Original Article

An Investigation into the Status of Water Quality Health Indicators of the Swimming Pools in Tehran in 2015

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Abstract

Background: Poor quality of water in swimming pools may cause health problems and transmission of infectious diseases to swimmers. The aim of this study was to study the status of Water Quality Health Indicators of the swimming Pools in Tehran in 2015. **Materials and Methods:** This cross - sectional study was conducted in the 24 pools (n=288) in west of Tehran. Residual chlorine, temperature and pH were measured in field and microbial tests according to standard protocols. The SPSS software was used for data analysis. **Results:** Average residual chlorine, pH, pool and Jacuzzi temperature, were calculated as 1.7 ± 1.05, 7.70 ± 0.24, 26.92 ± 0.97, 39.39 ± 1.48, respectively. Heterotrophic plate count (HPC) in 5.21%, total coliforms in 9.4% and fecal coliforms 17% of the samples were above the standard level. A significant but inverse correlation between residual chlorine and HPC, total coliform and fecal coliform were found. **Conclusion:** Results showed that the Water Quality Health Indicators of the Swimming Pools in more than 80% of pools as compared to standards is at desirable and expected levels. To improve the sanitary conditions of other pools, standards compliance and sanitary requirements and regular and periodic monitoring of above indicators is necessary.

Keywords: Chemical quality; Health indicators; Swimming pools

Introduction

Swimming pools are one of the most popular and attractive sports places, and swimming is an enjoyable and interesting sport particularly in hot seasons. [1] In addition to creating vitality and spiritual expansion, this sport has certain and known effects on physical health, especially in muscles and joints. [2] Inappropriate maintenance and monitoring of swimming pools can lead to serious hazards to the swimmers' health. It is necessary to properly manage and consistently monitor swimming pools to make sure about water treatment methods and health so as to protect public health. [3] From the standpoint of health, the physical, chemical, and microbial quality of water used in swimming pools should be as desirable and standard as drinking water. Failure to comply with standards brings about serious hazards to the swimmers' health leading to the development of different diseases among them. In many cases, the risk of disease or infection caused by swimming pools is related to fecal contamination of water. Fecal contamination may result from animal waste in outdoor swimming pools, accidental or involuntary release of urine and feces by swimmers, or other pollution sources. [4-6] Other microbial hazards and diseases include gastrointestinal diseases (cholera, typhoid fever, shigellosis, and infectious hepatitis A and E), eye diseases (trachoma and conjunctivitis), ear, nose and throat diseases (infectious sore throat), and skin diseases (different types of piedra, fungal infection between the toes, and infections caused by *Mycobacterium marinum*). [7] In order to become aware of water quality health in swimming pools, indices related to physical, chemical, and microbial quality of swimming pool water should be measured and recorded at certain times so as to make sure about the health of swimming pool water. Parameters like water temperature, turbidity, pH, hardness and alkalinity, microbial population including fecal coliforms, heterotrophic bacteria, *Staphylococcus aureus* bacteria, fecal streptococci, and *Pseudomonas aeruginosa* are usually controlled in

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swimming pool water. [8-11] In a review study carried out over 1992-2003 in England, out of 89 reported outbreak of infectious diseases, public swimming pools were reported as the most common and abundant spread source of such diseases (39% of all cases). [12] In 2008, another study was carried out in order to evaluate the quality of water in swimming pools, and the results showed that 67% of the 462 collected samples complied with microbiology standard while 32.9% did not. [13] In the study conducted on public swimming pools in Amman by Rabi et al. the bacteriological quality of water, residual chlorine, pH, and temperature were respectively 43.5%, 50.6%, 12.2%, and 51.2% inconsistent with the standard. [14] The most important and effective factors in making swimming pool water healthy and protecting the swimmers' health include consistent maintenance of the desired level of water quality indicators in swimming pools and controlling and monitoring of water health in order to prevent the spread of pathogenic agents that are commonly transmitted through contaminated swimming pool water. [15] Compliance with the standards always plays an effective role in preventing the spread of pathogens. The present study was carried out in order to examine the health indicators of water in the swimming pools in northwest of Tehran in 2015.

