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Physical, chemical, and microbial quality of drinking water in Sanandaj, Iran

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ABSTRACT

Drinkability of water is determined based on its physical, chemical, and microbial properties. Undesirable changes in these parameters could threaten the health of consumers. The present study aimed to assess the physical, chemical, and microbial parameters of the drinking water sources in Sanandaj, Iran and compare them with the national standard values. This descriptive, cross-sectional study was conducted for 24 months. Samples were collected via simple random sampling from 116 stations in accordance with the principles of water sampling, including 51 stations of Sanandaj water distribution system, 15 reservoir stations, 25 stations for the outlet of the water treatment plant, and 25 stations for raw water. In total, 2,784 samples were obtained from the stations and transferred to the laboratory in standard conditions. Residual chlorine, pH parameters, turbidity, total coliforms, thermophilic coliforms, and heterotrophic plate count (HPC) were measured. Data analysis was performed in SPSS version 18 using t-test and ANOVA. According to the results, the mean values for the physical parameters of turbidity and pH in the water distribution system were 0.9522 NTU and 7.9644, respectively. With regard to the chemical parameters, the mean residual chlorine in the water distribution system was 0.5548 mg/L, and the microbial parameters of total coliforms, thermophilic coliforms, and HPC were 0 MPN/100 mL, 0 MPN/100 mL, and 107.6533 CFU/ml, respectively. Our findings indicated that the mean concentrations of the measured parameters in the water distribution system of Sanandaj were within the national standard limits.

Keywords: Physical Quality, Chemical Quality, Microbial Quality, Drinking Water

Introduction

Water was created without contamination, but the development and industrialization of human societies have caused significant water pollution, reducing water quality.[1] Access to safe drinking water sources is a major concern in many countries across the world. According to the World Health Organization (WHO), 1.1 billion people in the world have no access to clean drinking water.[2] Population growth, rapid urbanization, industrialization, and inappropriate actions have led to numerous environmental issues, one of the most important of which is water pollution.[3]

Statistics suggest that approximately 80% of child deaths occur due to the gastrointestinal diseases (e.g., diarrhea) that are caused by consuming contaminated drinking water.[4] According to the reports in 2009, three children died every minute due to waterborne diseases.[5] In Iran, the need for water is constantly growing not only due to population growth, but also due to the activities of healthcare, industrial, and agricultural sectors. The majority of the qualitative studies in this regard have been

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focused on drinking water, public health, and consumer health.[6, 7]

Water providers and urban water supply systems should guarantee the quality of water, while also ensuring access to adequate water.[8] Therefore, water quality could be assessed by measuring the physical, chemical, and biological properties of water and attempts to reach the global, regional or national standards in this regard.[9, 10] Physical parameters of water are the features that could be distinguished by the visual, tactile, gustatory, and olfactory senses; such examples are the presence of suspended solids, turbidity, color, odor, temperature, residual chlorine, and pH.

Index organisms are the only investigated parameters to evaluate the microbial quality of water. These parameters include total coliforms, total fecal coliforms, and heterotrophic plate count (HPC).[2, 11, 12] Optimal drinking water should be transparent, odorless, non-flavored, and without pathogenic organisms and other harmful compounds.[13, 14] Despite the efforts to improve water quality, waterborne diseases remain highly prevalent across the world; such examples are cholera, typhoid, basil diarrhea, infectious hepatitis, leptospirosis, giardiasis, and gastroenteritis.[15, 16] To determine the quality of drinking water, the physical, chemical, and microbial properties of water should be compared to the standard limits. During 1984-1985, WHO published the first guidelines for drinking water quality, which were last revised in 2003.[17] To date, several studies have been focused on the quality of drinking water in different cities. According to a study by Dehghanitafti *et al*., which aimed to examine the qualitative status of drinking water sources in Taft region in Yazd (Iran), blending the water of several wells into the wells with chemical problems could result in parameter adjustments and adaptation with the standards of drinking water quality.[18]

The results of a research by Dindarloo *et al*. demonstrated that the chemical quality of the drinking water in Bandar Abbas (Iran) was acceptable from a healthcare perspective.[19]

With this background in mind and given the importance of the constant monitoring of water quality in urban water supply facilities, as well as the lack of comprehensive and new research in this regard, the present study aimed to investigate the physical, chemical, and microbial quality of drinking water on a macro level in the treatment plant and raw water systems and reservoirs in Sanandaj, Iran and compare them with the national standards.

