RESEARCH ARTICLE

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Microbiological Quality of Drinking Water in Rural Areas of a City

Nader Yousefi[a,b], Amin Bagheri[a,b], Nezam Mirzaei[c,a]*, Mohammad Khazaei[d], Mehdi Vosoughi Niri[e]

[a] Department of Environmental Health Engineering, School of Health, Tehran University of Medical Sciences, Tehran, Iran.
[b] National Institute of Environmental Research, Tehran University of Medical Sciences, Tehran, Iran.
[c] Environmental Health Research Center, Kurdistan University of Medical Sciences, Sanandaj, Iran.
[d] Research Center for Environmental Pollutants, Qom University of Medical Sciences, Qom, Iran.
[e] Department of Environmental Health Engineering, School of Public Health, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran.

*Correspondence should be addressed to Dr. Nezam Mirzaei; **Email:** nezammirzaei@yahoo.com

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Background & Aims of the Study: Lack of access to safe drinking water can lead to undesirable aesthetic problems and adverse health effects such as infectious diseases. The aim of this study was to investigate the microbiological quality of the drinking water distribution network in Divandareh City (Kordestan-western Iran).

Materials & Methods: This study was performed in a 12 months period from March 2011 to February 2012. For purposes of drinking water resources quality measurement in Divandareh City, samples from springs, deep and semi-deep wells were analyzed for residual free chlorines, turbidity, total and fecal coliform. The size of samples was 2088 and the sampling was performed according to guidelines of WHO for water sampling. The results were analyzed using the Statistical software SPSS and Excel and for the comparison between average parameters ANOVA test were used.

Results: In 95% of samples, the residual free chlorine was in the range of 0 to 0.5 mg/L, turbidity 0 to 1.8 NTU and total and fecal coliforms 0 to 240 and 0 to 9.1 (MPN/100mL), respectively. According to data analysis, the chlorine residual and turbidity had significant effect on the amount of thermophilic coliforms (P=0.047).

Conclusions: High rate of total and fecal coliforms in the drinking water is due to failures in the transport system, lack of sanitation in the water resource, and lack or failure in the chlorination system.

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Background

The population growth of cities and the improvement of life standards have increased drinking, agricultural, industrial, and recreational water needs. (1). Contaminants may enter the drinking water because of failures in the transport system, water treatment system or the distribution network and lead to deterioration of water quality and health problems (2,3).

A large number of people in the developing countries suffer insufficient access to safe drinking water (4). Lack of access to safe drinking water can lead to undesirable aesthetic problems and adverse health effects such as infectious diseases mainly caused by human and animal enteric pathogens, including bacteria, protozoa, and viruses (2). According to the report of the US Centre for Disease Control, about 780 diseases associated with the consumption of contaminated drinking water outbreaks, have occurred from 1971 to 2006. In addition, outbreaks have also happened in other world parts such as Spain in the 1999–2006 periods (5).

Commonly, water quality in the point of use is a critical public health indicator (6). According to World Health Organization (WHO) definition "drinking water" is high quality water suitable for human consumption and other uses in the home with high quality water suitable for human consumption and other uses in the home while being available in the community (7). Safe drinking water sources are piped in the household water connections, boreholes, protected dug wells, protected springs, and rainwater collection (8). International drinking water-quality monitoring programs have been established in order to prevent or reduce the risk of disease associated with polluted water consumption (6).

A main objective of the water distribution network monitoring is to ensure safe drinking water. Different factors affect the bacterial growth in the distribution system including concentration of disinfectant, concentration of biodegradable dissolved organic carbon, nutrient concentrations, water temperature and disinfectant residuals (9,10).

However, the bacteriological quality of drinking water may be changed in the distribution network due to higher temperatures, depletion of disinfectant residuals and existence of nutrients (9). The maintenance of free residual chlorine is key criteria that ensure the portability of the water in the chlorine fed distribution systems (6). Presence of turbidity in water can affect the disinfection process and microbial inactivation. The permissible guideline for turbidity based on Iranian national drinking standard is 5 Nephelometric Turbidity Units (NTU) (7). Raw water treatment may result in a decrease in the microbial load, but in the distribution system secondary pollution could occur and it is recognized as a major problem within many water distribution systems (11).

Monitoring of the distribution network water quality will allow designing efficient and effective control strategies that will ensure safe and high-quality drinking water (12,13) and protect consumers from illness and drinking-water related illness outbreaks (5). In this basis, WHO published "Emerging Issues in Water and Infectious Diseases" that expresses the problem of emerging pathogens and other aspects that jeopardize water safety (5,14).

In recent years, some studies have been performed on microbial quality of drinking water distribution network, for instance Dehghani *et al.*, investigated the drinking water quality of Shadegan township (Iran), and Ghaderpoor *et al.*, in Saqqez City (Iran) (1,7).

Aims of the study: The objective of the present study was to investigate the microbiological quality of drinking water distribution network in Divandareh City (Kurdistan, Western Iran).

Materials & Methods

The population of Divandareh is 22842 people (in villages of this city there is around 55704 persons) (2007) and it is characterized by cold climate (15).

