RESEARCH ARTICLE
• Arch Hyg Sci 2020;9(3):224-233
• Journal Homepage: http://jhygiene.muq.ac.ir

Investigation of Physicochemical and Microbial Parameters of Drinking Water Supply Sources in Villages of Saqqez, Iran

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A-R-T-I-C-L-EI-N-F-O

Article Notes:
Received: May 05, 2020
Received in revised form: Aug 19, 2020
Accepted: Aug 19, 2020
Available Online: Sep 23, 2020

Keywords:
Drinking water
Fecal coliforms
Water microbiology
Water quality

A-B-S-T-R-A-C-T

Background & Aims of the Study: Providing safe drinking water is one of the most important goals in human societies. It is clear that people's health depends on the provision of favorable drinking water. This study examined the physicochemical and microbial parameters of drinking water resources in the villages of Saqqez, Iran, within 3 months in 2018.

Materials and Methods: This descriptive cross-sectional study was carried out on 24 sources of drinking water supply (i.e., wells and springs) in the villages covered by rural water and sewage in Saqqez within 3 months in 2018. The cultivation of the samples was performed by the most probable number (MPN) technique to evaluate the number of total coliforms and fecal coliforms. Chemical experiments were conducted based on titration, and physical experiments were performed through analytical methods. Finally, SPSS statistical software (version 20) was used for the statistical analysis of the results.

Results: The obtained results of the present study showed that the parameters of turbidity, electrical conductivity (EC), pH, and total dissolved solids (TDS) were within the range of the national and international standards. In addition, the total hardness parameter in 100% of the samples was within the range of national standards; however, it was within the standard range of the World Health Organization in 87.5% of the samples. The levels of total coliforms and fecal coliforms were reported within the range of the national and international standards in 66.67% and 85.82% of the samples, respectively.

Conclusion: According to the obtained results, the parameters, including turbidity, EC, chlorine, pH, and TDS, were in accordance with the national and international standards. Moreover, the levels of total and fecal coliforms were within the range of the national and international standards in 66.67% and 85.82% of the samples, respectively. The maximum values of total coliforms and fecal coliforms were within the range of 6-9 MPN per 100 mL, respectively. These low values can be eliminated with simple chlorination.

Please cite this article as: Yousefi A, Hojati Bonab Z. Investigation of Physicochemical and Microbial Parameters of Drinking Water Supply Sources in Villages of Saqqez, Iran. Arch Hyg Sci 2020;9(3):224-233

Background

One of the goals of the Global Water Organization is the provision of safe drinking water for all people by 2025 (1). The largest populations in the world are deprived of the blessing of having safe water, living in Asia and Africa, and living in rural areas (2). About 80% of the earth's surface is covered with water, 97% of which consisted of the oceans and seas; however, it is too salty to be directly drunk and unusable for human activities. Furthermore, about 2.4% of water resources has trapped in large glaciers and polar ice caps. Therefore, less than 1% of water resources are accessible for drinking, agriculture, and domestic and industrial uses (3).

Access to safe drinking water is an important issue in many countries around the world. According to the World Health Organization (WHO), 1.1 billion people worldwide do not have access to safe drinking water each year (4). Water quality is one of the issues that is directly related to health, personal, and public hygiene. The need for monitoring and ensuring sanitary conditions and standards for drinking water indicates the great importance of water quality control (5). Water quality includes chemical, physical, biological, and radiological qualities (6). Water pollution is an adverse change in physical, chemical, and biological properties endangering human health, survival, and activity of other organisms (7, 8).

Different types of bacteria, viruses, and parasites can easily enter water supply networks and cause acute intestinal diseases (7). The presence of some salts and chemicals in water is essential for humans and their health; nonetheless, some of these chemical parameters may be toxic at low concentrations, and the concentrations higher than standard values can cause various diseases and disabilities for the body in the long term (4, 7).

