer system for managing spatial data. The geographical term indicates that the position of the data is known or can be known in terms of geographical coordinates (latitude and longitude), with the capability of collecting, logging, processing, transforming, illustrating, typing, searching, analyzing, modeling, and outputting data. An important aspect of GIS is that it simplifies the information and makes the real world easier [24,25].

2.4. Determination of HPC

In order to determine the HPC of the samples, water was first diluted to 0.001. Then, the R^2 agar culture medium was used to culture the samples; 0.2 cc of diluted samples was cultured on the medium near the flame, incubated at 35°C for 3 d, and then counted [18].

2.5. Determination of MPN

The determination of most probable number (MPN) was performed using microbial culture combined with possible, confirmatory, and complementary steps. The determination of the coliform according to the type of drinking water was conducted using a 10-pipe method. All chemicals used in chemical and microbiological experiments were manufactured by Merck Company (Germany) [18]. Finally, the data were analyzed in Microsoft Office Excel and statistical package for the social sciences.

2.6. Statistical methods

Data are presented as mean, standard deviation, median, and range. Paired-samples *t*-test and Pearson correlation were employed to compare the results between two and determine the correlation between residual chlorine values and microbial parameters, respectively.

3. Results and discussion

A summary of the physical and chemical parameters for the collected drinking water samples is presented in Table 1. After entering the concentrations of chemical parameters, the layers were prepared in ArcGIS based on field information. Figs. 2–6 illustrate the spatial changes of the distribution network of drinking water in Maku in cold and warm seasons of 2016–2017.

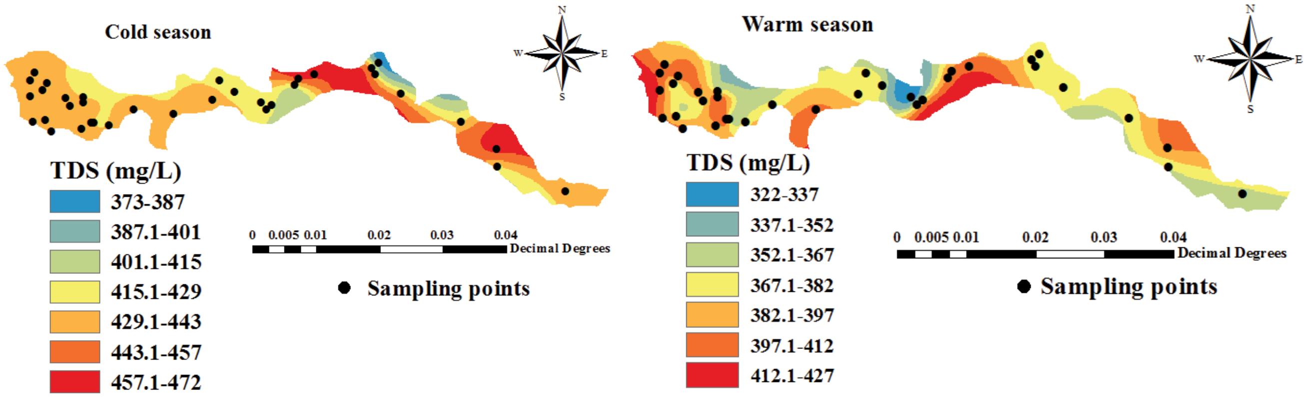

Fig. 2. The amount of TDS in the samples studied in cold and warm seasons.

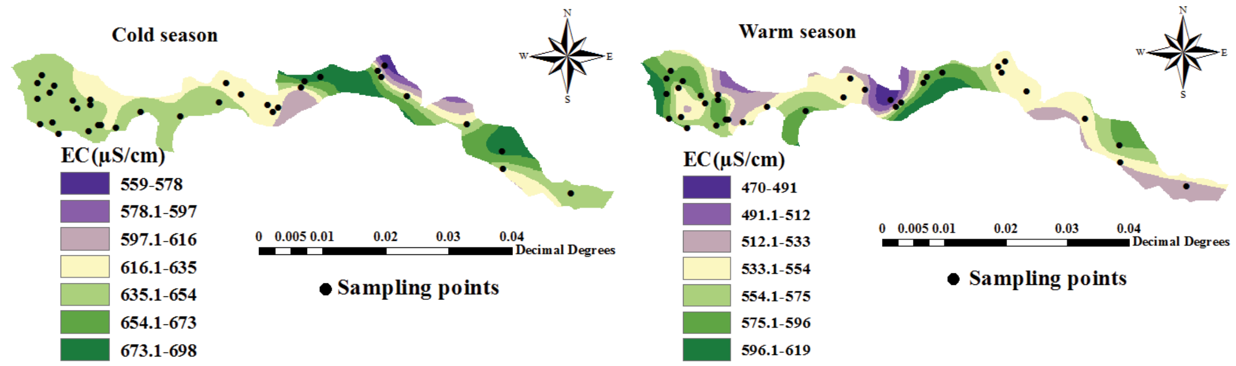

Fig. 3. The amount of EC in the samples studied in cold and warm seasons.