Materials and Methods

This descriptive, cross-sectional study was conducted for 24 months (during 21.03.2015-21.03.2017) in the water supply facilities in Sanandaj city. The chemical (e.g., pH and residual chlorine), physical (e.g., turbidity), and microbial parameters of water (e.g., total coliforms, thermophilic coliforms, and HPC) were measured in the raw water, reservoirs, treatment plant, and drinking water facilities of Sanandaj. Samples were collected via simple random sampling from 116 stations, including 51 stations of Sanandaj water distribution system, 15 reservoir stations, 25 stations for the outlet of the water treatment plant, and 25 stations for raw water, in accordance with the principles of water sampling.

In total, 2,784 samples were collected. Sterile glass containers with sodium thiosulfate were used for microbial sampling. The samples were maintained on ice and immediately transferred to the microbiology laboratory of the School of Health at Kurdistan University of Medical Sciences for microbiological tests. To determine the physical and chemical parameters of the samples, clean polyethylene bottles (volume: one liter) were used. Residual chlorine and pH were measured on site, and to measure turbidity, the samples were transferred to the laboratory.[8]

The microbial tests of HPC, total coliforms, and thermophilic coliforms were performed based on the standard methods. To assess the HPC, we used the R2A culture medium at the temperature of 36 ºC for 40 hours. Afterwards, the colonies formed on the agar surface were counted using the Scan 100 intuition colony counter (made in France) and expressed as colony-forming unit per milliliters (CFU/mL). Total coliforms and fecal coliform

bacteria were also measured using the multiple tube fermentation technique in accordance with standard No. 3762 proposed by Iran Institute of Standards and Industrial Research, and the results were presented as MPN/100Ml.[8]

Results and Discussion

The physical, chemical, and microbiological parameters in various sampling sources and their comparison with the national standards are presented in Table 1. Accordingly, the mean values of turbidity and pH as the physical parameters of the water distribution system were 0.9522 NTU and 7.9644, respectively. Residual chlorine (chemical parameter) in the water distribution system was 0.5548 mg/L, and the microbial parameters of total coliforms, thermophilic coliforms, and HPC in the water distribution system were 0 MPN/100 mL, 0 MPN/100 mL, and 107.6533 CFU/ml, respectively.

Table 2 shows the comparison of the physical, chemical, and microbial parameters in different seasons. In addition, the mean maximum values of residual chlorine in autumn, pH in spring, turbidity in summer, total coliforms and thermophilic coliforms in autumn, and HPC in summer have been reported. The values obtained for the studied parameters based on different sources are presented in Table 3. Moreover, the mean maximum values of residual chlorine (samples collected from the treatment plant), pH, turbidity, total coliforms and thermophilic coliforms (samples collected from raw water), and HPC (samples collected from the reservoirs) have been reported.

Table 1. The amount of different parameters measured over two years in different water sources and compared with the national standard value (Standard 1053, 1011 and National primary drinking water regulations)[20, 21, 22]