Materials and Methods

The present study was a cross-sectional descriptive-analytic investigation that was carried out in 24 swimming pools in northwest of Tehran over a period of 6 months in 2015. The swimming pools were selected by a cluster random sampling method. A total of 288 samples were collected; 12 samples from each swimming pool over a period of six months. The samples were retrieved once every two weeks on Fridays and after a swimming shift. Out of the 288 samples, 140 belonged to the pools and 48 to the Jacuzzis. Samples were retrieved from a depth of 20 cm in order to determine temperature, residual chlorine, pH, HPC, total coliform, fecal coliform of the water of the swimming pools. Free residual chlorine and pH were measured using portable kits, and the temperature with a thermometer. According to the book of standard methods, culture, identification and enumeration of HPC, total coliform, and fecal coliform of the samples were carried out after they were transferred to the laboratory (under specific conditions in a special box at a temperature of 6°C and in a time period of below 2 hours). To keep the data of the swimming pools confidential, the results were reported anonymously in the form of swimming pool code. After the data were fed into SPSS 16.0, they were described in tables of frequency, central and distribution indices, and Pearson correlation coefficient was used to determine the relationship between the numerical variables, so that the state of health quality of the water in the swimming pools with desirable level (determined standards) can be compared and reported.

Results

The measurement results of physicochemical and bacteriological parameters of studied pools are presented in Table 1.

The highest bacterial load and difference in residual chlorine and pH were related to the samples retrieved in July-August. The results showed that the level of residual chlorine, pH, pool temperature, Jacuzzi temperature, HPC, total coliform, and fecal coliform was desirable in 72.6%, 86%, 89.6%, 79.15%,

Table 1: Mean and standard deviation of physicochemical and microbial parameters in water of swimming pools, Tehran.

Variables / Pool Code	Residual chlorine (mg/l)	pH	Pool temperature (°C)	Jacuzzi temperature (°C)	HPC (CFU/100 ml)	Total coliform (MPN/100 ml)	Fecal coliform (MPN/100 ml)
	N=288	N=288	N= 192	N= 48	N=288	N=288	N=288
1	1.87 ± 1.27	7.8 ± 0.21	27.5 ± 0.92	39 ± 2.82	496.16 ± 1422/16	212.33 ± 489.48	7.16 ± 16.73
2	1.68 ± 0.85	7.7 ± 0.12	26.37 ± 1.68	38.5 ± 0.7	63.66 ± 81.33	116.66 ± 404.14	3.58 ± 12.41
3	1.53 ± 1.16	7.76 ± 0.07	26.62 ± 1.06	40.5 ± 3.5	712.83 ± 2056.3	5.41 ± 12.33	1.41 ± 2.84
4	1.25 ± .92	7.76 ± 0.14	26.75 ± 0.88	38.5 ± 0.7	2859.18 ± 5927.9	147.58 ± 371.08	105.83 ± 315.97
5	1.83 ± 0.53	7.7 ± 0.17	26.25 ± 1.03	37.5 ± 2.12	91.85 ± 211.3	0	0
6	2.45 ± 0.39	7.75 ± 0.07	26.25 ± 1.28	38.5 ± 0.7	14.91 ± 12.89	0.75 ± 2.59	0
7	1.56 ± 1.32	7.76 ± 0.33	26.25 ± 1.98	40 ± 2.82	98.75 ± 199.09	8.25 ± 13.23	1 ± 1.8
8	1.58 ± 1.17	7.76 ± 0.33	26.75 ± 0.88	41.5 ± 2.12	414.75 ± 1030.35	136.41 ± 342.66	9.83 ± 16.91
9	1.8 ± 1.15	7.47 ± 0.16	26.37 ± 1.06	39.5 ± 0.7	103.58 ± 112.78	16.16 ± 30.57	1.5 ± 3.5
10	1.72 ± 1.13	7.7 ± 0.31	27 ± 1.19	39.5 ± 0.7	170.16 ± 336.33	234.75 ± 485.52	184.91 ± 427.46
11	2.62 ± 0.82	7.65 ± 0.19	26.75 ± 0.7	39.5 ± 0.7	37.66 ± 90.13	0	0
12	1.85 ± 0.74	7.75 ± 0.07	27.37 ± 0.51	40 ± 1.41	637.58 ± 1609.95	2.08 ± 3.8	0.66 ± 1.55
13	0.9 ± 1.13	7.76 ± 0.2	26.75 ± 0.46	39 ± 1.41	937.16 ± 1722.88	47.41 ± 130.24	20.33 ± 59.82
14	1.31 ± 1.03	7.58 ± 0.24	27 ± 0.53	39.5 ± 0.7	197 ± 324.57	227.83 ± 468.47	130.33 ± 344.14
15	1.92 ± 1.28	7.75 ± 0.11	27.25 ± 0.46	40.5 ± 0.7	226.08 ± 450.16	190.41 ± 425.08	0.83 ± 1.99
16	1.15 ± 0.92	7.76 ± 0.07	27.5 ± 0.53	39 ± 1.41	1610.41 ± 3462.12	129.75 ± 313.15	36.91 ± 73.02
17	0.8 ± 0.7	7.74 ± 0.12	27.37 ± 0.51	39.5 ± 2.12	60.09 ± 69.19	2.08 ± 2.9	0.33 ± 1.15
18	1.25 ± 0.96	7.82 ± 0.28	26.62 ± 0.51	38.5 ± 0.7	114.58 ± 147.57	2.01 ± 2.5	0.75 ± 2.59
19	2.45 ± 1.11	7.73 ± 0.38	27.25 ± 0.7	40.5 ± 2.12	7.33 ± 8.43	0	0
20	1.25 ± 0.96	7.55 ± 0.56	27.37 ± 0.74	40.5 ± 0.7	38 ± 56.15	0	0
21	1.7 ± 0.68	7.66 ± 0.17	27.37 ± 0.91	39.5 ± 0.7	830.75 ± 2636.32	6 ± 14.32	0.33 ± 1.15
22	2.58 ± 0.7	7.63 ± 0.29	27 ± 0.53	38.5 ± 0.7	21.25 ± 31.03	0.75 ± 2.59	0
23	1.55 ± 0.98	7.73 ± 0.09	27.12 ± 0.64	40 ± 1.41	250.5 ± 621.37	0.66 ± 1.55	0.33 ± 1.15
24	2.25 ± 0.45	7.73 ± 0.13	27.37 ± 0.74	38 ± 1.41	65.75 ± 95.32	0	0