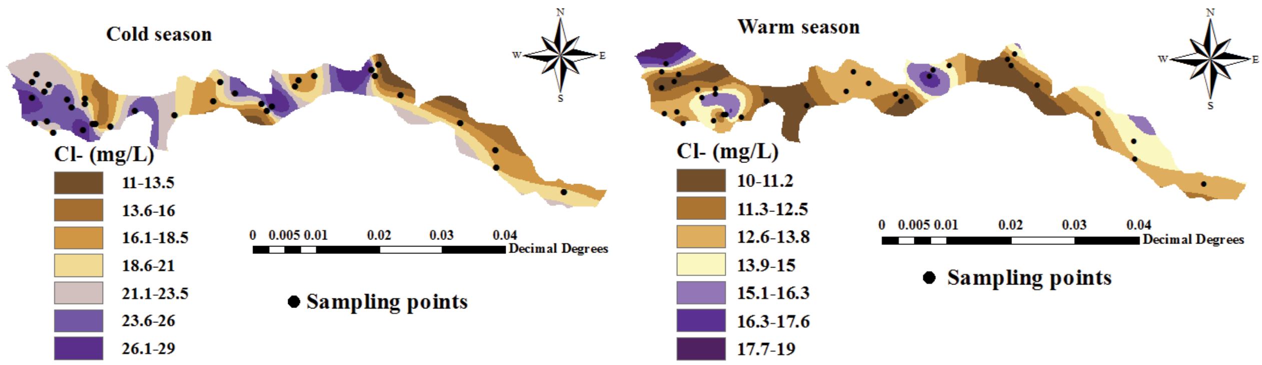

Fig. 4. The amount of Cl^- in the samples studied in cold and warm seasons.

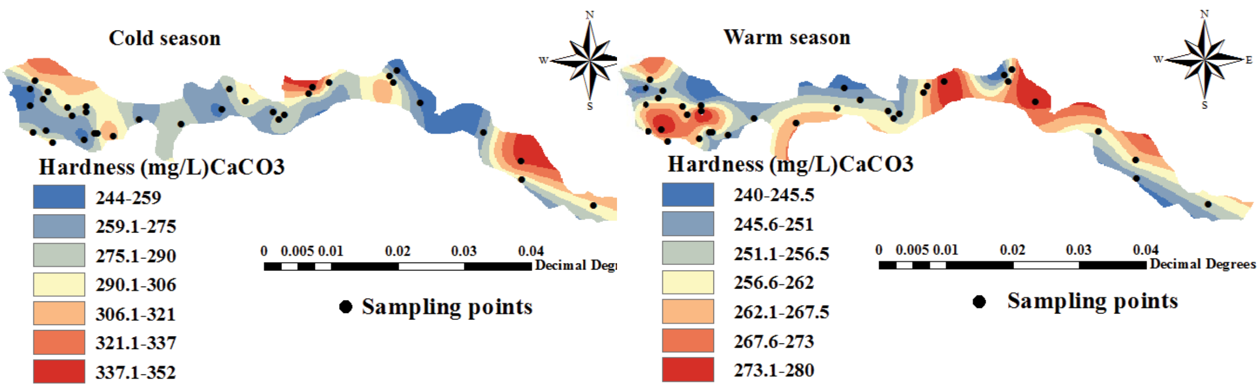

Fig. 5. The amount of hardness in the samples studied in cold and warm seasons.