Parameters	Source	Number of sample	Minimum amount	Maximum amount	Average	Standard deviation	Standard range	Unit
Residual chlorine	System	1225	0	5	0.5548	0.17809	1-0.5	mg/L
	Reservoir	362	0	5	0.6152	0.29022		
	Treatment plant	611	0	1.5	1.0965	0.24637		
PH	Raw water	574	0	0.80	0.0014	0.03339	9-6.5	-
	system	1225	7.32	8.27	7.9644	0.10226		
	reservoir	362	7.12	8.85	8.0245	0.21880		
	Treatment plant	610	7.11	8.35	7.9394	0.19198		
Turbidity	Raw water	574	7.27	8.93	8.1117	0.17722	> 5	NTU
	system	1225	0.14	10.40	0.9522	0.60252		
	reservoir	362	0.16	54.50	1.4081	3.04967		
	Treatment plant	611	0	5.91	1.2662	0.49769		
Total coli forms	Raw water	574	0	38.00	6.8404	6.50125	Zero	MPN/100 mL
	system	1225	0	0	0	0		
	reservoir	362	0	7	0.0331	0.45154		
	Treatment plant	611	0	0	0	0		
Thermophilic coliforms	Raw water	574	0	240	6.6899	15.23457	Zero	MPN/100 mL
	system	1225	0	0	0	0		
	reservoir	362	0	4	0.0193	0.26244		
	Treatment plant	611	0	0	0	0		
HPC	Raw water	574	0	95	4.4974	9.21682	> 500	CFU/ml
	System	1225	0	2700.00	26.7320	107.6533		
	Reservoir	362	0	6500.00	100.745	397.1250		
	Treatment plant	607	0	1600.00	16.4437	96.35667		
	Raw water	574	0	810.00	43.6498	79.88188		

Table 2. Comparison of different parameter values in different seasons

Parameters	Season	Minimum amount	Maximum amount	Average
Residual chlorine	Spring	0.00	1.30	0.5644
	Summer	0.00	1.50	0.5591
	Autumn	0.00	5.00	0.5808
	Winter	0.00	5.00	0.5658
PH	Spring	7.32	8.93	8.0081
	Summer	7.11	8.93	7.9992
	Autumn	7.12	8.93	8.0011
	Winter	7.12	8.85	7.9814
Turbidity	Spring	0.14	31.20	2.0290
	Summer	0.00	54.50	2.9963
	Autumn	0.16	29.30	1.9348
	Winter	0.17	35.00	2.2049
Total coliforms	Spring	0.00	33.00	0.7331
	Summer	0.00	50.00	1.0530
	Autumn	0.00	240.00	2.4857
	Winter	0.00	40.00	1.2539
Thermophilic coliforms	Spring	0.00	17.00	0.4049
	Summer	0.00	29.00	0.7067
	Autumn	0.00	95.00	1.6719
	Winter	0.00	31.00	0.9177
HPC	Spring	0.00	1200.00	24.4023
	Summer	0.00	6500.00	62.3773
	Autumn	0.00	1300.00	33.6585
	Winter	0.00	2700.00	28.9092

According to the information in Table 2, the annual mean residual chlorine was within the standard limit (0.5-0.8) in all the seasons and sampling sources, with the exception of the treatment plant and raw water. The amount of residual chlorine in raw water was lower than the standard, which was due to not using chlorine in raw water. In the water treatment plant, the reason for adding more chlorine is to have the residual chlorine at the lowest point within an optimal limit, which led to the increased amount of residual chlorine. Therefore, the annual mean residual chlorine for distribution systems and reservoirs at the national standard level was within the range of 0.5-0.8.[23]

In a study by Keramati *et al*., the mean residual chlorine content in the drinking water in Gonabad city (Iran) was within the standard range (0.72),[24] which is consistent with the results of the present study. In addition, our findings indicated that the annual mean pH in drinking water systems and reservoirs in Sanandaj city was acceptable and in the national standard range (Standard 1053) (6.5-8.5).[25] According to the studies by Keramati *et al*. and Mokhtari *et al*., the mean pH was within the standard national limit,[3, 24] which is in congruence with the current research.