The sampling program covered a 12-months period from March 2011 to February 2012. Drinking water resources in Divandareh City are springs, deep and semi-deep wells. Because all sources were used in the city as well as different storage sources, 2088 samples were collected during a 12 months period. The choice of zones for the study was based on archival data and was selected based on general microbiological quality, age and turbidity levels of the water and the construction and layout of distribution system that can be of importance in the bacterial regrowth. Additional sampling sites were determined in each village by observing and inquiring residents about primary household water sources. The sampling of Divandareh City water was performed according to the guidelines of WHO for the water sampling (16).

At each site, water samples were collected in 250 mL polypropylene bottle containing 0.4 mL of a 10% solution of sodium thiosulfate (to neutralize residual chlorine) and transported to laboratory in 6 h and 4 ^{0}C. Before the sampling, the sampling bottles were sterilized in autoclave apparatus. Household taps were used for the sampling of residential sites and external attachments were removed before the sampling. Prior to the sampling, the taps were flushed for 2±3 min at full force. In order to determine the water quality, the free residual chlorines, turbidity, total and fecal coliform were analyzed. All the examinations were performed according to Standard Methods for the Examination of Water and Wastewater (17).

Data analysis: The results were analyzed using the Statistical software SPSS and Excel and for the comparison between average parameters ANOVA test was used. Free residual chlorine was measured by a colorimeter kit on annually basis. Most Probable Number (MPN) was done on nine-tube cultivation basis and turbidity test was done using turbidimeter HACH®.

Results

The amount of residual chlorine in the drinking water distribution systems of rural areas of Divandareh in different months is shown in figure 1. In 95% of samples residual free chlorine was in the range of 0 to 0.5 mg/L (with a mean of 0.074 mg/L and standard deviation of 0.19).

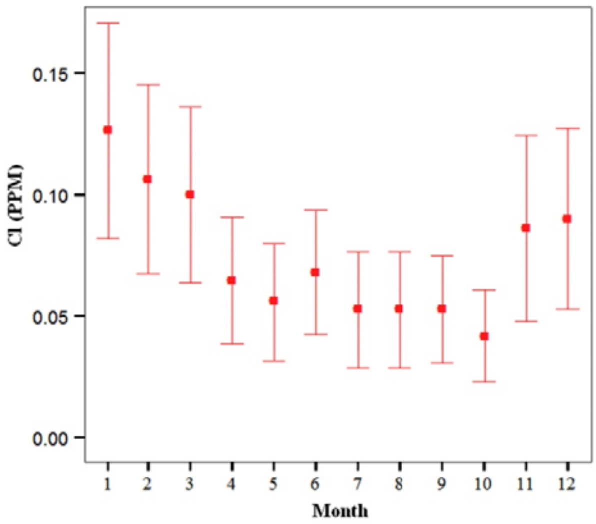

Figure 1) Residual free chlorine in the different months in the drinking water of Divandareh's villages

Figure 2 illustrates the results of turbidity rate in drinking water of Divandareh's villages. The results showed that in 95% of samples, the turbidity was in the range of 0 to 1.8 NTU (Mean of 0.91 NTU and standard deviation of 0.67).

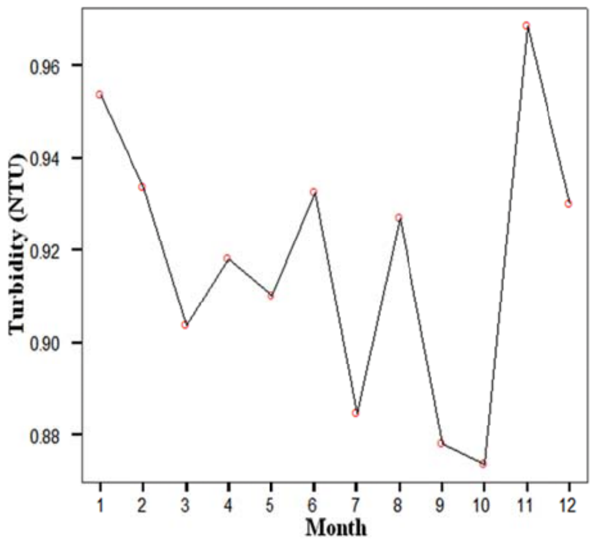

Figure 2) Average of turbidity in different months in drinking water of Divandareh's villages

In Figure 3, the amount of total coliforms in drinking water of Divandareh's villages is shown. Accordingly, the amount of total coliform in 95% of tested samples was in the range of 0 to 240 (MPN/100mL) (Mean of 52.14 (MPN/100mL) and standard deviation of 199.2 (MPN/100mL)).