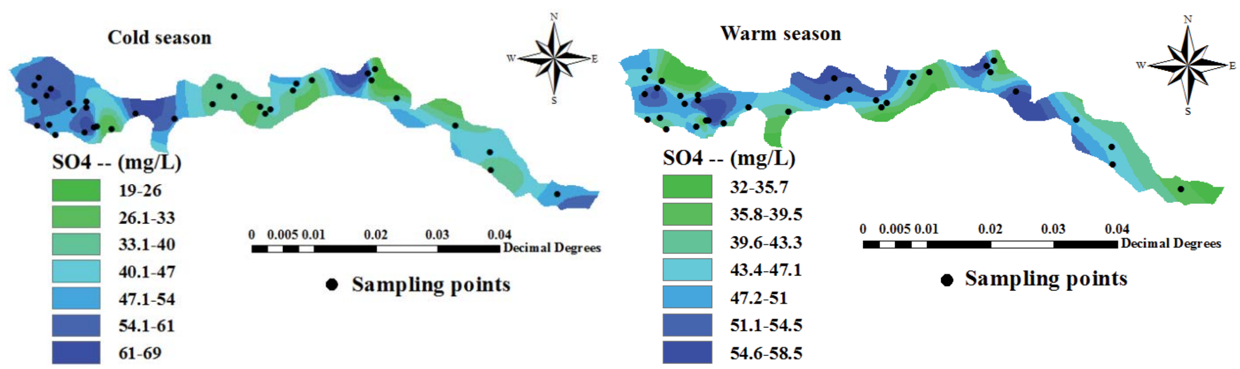

Fig. 6. The amount of SO_4^{2-} in the samples studied in cold and warm seasons.

Table 1
Descriptive statistics for the chemical factors of drinking water samples in the distribution network system of the study area in cold and warm season of 2016–2017

Parameter	Unit	1053IR	WHO	Cold season				Warm season			
		Standard	Guideline	Mean	Maximum	Minimum	Standard deviation	Mean	Maximum	Minimum	Standard deviation
Temperature	°C	–	–	8.8	14.8	5.2	2.1	21.8	26.4	16.3	2.6
pH	–	6.5–8.5	6.5–8.5	7.9	8.1	7.7	0.1	7.8	8	7.4	0.2
O_2	mg/l	–	–	6.3	8.7	4.3	1.1	5.9	7.1	4.8	0.6
Turbidity	NTU	1	–	0.4	4.5	0.07	0.19	0.7	6.1	0.09	1.49
EC	µs/cm	–	1500	618.1	673	534	22	570.6	609	460	27.2
TDS	mg/l	1000	500	432.6	471.1	373.8	15.4	399.4	426.3	322	19
Total hardness	mg/l as $CaCO_3$	200	200	277.7	352	244	24.4	256.5	280	240	10.5
Ca hardness	mg/l as $CaCO_3$	–	–	139.7	172	120	14.5	114.6	128	80	12.5
Ca^{2+}	mg/l	300	200	56	68	48	5.8	46	51	32	4.9
Mg^{2+}	mg/l	30	50	33	52	21	6.1	34	41	29	3.3
Na^+	mg/l	200	200	75	170	20	51.5	79	178	24	50.1
K^+	mg/l	–	12	5.1	2.8	0.6	0.8	6.2	8.9	1.7	8.3
Total alkalinity	mg/l as $CaCO_3$	–	–	268.7	396	238	28	218.3	234	208	6.3
SO_4^{2-}	mg/l	250	200	50.32	72.3	20.5	14.9	50.3	63.9	36.5	7.8
Cl^-	mg/l	250	200	19.24	28.5	11.5	4.1	13.4	18.9	10.5	2.1

3.1. Turbidity

In Iranian drinking water standards, the optimum and maximum permissible levels for turbidity are 1 and 5 NTU, respectively [26]. Results revealed that minimum and maximum turbidity levels in the drinking water of the distribution network in cold and warm seasons fell in the range of 0.07–4.5 and 0.7–6.1 NTU, respectively (Table 1). The results indicated that turbidity is higher in warm than cold seasons. Since turbidity protects microorganisms, the amount of residual chlorine in warm seasons should be higher than its value in cold seasons. A research conducted by Lehtola et al. [27] indicated that turbidity removal and soft deposits from water distribution network decrease microbial growth in the distribution system during warm seasons when there are favorable conditions, such as temperatures for microbial growth. A similar study conducted by the National Water Quality Program [28] reported that the range of turbidity falls between 1.10 and 6.40 NTU. The deterioration of drinking water quality in distribution networks is probably due to an increase in microbial number [28].