At present, water quality control in distribution networks is defined as the determination of physical, chemical, and microbial characteristics (8). Industrialization, regardless of sustainable principles, population growth, and mechanized agriculture, has been involved in water pollution in recent years. Especially in developing countries, in some villages, domestic sewage flows through open spaces; this type of flow and waste collection leads to surface water and groundwater pollution (8).

All intestinal pathogens that are transmitted through the fecal route can be transported through water (9). The first indicator of fecal contamination is *Escherichia coli*, which is the opportunistic pathogen inhabiting the large intestine of humans and other animals. The presence of this bacterium in the water is the cause of contamination through fecal sources (10). The index organisms of total coliforms and fecal coliforms are most commonly used to determine the microbial quality of drinking water (11), and aquatic environments are a good place for the growth of microorganisms. The entry of organic matter pollutes the water and makes the environment more suitable for the growth of organisms (12). Because groundwater is less polluted with high storage capacity, it is considered a more important source than surface waters (13).

Recently, the investigation of the microbial status and physicochemical parameters of drinking water supply sources have received much attention. In a study carried out by Mujahid et al., the bacteriological quality of drinking water was studied in Karachi, Pakistan. The results of the aforementioned study showed that there were a large number of coliforms in freshwater, and the most probable number (MPN) index was higher than the permissible level in all samples. Total coliforms were present in 90% of total coliform samples except for 1 sample, and fecal coliforms were observed in 90% of fecal coliform samples except for 1 sample (14). In another study, 15. Pirsaheb et al. measured some water quality parameters of the Chahnimeh 1 reservoir in Sistan and Baluchistan, Iran (15).

In rural areas, providing, distributing, and monitoring water quality is essential due to various problems, such as scattered villages, worn-out water distribution facilities and networks, lack of proper care, distribution of animal wastes in the environment, and low level of public health in the village (13). Saqqez is one of the northern cities of Kurdistan province, Iran, with 4 districts (i.e., Markazi, Imam, Sarshive, and Ziviyeh) and 308 villages, out of which 164 villages are covered by Saqqez rural water and sewage. Therefore, it is necessary to increase the quality of water and compare it with international studies on the microbial future and determine the physic-chemical resources of drinking water supply in the villages of Saqqez. Accordingly, based on the need for continuous monitoring of water quality and comparing it with the national and international standards, this study was conducted to comprehensively investigate and determine the microbial contamination and physicochemical parameters of drinking water in Saqqez villages.

Materials & Methods

The present study was a descriptive cross-sectional carried out on the drinking water supply sources of the villages covered by the rural water and sewage of Saqqez within June 22, 2018, to September 22, 2018. The samples were obtained from the drinking water supply sources of 20 villages, including 12 wells and 12 springs, covered by the rural water and sewage of these 4 districts in Saqqez.

Sampling for the evaluation of the microbial and physicochemical parameters was performed in several steps. The criteria for the selection of villages in each district were the distance from the city center (two villages with a distance of 15 km from the city center, two villages with a distance of 15-15 km, and one village with a distance of more than 30 km) and type of drinking water supply source in each district (two villages with well supply sources, two villages with spring supply sources, and one village with a well and spring supply source). The microbial samples were collected in wide-mouth glass containers made of borosilicate. Before the sterilization of these containers, 10% sodium thiosulfate was used for the neutralization of the residual chlorine.

The secondary contamination of microbial samples was prevented during transporting, sampling, and conducting relevant experiments. Furthermore, coldboxes and ice packs were used for the transfer without contact with the sampling containers. Chemical sampling was carried out in plastic containers with a volume of 3 liters (16). A total of 24 chemical samples and 24 microbial samples were taken from the supply sources.

Physical experiments were performed by the analytical methods, including turbidity (measured with a turbidity meter in terms of Nephelometric Turbidity Units (NTU), Wagtech Ltd., UK), electrical conductivity (EC) (measured with an EC meter in terms of µS/cm, Metrohm, Switzerland), pH (measured with a pH meter, Wagtech Ltd., UK), and total dissolved solids (TDS) (measured with a TDS meter, Hm-Digital, Iran). The chemical experiments, including total hardness and chlorine concentration, were measured by titration. Total hardness was calculated with ethylenediaminetetraacetic acid titration in milligrams per liter, and chloride concentration was determined by potassium chromate titration in milligrams per liter (16).