According to the present study, the annual mean system turbidity was 0.8-1.6 NTU in the drinking water reservoirs of Sanandaj city, which is lower than the maximum contaminant level and higher than the maximum desired value, while within the national standard limit and below 5 NTUs. In a study by Majdi *et al*., the mean turbidity was estimated at 1.36 NTU.[23] In another research by Karrabi *et al*., the total turbidity of the samples was within the standard limit, which is consistent with the results of the present study.[26]

Table 3. Comparison of Different Parameters Based on Resources in 1394 and 1395

Parameters	Source	Year	Minimum amount	Maximum amount	Average
Residual chlorine	system	1394	0.00	5.00	0.5559
	reservoir		0.00	5.00	0.6115
	Treatment plant		0.00	1.5	1.0623
	Raw water		0.00	0.80	0.0028
	system	1395	0.00	1.00	0.5538
	reservoir		0.20	1.50	0.6198
	Treatment plant		0.70	1.40	1.1345
	Raw water		0.00	0.00	0.00
pH	system	1394	7.32	8.27	7.9655
	reservoir		7.12	8.27	8.0352
	Treatment plant		7.11	8.11	7.8448
	Raw water		7.27	8.93	8.0149
	system	1395	7.77	8.05	7.9632
	reservoir		7.33	8.85	8.0113
	Treatment plant		7.48	8.35	8.0439
	Raw water		7.92	8.67	8.2085
Turbidity	system	1394	0.14	2.80	0.8697
	reservoir		0.16	54.50	1.5761
	Treatment plant		0.00	5.91	1.2305
	Raw water		0.00	10.00	2.9394
	system	1395	0.17	10.40	1.0354
	reservoir		0.17	7.26	1.2008
	Treatment plant		0.60	3.02	1.3057
	Raw water		1.70	38.00	10.7414
Total coliforms	system	1394	0.00	0.00	0.00
	reservoir		0.00	7.00	0.0600
	Treatment plant		0.00	0.00	0.00
	Raw water		0.00	240.00	13.3798
	system	1395	0.00	0.00	0.00
	reservoir		0.00	0.00	0.00
	Treatment plant		0.00	0.00	0.00
	Raw water		0.00	0.00	0.00
Thermophilic coliforms	system	1394	0.00	0.00	0.00
	reservoir		0.00	4.00	0.0350
	Treatment plant		0.00	0.00	0.00
	Raw water		0.00	95.00	9.0105
	system	1395	0.00	0.00	0.00
	reservoir		0.00	0.00	0.00
	Treatment plant		0.00	0.00	0.00
	Raw water		0.00	0.00	0.00
HPC	system	1394	0.00	500.00	22.5854
	reservoir		0.00	1600.00	105.00
	Treatment plant		0.00	1600.00	28.4584
	Raw water		0.00	810.00	87.2997
	system	1395	0.00	2700.00	30.9195
	reservoir		0.00	6500.00	95.4938
	Treatment plant		0.00	0.00	0.00
	Raw water		0.00	310.00	3.3103

With regard to the microbial parameters of drinking water, the findings of the current research indicated that the number of the positive samples in terms of total coliforms and thermophilic coliforms in the distribution systems and treatment plant was zero during

both years of the study. On the other hand, two of the samples obtained from the reservoirs were positive for total coliforms and thermophilic coliforms. According to the standards in Iran, drinking water should be free of index bacteria (e.g., thermophilic coliforms), and up to three coliform bacteria could exist in drinking water in 95% of the cases. Therefore, the microbial quality of the water in the studied reservoirs was within the standard limit.[27]

On average, in all seasons and different sections of sampling, the annual mean HPC was at a standard level and lower than the standard 500 CFU/ml. The results of the microbial tests indicated that the water in the system and reservoirs used by the public was healthy on all days of the year, and the overall condition of drinking water was acceptable in terms of the microbial parameters and national standards in this regard.[25] In a study by Jafarzadeh *et al*., the mean thermophilic coliforms was reported to be 1.81, and the standard value was within the appropriate range.[28]

Conclusion

According to the results, the physical, chemical, and microbial parameters in the drinking water reservoirs and distribution systems in Sanandaj were within the national standard range. In conclusion, it is recommended that other physical and chemical parameters, as well as the concentrations of heavy metals, be measured in the drinking water of Sanandaj city

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