3.2. Total dissolved solids

The maximum and minimum Total dissolved solids (TDS) values for drinking water in the distribution network in cold and warm seasons were in the range of 471.1–373.8 and 322–426.3, respectively (Table 1). According to drinking water quality standards set by the Institute of Standards and Industrial Research of Iran and WHO, 100% of the samples had total dissolved solid concentrations within the permissible limit (500 mg/l) in warm and cold seasons. These results are in agreement with the findings reported by other researchers [29]. In a study conducted by Singh et al. [30] on groundwater quality assessment of Dhankawadi Ward of Pune using GIS, results equaled 16–559.97 mg/l, which are different from the findings of the present study.

3.3. pH

The pH value measured for drinking water in the distribution network in cold and warm seasons was in the range of 7.7–8.1 and 7.8–8, respectively (Table 1) which is within the desirable limit, i.e. 6.5–8.5, as specified by the Iranian National Standard. These results are also in accordance with earlier studies conducted by Hashmi et al. [29] and Singh et al. [30] in which the pH values varied from 7.41 to 7.73 and 7.15 to 7.8, respectively.

3.4. Total hardness

The total hardness values of samples in cold and warm seasons equaled 244–352 mg/l and 240–280 mg/l, respectively (Table 1). By comparison with the Iranian standards, it can be concluded that all samples fall within the permitted range and can be classified as hard water. The TDS concentration is categorized as the secondary drinking water standard, which means that it is not a health hazard but is problematic for industrial use. These findings are in agreement with those reported by Mohammadi et al. and Farooq et al. [31,32].

3.5. Chlorine residual

Results show that residual chlorine contents in drinking water in the distribution network in cold and warm seasons were in the range of 0.63–1.2 mg/l and 0.68–1 mg/l, respectively (Table 2). These results are in line with the findings of Hashmi et al. [29] and Ghaderpoori et al. [33]. Olivieri et al. [34] reported free and combined chlorine to be in the range of 0.2–1.0 mg/l in the drinking water distribution system. The availability of a disinfectant residual is especially important in developing countries because of poor sanitary conditions and the high risk of recontamination during distribution.

3.6. Heterotrophic bacteria

Results revealed that HPC in drinking water samples in Maku was in the range of 25–60 and 30–360 (MPN/100 ml) in cold and warm seasons, respectively. Also, results suggested that fecal coliforms in 100% of drinking water samples were in the range of 1.1–2.2 (MPN/100 ml) (Table 2). The mean total coliforms of 71% of samples in cold seasons and mean total coliforms of 54% of samples in warm seasons were less than 1/1, and the amount of thermophilic coliform of the samples in each season equaled 100 ml. According to the paired-samples test, a significant correlation was found between the HPC measured in cold and warm seasons (*p*-value = 0.012). In this study, based on the Pearson correlation test, there was no significant difference between the measured chemical parameters and HPC (Table 2). The study conducted by Hashmi et al. [29] on chlorination and water quality monitoring within a public drinking water supply in Rawalpindi Cantt showed that the total coliforms varied from 1.1 to 3.6 (MPN/100 ml) with the presence of *Escherichia coli* in all samples. This report recommended that agencies ensure the availability of chlorine residual at the standard level at consumer end [29].

Based on a study conducted by Agard et al. [35] in Trinidad, as the chlorine residual decreased from 4.6 ppm at the plant to 0.2 ppm at the household, a statistically significant increase was observed in total and thermotolerant coliforms. The results of this study differ from those presented here. Similarly, in Pietermaritzburg, South Africa, coliforms were found to be associated with a low chlorine residual; as the distance from the water plant increased, the level of free chlorine decreased, thereby increasing the coliforms [36].

Monitoring the quality of drinking water based on physical, chemical, and bacteriological standards can be defined as the assessment of public health and the appropriateness of drinking water. Prevention of microbial and chemical contamination of water sources is the first barrier to drinking water pollution in order to maintain health, and the key to it is familiarity with drinking water quality standards and criteria. The results of the present study revealed that drinking water in the city of Maku is acceptable for drinking in terms of physical, chemical, and bacteriological quality compared to the WHO standards and the change of seasons does not have a significant effect on test results. The color, turbidity, and pH of samples were in the normal range and the limits recommended by WHO.