The microbial experiments included the determination of total coliforms and fecal coliforms (thermophilic), which were performed by the most probable number (MPN). For this purpose, weak and strong for lactose broth culture medium were used for Presumptive test. Brilliant green bile broth was used as the confirmatory test and determination of total coliforms, and EC broth culture medium was employed as the completion test and determination of fecal coliforms (17).

All the materials used in this study were purchased from Merck Company, Germany. Finally, SPSS statistical software (version 20), one-sample t-test, and mean and standard deviation were utilized for the statistical analysis of the obtained data. In addition, the results were compared with the national and international (i.e., the US Environmental Protection Agency (EPA) and WHO) standards (18, 19).

Results

Table 1 shows the mean and standard deviation of the research parameters according to the supply resource (i.e., well or spring). In the well supply source, turbidity (0.76 NTU), TDS (392.35 mg/L), EC (596.59), chloride (497.40), total hardness (255.62), total coliforms (2.16), and fecal coliforms (0.25) were reported with higher mean values, and the higher mean values for the source of the spring were related to pH (7.35). The residual chlorine in all the sources was reported as 0, given that chlorination occurs in storage tanks.

Table 2 shows the mean and standard deviation of each research parameters in the water supply resources according to the different districts of Saqqez. Turbidity in the Ziviyeh district had the highest mean value (0.72), and the lowest mean value (0.63) was related to the central district. pH in the Ziviyeh district had the lowest mean value (7.25), and its highest mean value (7.48) was observed in the central district. The lowest mean value (236.67) of TDS was related to the Sarshive district, and its highest mean value (315.55) was reported for the Imam district.

Table 1) Descriptive statistics of water supply resource parameters (based on the type of supply resource)

Supply resource	Turbidity (NTU)		pH		Total dissolved solids		Electrical conductivity (μS/cm)		Chloride (mg/L)		Total hardness (mg/L)		Total coliforms (MPN per 100 ml sample)		Fecal coliforms (MPN per 100 ml sample)	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Well	0.76	0.16	7.3	0.31	329.3	44.1	596.5	96.1	79.4	18.7	255.6	40.26	2.16	2.55	0.25	0.75
Spring	0.47	0.11	7.3	0.22	279.3	36.1	585.1	71.1	64.3	23.8	190.5	5.53	0.5	1.6	0	0

MPN: The most probable number

Table 2) Descriptive statistics of water supply resource parameters based on the district

		Imam	Ziviyeh	Central	Sarshive
Turbidity	Mean	0.64	0.72	0.63	0.67
	Standard deviation	0.23	0.21	0.21	0.18
pH	Mean	7.27	7.25	7.48	7.33
	Standard deviation	0.19	0.35	0.26	0.29
Total dissolved solids	Mean	311.55	294.32	308.23	236.67
	Standard deviation	52.69	40.37	46.33	51.64
Electrical conductivity	Mean	651.75	511.5	595.42	613.25
	Standard deviation	59.72	84.13	70.4	82.44
Chloride	Mean	89.33	71.47	67.0	69.68
	Standard deviation	26.19	10.54	23.67	16.95
Total hardness	Mean	233	233.67	238.68	230.33
	Standard deviation	48.18	28.55	56.21	55.59
Total coliform	Mean	2.17	0.5	1.67	0.5
	Standard deviation	3.71	1.22	1.86	1.22
Fecal coliform	Mean	0	1	0	1
	Standard deviation	0	2	0	1

Table 3) Compliance of parameter percentage with standards

		Percentage	Chlorine	Turbidity	pH	Total dissolved solids	Electrical conductivity	Chloride	Total hardness	Total coliforms	Fecal coliforms
Water supply resource	Iran	Maximum desired								66.67	85.82
		Maximum permissible								-	-
		Out of standard range								33.33	14.28
	WHO	Maximum desired								66.67	85.72
		Maximum permissible								-	-
		Out of standard range								33.33	14.28
	EPA	Maximum desired								66.67	85.72
		Maximum permissible								-	_
		Out of standard range								33.33	14.28