78.5%, 96.1%, and 83% of the cases, respectively. Regarding physiochemical parameters, residual chlorine in 79 samples, pH in 40 samples, pool temperature in 20 samples, and Jacuzzi temperature in 10 samples did not comply with the standard. Microbial parameters including HPC, total coliform, and fecal coliform did not comply with 21.5%, 4.9%, and 17% of the samples, respectively [Table 2].

Pearson correlation coefficient and the significance level of the data are presented in Table 3. As seen, there is a reverse significant relationship between the amount of residual chlorine and values of HPC (p=0.0001, r=0.295), total coliform (p=0.0001, r=-0.327), and fecal coliform (p=0.0001, r=-0.218). Also, there was a significant relationship between the free residual chlorine and pH (p=0.0001, r=0.239). The results also showed that there was a direct and significant relationship between HPC and total coliform (p=0.0001, r=0.233) and total coliform and fecal coliform (p=0.0001, r=0.664).

The diagram of changes in the residual chlorine and fecal coliform in the swimming pools under study is presented in Figures 1 and 2.

Discussion

To preserve public health with regard to and bacteriological physicochemical factors such as the amount of residual chloride, pH, water temperature, the quality of the water in swimming pools needs to be continuously controlled and monitored so as to make sure about the health of the water in the swimming pools for the health supervisors and swimmers.

Nowadays, chlorination is the commonest method of disinfecting

Table 2: Mean standard deviation, range and percentage of non- standard, physicochemical and microbial parameters in water of swimming pools, Tehran.