Table 2
Relationship of residual chlorine with fecal coliform and HPC in the distribution network of Maku in cold and warm seasons of 2016–2017

Parameters		Mean	Maximum	Minimum	Standard deviation	The difference of HPC and chemical parameters between cold and warm season samples	The difference of HPC between cold and warm season samples
Cold season	Residual chlorine	0.63	1.2	0	0.26	Pearson correlation test	Paired samples test
	HPC (cfu/ml)	25.6	60	0	11	*p* value 0.08	*p* value 0.012
	MPN/100 ml	–	2.2	<1.1	–		
Warm season	Residual chlorine	0.68	1	0	0.22		
	HPC (cfu/ml)	30.3	360	0	61		
	MPN/100 ml	–	2.2	<1.1	–		

Studies suggest that, in cold seasons, consumers complain less about the taste and color of water, indicating a low level of chemical interactions in cold water. Of the total samples collected for chemical testing, the average annual calcium, sulfate, and chlorine parameters have been desirable in terms of national and global standards. The water hardness parameter of the city of Maku, with the amount of about 266 mg/l calcium carbonate, indicates that the water is hard water and, given its permissibility of up to 500 mg/l, its consumption will cause no health and medical problem [19,26].

Studies report that the major sediments formed in water distribution systems include calcium carbonate, magnesium carbonate, calcium sulfate, and magnesium chloride, so that in some cases the sedimentation of the above factors leads to the blockage of tubes and increased cost of utilizing water supply facilities [37]. According to the results of microbial tests performed on coliform bacteria, and since 100% of the samples lacked thermophilic coliform, the drinking water in Maku is healthy when compared against national standards [19,26]. Moreover, since the residual chlorine level in most cases was at the optimal level (6.0 mg/l average annual), this also contributes to the reduction of water pollution and confirms the results [38]. Finally, it is recommended that water quality status be systematically and periodically reviewed so that in case of changes, appropriate interventions can be taken. Furthermore, the maintenance of chlorine is suggested in view of increasing the probability of water contamination with types of pollutants originating from human and industrial activities. Maintaining the standard level and repairing network defects will keep microbial indices in check.

4. Conclusion

The findings of this study indicated that the chemical and microbial parameters are compatible with Iranian national standards and W.H.O guideline, in terms of health considerations, desirable. The quality of water in the distribution network is good. According to the zoning maps of drinking water, turbidity is higher than the standard level in warm seasons. Therefore, more attention must be paid to water quality in summer. Operation management and groundwater conservation must be a basic principle of urban planning to maintain the desired quality of the groundwater resources of Maku city.

Acknowledgements

The authors want to thank authorities of Tehran University of Medical Sciences for their comprehensives support for this study.

Conflict of Interest

The authors of this article declare that they have no conflict of interests.

References

[1] A. Abbasnia, N. Yousefi, A.H. Mahvi, R. Nabizadeh, M. Radfard, M. Yousefi, M. Alimohammadi, Evaluation of groundwater quality using water quality index and its suitability for assessing water for drinking and irrigation purposes: case study of Sistan and Baluchistan province (Iran), Hum. Ecol. Risk Assess, (2018) 1–18, doi: 10.1080/10807039.2018.1458596.

[2] H. Amini, G.A. Haghighat, M. Yunesian, R. Nabizadeh, A.H. Mahvi, M.H. Dehghani, R. Davani, A.-R. Aminian, M. Shamsipour, N. Hassanzadeh, Spatial and temporal variability of fluoride concentrations in groundwater resources of Larestan and Gerash regions in Iran from 2003 to 2010, Environ. Geochem. Health, 38 (2016) 25–37.

[3] M. Yousefi, H.N. Saleh, M. Yaseri, A.H. Mahvi, H. Soleimani, Z. Saeedi, S. Zohdi, A.A. Mohammadi, Data on microbiological quality assessment of rural drinking water supplies in Poldasht county, Data Brief, 17 (2018) 763–769.

[4] M. Yousefi, M. Ghoochani, A.H. Mahvi, Health risk assessment to fluoride in drinking water of rural residents living in the Poldasht city, Northwest of Iran, Ecotoxicol. Environ. Safety, 148 (2018) 426–430.

[5] M. Yousefi, M. Yaseri, R. Nabizadeh, E. Hooshmand, M. Jalilzadeh, A.H. Mahvi, A.A. Mohammadi, Association of hypertension, body mass index, and waist circumference with fluoride intake; water drinking in residents of fluoride endemic areas, Iran, Biol. Trace Elem. Res., 185 (2018) 282–288.

[6] A. Bay, K. Poorshamsian, K. Karimi, M. Hashemi, B. Maghsodlo, Determination of bacteriological and physiochemical parameters of drinking water of Gorgan city, Iran (2010), Med. Lab. J., 5 (2011) 13–17.