WHO: World Health Organization
EPA: Environmental Protection Agency

The EC in the Ziviyeh district had the lowest mean value (511.50), and the highest mean value (651.75) was observed in the Imam district. Chloride was reported with the lowest average (67) in the central district, and its highest mean value (89.33) was observed in the Imam district. The total hardness in the Sarshive district had the lowest mean value (302.33), and its highest mean value (238.68) was related to the central districts. The highest mean value of total coliform (2.17) was observed in the Imam district, and the Ziviyeh and Sarshive districts were reported with the lowest mean value (0.50). Finally, the parameter of the fecal coliforms was reported in its highest mean value (1) in the Sarshive and Ziviyeh districts.

In this study, it was observed that the minimum and maximum turbidity, pH, TDS, EC, chloride, total hardness, total hardness, and fecal coliforms were reported as 0.35-0.98 NTU, 6.9-7.9, 280-410 mg/L, 455.5-742 µS/cm, 37.52-112.56 mg/L, 182-328 mg/L, 90 MPN per 100 ml sample, and 60 MPN per 100 ml sample, respectively.

Table 3 tabulates the compliance percentage of the parameters with the national and international standards. Turbidity, EC, pH, and TDS were within the range of the national and international standards. Furthermore, the total hardness parameter in 100% of the samples was observed within the range of the national standard, and it was reported within the WHO standard range in 87.5% of the samples. Total coliforms and fecal coliforms were within the range of the national and international standards in 66.67% and 85.82% of the samples, respectively.

Table 4 shows the inferential statistics of the parameters (t-test) and comparison of the measured values of each parameter with the desired and permissible values of the national and international standards. The turbidity parameter was higher than the desired value of the WHO (with a significance of 0.0). Total hardness was higher than the desired value recommended by the Iranian and WHO standards (with a significance of 0.1).

Total coliforms and fecal coliforms were higher than the favorable and permissible values of the national and international standards (with significances of 0.14 and 0.166,

Table 4) One-sample t-test and mean comparison of parameters with the favorable and permissible values of the standards

Parameter	Standard	Range	-8.244, P>0.5	Degree of freedom	Significance	Description
Turbidity	Iran	Desired	-108.5, P>0.5	23	0.000	Significant, less than the desired value
		Permissible	-4.65, P>0.5	23	0.000	Significant, less than the permissible value
	WHO	Desired	-108.5, P>0.5	23	0.000	Significant, more than the desired value
		Permissible	-108.5, P>0.5	23	0.000	Significant, less than the permissible value
	EPA	Permissible	-71.21, P>0.5	23	0.000	Significant, less than the permissible value
Total dissolved solids	Iran	Desired	-132.687, P>0.5	23	0.000	Significant, less than the desired value
		Permissible	-71.21, P>0.5	23	0.000	Significant, less than the permissible value
	WHO	Desired	-19.355, P>0.5	23	0.000	Significant, less than the desired value
		Permissible	-50.97, P>0.5	23	0.000	Significant, less than the permissible value
Electrical conductivity	Iran	Desired	-41.113, P>0.5	23	0.000	Significant, less than the desired value
Chloride	Iran	Desired	-76.227, P>0.5	23	0.000	Significant, less than the desired value
		Permissible	-29.409, P>0.5	23	0.000	Significant, less than the permissible value
	WHO	Desired	-41.113, P>0.5	23	0.000	Significant, less than the desired value
		Permissible	-41.113, P>0.5	23	0.000	Significant, less than the permissible value
	EPA	Permissible	-3.67, P>0.5	23	0.000	Significant, less than the desired value
Total hardness	Iran	Desired	-28.791, P>0.5	23	0.001	Significant, more than the desired value
		Permissible	-3.67, P>0.5	23	0.000	Significant, less than the permissible value
	WHO	Desired	-1.74, P>0.5	23	0.001	Significant, more than the desired value
		Permissible	-2.659, P>0.5	23	0.095	Significant, less than the permissible value
Total coliform	Iran	Desired	-2.659, P>0.5	23	0.014	Significant, more than the desired value
	WHO	Desired	-2.659, P>0.5	23	0.014	Significant, more than the desired value
	EPA	Permissible	-1.430, P>0.5	23	0.014	Significant, more than the desired value
Fecal coliform	Iran	Desired	-1.430, P>0.5	23	0.166	Significant, more than the desired value
	WHO	Desired	-1.430, P>0.5	23	0.166	Significant, more than the desired value
	EPA	Permissible	-8.244, P>0.5	23	0.166	Significant, more than the permissible value