Month Parameters		April	May	June	July	August	September	Total	Standard
Residual chlorine (mg/l)	M ± SD	1.74 ± 1.1	1.72 ± 1.1	1.6 ± 1.1	1.66 ± 1.1	1.54 ± 1.1	1.97 ± 0.8	1.7 ± 1.1	
	Min and Max	0-3	0-4	0-3.5	0-3	0-3.5	0-3.5	0-4	1-3
	Non-standard (%)	12 (25)	12 (25)	15 (31.2)	13 (27.1)	18 (37.5)	9 (18.8)	79 (27.4)	
pH	M ± SD	7.72 ± 0.2	7.69 ± 0.3	7.7 ± 0.2	7.7 ± 0.2	7.76 ± 0.2	7.65 ± 0.3	7.7 ± 0.2	
	Min and Max	6.8 – 8.2	6.8 – 8.2	7.2 - 8	6.8 – 8.2	7.2 – 8.2	6.8 – 8.2	6.8 – 8.2	7.2-7.8
	Non-standard (%)	5 (10.4)	7 (14.6)	5 (10.4)	8 (16.7)	10 (20.9)	6 (12.5)	41 (14.3)	
Pool temperature (°C)	M ± SD	26.93 ± 1.3	26.82 ± 1	26.86 ± 1	26.8 ± 1	26.91 ± 0.8	27.34 ± 0.7	26.92 ± 0.9	
	Min and Max	23 - 28	24 - 29	25-29	24-28	25-28	26-29	23-29	26-28
	Non-standard (%)	2 (6.2)	4 (12.5)	6 (18.7)	3 (9.3)	3 (9.3)	2 (6.2)	20 (10.4)	
Jacuzzi temperature (°C)	M ± SD	39.1 ± 1.5	40 ± 2.8	39.8 ± 1.3	38.6 ± 0.5	38.6 ± 1.5	39.6 ± 1.5	39.43 ± 1.4	
	Min and Max	37-43	38 - 42	38-41	38-39	37-40	36-43	36-43	36-40
	Non-standard (%)	4 (50)	1 (12.5)	2 (25)	0	0	3 (37.5)	10 (20.8)	
HPC cfu/100	M ± SD	270.4 ± 847.7	146.7 ± 691.6	859.7 ± 3124	373.5 ± 1083.4	525.7 ± 1728.5	281.6 ± 1431	409.6 ± 1692.7	
	Min and Max	0 - 5500	0 - 4800	0-18400	0-5000	0-9200	0-900	0-18400	<200
	Non-standard (%)	10 (20.8)	5 (10.4)	12 (25)	10 (20.8)	18 (37.5)	7 (14.6)	62 (21.5)	
Total coliform (MPN/100 ml)	M ± SD	38.4 ± 167.4	52.08 ± 232	40.3 ± 170.4	34.5 ± 186.9	172.06 ± 428.3	34.3 ± 170.4	61.9 ± 247.2	
	Min and Max	0 - 1100	0 - 1200	0 - 1100	0 - 1280	0 - 1400	0 - 1100	0 - 1400	<500
	Non-standard (%)	1 (2.1)	2 (4.2)	2 (4.2)	1 (2.1)	6 (12.5)	2 (4.2)	14 (4.9)	
Fecal coliform (MPN/100 ml)	M ± SD	8.95 ± 37.1	1.6 ± 6.4	5.97 ± 25.1	2.16 ± 7.2	98.2 ± 313.4	9.54 ± 45.5	28.01 ± 134.1	
	Min and Max	0 - 210	0 - 43	0 - 150	0 - 43	0 - 1200	0 - 240	0 - 1200	<1
	Non-standard (%)	6 (12.5)	7 (14.6)	10 (20.8)	8 (16.7)	14 (29.2)	4 (8.3)	49 (17)	

Table 3: Correlation matrix between parameters of Available in water of swimming pools, Tehran.

Parameters	Temperature (°C)	Residual chlorine (mg/l)	pH	HPC (cfu/100)	Total coliform (MPN/100 ml)	Fecal coliform (MPN/100 ml)
Temperature (°C)	r=1	r= - 0.021 p=0.722	r= 0.163 p=0.006	r= 0.085 p=0.153	r= 0.08 p=0.178	r= 0.06 p=0.309
Residual chlorine (mg/l)	r= - 0.021 p=0.722	r=1	r= - 0.239 p=0.0001	r= - 0.295 p=0.0001	r= - 0.327 p=0.0001	r= - 0.218 p=0.0001
pH	r= 0.163 p=0.006	r= - 0.239 p=0.0001	r=1	r= - 0.002 p=0.971	r= - 0.07 p=0.239	r= - 0.097 p=0.099
HPC (cfu/100)	r= 0.085 p=0.153	r= - 0.295 p=0.0001	r= - 0.002 p=0.971	r=1	r= 0.233 p=0.0001	r= 0.091 p=0.125
Total coliform (MPN/100 ml)	r= 0.08 p=0.178	r= - 0.327 p=0.0001	r= - 0.07 p=0.239	r= 0.233 p=0.0001	r=1	r= 0.664 p=0.0001
Fecal coliform (MPN/100 ml)	r= 0.06 p=0.309	r= - 0.218 p=0.0001	r= - 0.097 p=0.099	r= 0.091 p=0.125	r= 0.664 p=0.0001	r=1