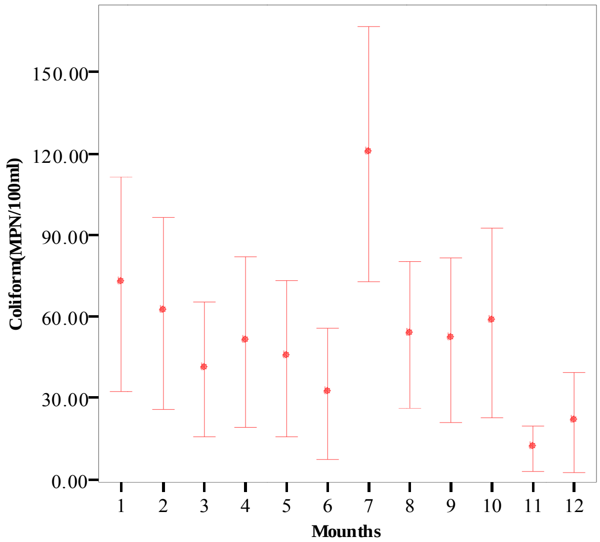

Figure 3) Average of coliforms bacteria in different months in drinking water of Divandareh's villages

Figure 4 presents the results of the thermophilic bacteria rate in the different months in drinking water of Divandareh's villages. In 95% of samples, the amount of thermophilic fecal coliforms was in the range of 0 to 9.1 (MPN/100mL) (Mean of 11.6 (MPN/100mL) and standard deviation of 91.1 (MPN/100mL)).

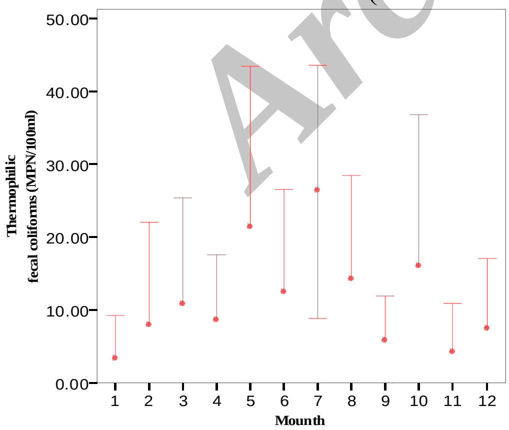

Figure 4) Average of thermophilic fecal coliforms in different months in drinking water of Divandareh's villages

Discussion

The amount of residual chlorine in the drinking water distribution systems of rural areas of Divandareh was in range 0 to 0.5 mg/L. According to Iranian drinking water guidelines, the optimum concentration of free residual chlorine in any point of water distribution network was in the range 0.5-0.8 mg/l and in epidemic conditions and disasters it must be 1 mg/l (18). Therefore, in this area, the amount of residual chlorine is less than standard level. This result is confirmed by Ghaderpoori et al. (1).

The results showed that the turbidity in the drinking water distribution systems was in the range of 0 to 1.8 NTU. According to Iran drinking water standards, the optimum and Maximum Permissible Levels for turbidity are 1 and 5 NTU respectively (19). The water turbidity in samples of this study was in permissible levels. These results confirmed by Ghaderpoori et al and Dehghani et al study in Microbiological quality of drinking water in Shadegan town ship Iran and Saqqez, Iran (1,7).

The amount of total coliforms in 95% of tested samples was in the range of 0 to 240 (MPN/100mL). In this study in 95% of samples, the amount of thermophilic fecal coliforms was in the range of 0 to 9.1 (MPN/100mL). According to WHO and Iranian standards for drinking water, fecal bacteria indicators must not be detectable in any 100 ml sample. In the case of large supplies, where sufficient samples are examined, fecal coliform must not be present in 95% of samples taken throughout any 12-months period. High rate of total and fecal coliforms in the drinking water can be due to failure in the transport system, lack of sanitation in water resource such as the springs and well, lack or failure in the chlorination system and so on. This result is in concord with Dehghani et al, Momba et al., on an overview of biofilm formation in distribution systems and its impact on the deterioration of water quality as well as with Ilkka et al., on how pipeline materials modify the effectiveness of disinfectants in drinking water distribution systems (7,20,21). Furthermore, linear regression test was used to determine the turbidity and residual chlorine effects on the amount of thermophilic coliforms in the water samples in different months. The coefficient of determination (R^2 = 0.047) shows that variables are independent. For instance, the chlorine residual and turbidity have no significant effect on the amount of thermophilic coliforms. The correlation between different months and the amount of the residual chlorine in all samples was evaluated by one-way analysis of variance (ANOVA) and post hock test. Although the effect of changes for chlorine are not significant in comparison between different months (*P*-value=0.001), the changes for chlorine in all months are significant. In addition, the ANOVA test was conducted to determine the effect of different months on the turbidity of water samples during 2011. Although, according to Figure 3, it can be seen that the average turbidity level in February is more than other months, the *P*-value = 0.99 demonstrated that there was no significant difference between the different months and the average turbidity levels measured in the different villages.

According to obtained results in this study:

- The amount of residual chlorine in drinking water distribution systems of rural areas of Divandareh was less than standard.
- The water turbidity in samples of this study was in permissible levels.
- The amount of total coliforms in 95% of tested samples was higher than standard level.
- Linear regression test showed that the turbidity and residual chlorine effects on the amount of thermophilic coliforms in the water samples in different months are independent.
- Failures in the transport system, lack of sanitation in water resource such as springs and well, lack, or failure in chlorination system and so on are causes of high rate total and fecal coliforms in drinking water of Divandareh City.

Footnotes

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Conflict of Interest:
The authors declare no conflict of interest.

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