WHO: World Health Organization
EPA: Environmental Protection Agency

Table 5) Matrix of correlation of studied parameters according to the water supply resource

		Turbidity	pH	Total dissolved solids	Electrical conductivity	Chloride	Total hardness	Total coliforms	Fecal coliforms
Turbidity	Correlation	1							
pH	Correlation	-0.159	1						
Total dissolved solids	Correlation	0.371	-0.14	1					
Electrical conductivity	Correlation	0.198	-0.3	0.646**	1				
Chloride	Correlation	0.211	-0.08	0.056	0.208	1			
Total hardness	Correlation	0.698**	0.000	0.309	0.168	0.494**	1		
Total coliforms	Correlation	0.631**	0.101	0.172	0.332	0.268	0.530**	1	
Fecal coliforms	Correlation	0.465**	0.089	0.205	-0.013	-0.113	0.154	0.245	1

** P<0.01

respectively), and other parameters were lower than the permissible and desired values of the national, WHO, and EPA standards. The mean value of the pH parameter in the present study was also shown to be within the confidence range of the desired value of this parameter (i.e., 5.8 in Iran); therefore, it can be concluded that the pH parameter was at the desired level of the Iranian community. Additionally, the obtained mean value was observed to be within the confidence range of the permissible value of this parameter (i.e., 5.9 in Iran); consequently, it can be inferred that the pH parameter was within the permissible national standards.

The mean value of the pH parameter, compared to the WHO indicators, was shown to be within the confidence range of the desired value of this parameter (i.e., 5.8 set by the WHO); as a result, it can be said that the pH parameter was at the desired level recommended by the WHO. Compared to WHO indicators, the mean value of the pH parameter was observed not to be within the confidence range of the permissible value of this parameter (i.e., 8-8.5 set by the WHO); therefore, it can be concluded that the pH parameter was not within the permissible limits recommended by the WHO.

Table 5 tabulates the correlation matrix of the studied parameters. The turbidity parameter positively and significantly correlated with the total hardness parameter (0.69), total coliforms (0.63), and fecal coliforms (0.46). The TDS parameter positively and significantly correlated with the EC parameter (0.64). The chlorine parameter had a positive and significant correlation with the total hardness parameter (0.49), and the total hardness parameter had a positive and significant correlation with the total coliforms (0.53). The rest of the parameters were not significantly correlated.

Discussion

The results of the present study showed that in the villages of Saqqez, EC, pH, and TDS of the supply sources were within the desired national standards. pH and TDS were in the optimal WHO levels, and the turbidity parameter was also within the range of the national and WHO standard limits. In a study conducted by Atefeh et al. in Lavasan-e Kouchak district, Tehran, Iran, (2013), the parameters of EC, turbidity, pH, and TDS were lower than the values set in the national standards (20). Another study was carried out by Hosseinzadeh et al. on the evaluation of the microbial status of rural drinking water sources of Romshegan village in Kuhdasht, Iran. In the aforementioned study, it was clarified that there were 27, 34, 36, 21, and 24 wells contaminated with Escherichia coli, Citrobacter koseri, Citrobacter freundii, Enterobacteriaceae, and klebsiella, respectively. In addition, only three wells were free of any microbial agents. All the samples were reported with a pH with an average of 7.6 within the national standard range, EC with an average of 951 µS/cm, and minimum and maximum levels of fecal coliforms as 4 and 100, respectively (21).