[7] A. Amouei, A. Mahvi, A. Mohammadi, H.A. Asgharnia, S. Fallah, A. Khafajeh, Physical and chemical quality assessment of potable groundwater in rural areas of Khaf, Iran, World Appl. Sci. J., 18 (2012) 693–697.

[8] G.H. Safari, M. Zarrabi, M. Hoseini, H. Kamani, J. Jaafari, A.H. Mahvi, Trends of natural and acid-engineered pumice onto phosphorus ions in aquatic environment: adsorbent preparation, characterization, and kinetic and equilibrium modeling, Desal. Water Treat., 54 (2015) 3031–3043.

[9] S.M. Yidana, B. Banoeng-Yakubo, T.M. Akabzaa, Analysis of groundwater quality using multivariate and spatial analyses in the Keta basin, Ghana. J. Afr. Earth Sci., 58 (2010) 220–234.

[10] V.K. Vase, G. Dash, K. Sreenath, G. Temkar, R. Shailendra, K.M. Koya, D. Divu, S. Dash, R.K. Pradhan, K.S. Sukhdhane, Spatio-temporal variability of physico-chemical variables, chlorophyll a, and primary productivity in the northern Arabian Sea along India coast, Environ. Monit. Assess., 190 (2018) 148.

[11] S. Kumari, A.K. Singh, A.K. Verma, N. Yaduvanshi, Assessment and spatial distribution of groundwater quality in industrial areas of Ghaziabad, India, Environ. Monit. Assess., 186 (2014) 501–514.

[12] H.C. Kataria, M. Gupta, M. Kumar, S. Kushwaha, S. Kashyap, S. Trivedi, R. Bhadoriya, K. Bandewar, Study of physico-chemical parameters of drinking water of Bhopal city with reference to health impacts, Current World Environ., 6 (2011) 95–99.

[13] A. Maleki, P. Teymouri, R. Rahimi, M. Rostami, H. Amini, H. Daraei, P. Bahmani, S. Zandi, Assessment of chemical quality of drinking water in rural area of Qorveh city, Kurdistan province, Iran. J. Adv. Environ. Health Res., 2 (2014) 22–29.

[14] Q. Rajaei, M. Mehdinejad, S. Hesari Motlagh, A survey of chemical quality of rural drinking water of Birjand and Qaen Plains, Iran. Health Care Res., 7 (2012) 737–745.

[15] G. Rabat Sarposhi, R. Chopani, M. Tarkhasy, A. Rhmanysani, Evaluation of drinking water biological and chemical quality in rural villages under vision rabate sarpush and Shamkan villages of Sabzevar city, J. Sabzevar Univ. Med. Sci. Res. Commun., 1 (2012) 25.

[16] M. Ghannadi, Steretagies for quality control in water supply networks. Water Environ., 52 (2003) 4–11.

[17] J. Jaafari, M. Seyedsalehi, G. Safari, M.E. Arjestan, H. Barzanouni, S. Ghadimi, H. Kamani, P. Haratipour, Simultaneous biological organic matter and nutrient removal in an anaerobic/anoxic/oxic (A^2O) moving bed biofilm reactor (MBBR) integrated system, Int. J. Environ. Sci. Technol., 14 (2017) 291–304.

[18] F.B. Asghari, J. Jaafari, M. Yousefi, AA. Mohammadi, R. Dehghanzadeh, Evaluation of water corrosion, scaling

extent and heterotrophic plate count bacteria in asbestos and polyethylene pipes in drinking water distribution system, Hum. Ecol. Risk Assess., 24 (2018) 1138–1149.
[19] E. Rice, R. Baird, A. Eaton, L. Clesceri, Standard Methods: For the Examination Water and Wastewater, 22nd ed., American Public Health Association, American Water Works Association, Water Environmental Federation, Lewis Publishers, 2012.
[20] S. Agarwal, I. Tyagi, V.K. Gupta, M. Dehghani, J. Jaafari, D. Balarak, M. Asif, Rapid removal of noxious nickel (II) using novel γ-alumina nanoparticles and multiwalled carbon nanotubes: kinetic and isotherm studies, J. Mol. Liq., 224 (2016) 618–623.
[21] D. Naghipour, K. Taghavi, J. Jaafari, Y. Mahdavi, M. Ghanbari Ghozikali, R. Ameri, A. Jamshidi, A.H. Mahvi, Statistical modeling and optimization of the phosphorus biosorption by modified Lemna minor from aqueous solution using response surface methodology (RSM), Desal. Water Treat., 57 (2016) 19431–19442.
[22] M. Shams, R. Nabizadeh Nodehi, M. Hadi Dehghani, M. Younesian, A. Hossein Mahvia, Efficiency of granular ferric hydroxide (GFH) for removal of fluoride from water, Fluoride, 43 (2010) 61–66.
[23] A.A. Mohammadi, M. Yousefi, M. Yaseri, M. Jalilzadeh, A.H. Mahvi, Skeletal fluorosis in relation to drinking water in rural areas of West Azerbaijan, Iran. Sci. Rep., 7 (2017) 17300.
[24] W. Edmunds, P. Shand, P. Hart, R. Ward, The natural (baseline) quality of groundwater: a UK pilot study, Sci. Total Environ., 310 (2003) 25–35.
[25] A. Panagopoulos, K. Kassapi, G. Arampatzis, B. Perleros, S. Drakopoulou, E. Tziritis, A. Chrysafi, I. Vrouhakis, Assessment of Chemical and Quantitative Status of Groundwater Systems in Pinios Hydrological Basin-Greece, in: Proc Int Conf Protection and Restoration of the Environment XI, Thessaloniki, 2012, pp. 511–517.
[26] Industrial Research and standard Institute of Iran, Physical and Chemical Quality of Drinking Water, 5th ed., No.1053, Tehran, 2010. Available from http://www.isiri.org/std/1053.pdf/.
[27] M.J. Lehtola, T.K. Nissinen, I.T. Miettinen, P.J. Martikainen, T. Vartiainen, Removal of soft deposits from the distribution system improves the drinking water quality. Water Res., 38 (2004) 601–610.
[28] WB-CWRAS. The World Bank ''Pakistan Country Water Resources Assistance Strategy Water Economy: Running Day''. Washington, DC: WB-CWRAS (November), 2005.
[29] I. Hashmi, S. Farooq, S. Qaiser, Chlorination and water quality monitoring within a public drinking water supply in Rawalpindi Cantt (Westridge and Tench) area, Pakistan, Environ. Monit. Assess., 158 (2009) 393.
[30] P. Singh, I. Khan, Ground water quality assessment of Dhankawadi ward of Pune by using GIS, Int. J. Geomat. Geosci., 2 (2011) 688–703.
[31] S. Farooq, I. Hashmi, I.A. Qazi, S. Qaiser, S. Rasheed, Monitoring of coliforms and chlorine residual in water distribution network of Rawalpindi, Pakistan, Environ. Monit. Assess., 140 (2008) 339–347.
[32] A.A. Mohammadi, K. Yaghmaeian, F. Hossein, R. Nabizadeh, M.H. Dehghani, J.K. Khaili, A.H. Mahvi. Temporal and spatial variation of chemical parameter concentration in drinking water resources of Bandar-e Gaz City using geographic information system. Desal. Water Treat., 68 (2017) 170–176.
[33] M. Ghaderpoori, M.H. Dehghani, M. Fazlzadeh, A. Zarei, Survey of microbial quality of drinking water in rural areas of Saqqez, Iran. Am-Eurasian J. Agric. Environ. Sci., 5 (2009) 627–632.
[34] V.P. Olivieri, M.C. Snead, C.W. Krusé, K. Kawata, Stability and effectiveness of chlorine disinfectants in water distribution systems, Environ. Health Perspect., 69 (1986) 15–29.
[35] L. Agard, C. Alexander, S. Green, M. Jackson, S. Patel, A. Adesiyun, Microbial quality of water supply to an urban community in Trinidad, J. Food Protect., 65 (2002) 1297–1303.
[36] I. Bailey, T.P. Thompson, Monitoring of water quality after disinfection in distribution systems, Water Supply, 13 (1995) 35–48.
[37] E.E. Geldreich, Microbial Quality of Water Supply in Distribution Systems, Lewis Publishers, Boca Raton, FL, 1996.
[38] A. Takdastan, M. Mirzabeygi, M. Yousefi, A. Abbasnia, R. Khodadadia, H. Soleimani, A.H. Mahvi, D.J. Naghan, Neuro-fuzzy inference system Prediction of stability indices and Sodium absorption ratio in Lordegan rural drinking water resources in west Iran, Data Brief., 18 (2018) 255–261.