In the present study, the pH and EC in the supply sources were within the ranges of national, WHO, and EPA standards. Furthermore, the minimum and maximum levels of fecal coliforms were determined to be within the range of 3-6. In a study carried out by Ahmadi et al. on the chemical quality of rural drinking water resources in Neishabour, Iran, (2013), it was observed that TDS in 83 wells were higher than the global standards and lower than the Iranian standards (22). In the current study conducted on the villages of Saqqez, this parameter in all the water supply sources (i.e., wells and springs) met the required national, WHO, and EPA standards.

Masindi et al. carried out a study on the datasets on the physicochemical and microbial properties of raw water in four drinking water treatment plants in South Africa. The results of the aforementioned study showed that the average total coliforms and E. coli in the four studied treatment plants were 9272.8 and 136.1 counts/100 mL, respectively (23). In another study, Yousefi et al. investigated the microbial and physicochemical quality of storage tanks and drinking water distribution networks in the villages of Saqqez. The results showed that the total coliforms and fecal coliforms in all the studied areas were 0 (24), which is not in line with the findings of the present study. This can be due to the fact that the present study investigated the water resources of Saqqez without chlorination (i.e., wells and springs); the chlorination can remove 100% of the total coliforms and fecal coliforms.

In another study, Mohammadi et al. evaluated the physical and chemical analysis of potable groundwater resources in the rural areas of Babol, Iran, and observed that turbidity was reported within the range of 0.10-13.8 NTU, considered within the desired range for 56.4% of samples, permissible range for 35.9% of samples, and beyond the permissible limit for 7.7% of samples. Moreover, total hardness was observed to be within the range of 238-578. In addition, total hardness was within the desired, permissible, and higher than permissible limits for 25.7%, 69.2%, and 5.13% of samples, respectively (25). In the present study conducted on the water supply sources of Saqqez villages, the average values of turbidity and TDS were 0.66 and 312.9, which were much lower than the national standards.

A study by Gopalakrishnan et al. surveyed four drinking water sources at the International Research Institute for Tropical Areas in India over 17 years within 1994 to 2010. They observed that the mean values of total coliform in borewell 1 source, borewell 2 source, Manjeeva supply source, and International Crops Research Institute supply source were reported as 22.9, 20, 13.4, and 0 over 17 years, respectively. Three sources with the total coliforms also had fecal contamination requiring treatment (i.e., disinfection) before consumption (26). In the present study on Saqqez villages, out of 12 studied wells, 6 wells were contaminated with total coliforms; however, the average value of total coliforms in these 6 wells was reported as 4.33. According to the comparison of the averages, it can be concluded that the wells supplying the villages of Saqqez had a much better condition in terms of pollution.

Conclusion

In this study, the parameters of turbidity, EC, chlorine, pH, and TDS were within the ranges of the national and international standards. The total coliforms and fecal coliforms were within the ranges of the national and international standards in 66.67% and

85.82% of the samples, respectively. Furthermore, 33.33% and 14.28% of the samples had total coliforms and fecal coliforms higher than the national and international standard values, respectively. The reason for the aforementioned finding is the lack of chlorination in the supply sources (i.e., wells and springs). The maximum values of total coliforms and fecal coliforms were MPN 6-9 per 100 mL, respectively; these low values can be eliminated with simple chlorination, and the measured parameters are generally acceptable with appropriate desirability.

Footnotes

Acknowledgements

The authors would like to express their gratitude to Sediq Mohammadzadeh (former director of Rural Water and Wastewater Company of Saqqez and current director of Rural Water and Wastewater Company of Kurdistan) and Deputy of Research and Technology of Islamic Azad University who cooperated and coordinated during the research project.

Funding

The current study was financially supported by a grant from Bonab Islamic Azad University.

Conflict of Interest

The authors declare that there is no conflict of interest.

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