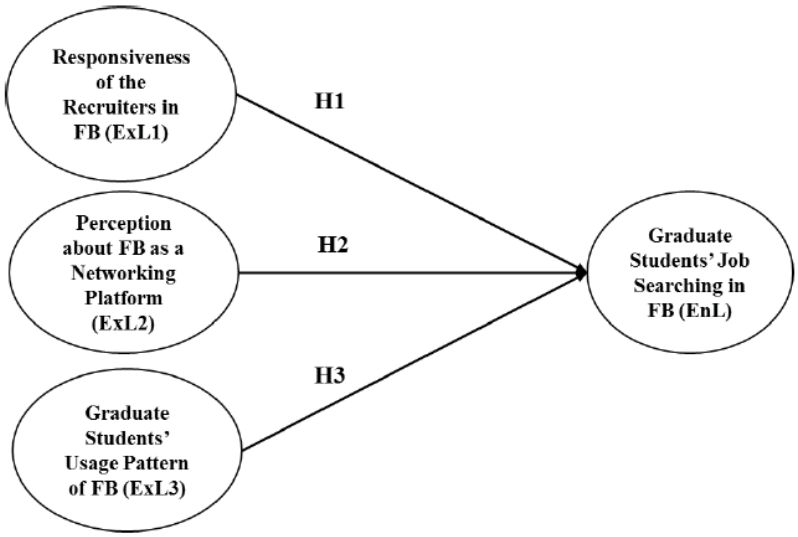

Figure 1: The mean of residual chlorine and fecal coliforms in the studied pools.

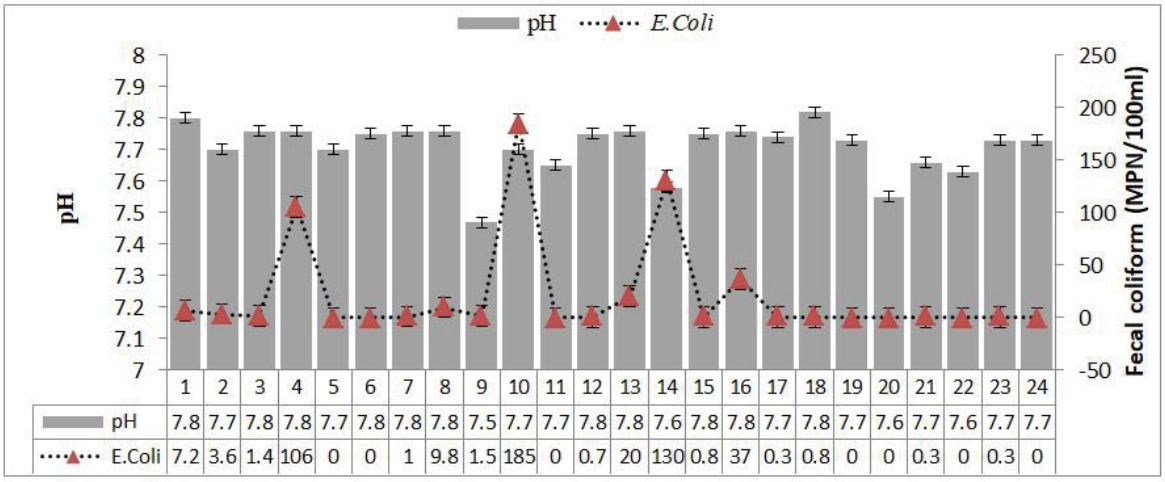

Figure 2: The mean of pH and fecal coliforms in the studied pools.

water of swimming pools, and according to standards, its residual amount in the water has been determined as 1-3 mg/l. [16-18] In the present study, the mean amount of residual chlorine was 1.7 mg/l, and below the standard level in 27.4% of the samples, while the same variables in the study carried out by Rasti et al. [19] were respectively 1.5 mg/l and 39%, which indicates a higher level of compliance with the standards and better conditions in the present study. Moreover, the results of the studies carried out by Zezvali et al. [20] Nikayin et al. [21] Ehrampoush et al. [22] and Yusefi [23] showed a lower mean level of residual chlorine with respectively 1.6 mg/l, 1.2 mg/l, 0.55 mg/l, and 1 mg/l, and higher level of noncompliance of respectively 33%, 43%, 100%, and 56.5% with standards compared to the present study. In addition, in the studies conducted by Shahriyari et al. 24 and Ghane'iyan et al. [11] the mean level of residual chlorine was reported to be 1.89 mg/l and 2.04 mg/l, respectively, which were higher than the level reported in the present study. At the same time, the level of their noncompliance with the standards compared to the present study was higher and respectively 58.85% and 55.82%, which shows a better condition of water quality of the swimming pools under investigation in the present study.

To achieve the maximum efficiency in disinfection through chlorination, it is necessary to regulate pH as one of the most important chemical properties of swimming pool water. Standard pH for water of swimming pools during disinfection through chlorination is 7.2-7.8. High water pH reduces the effectiveness of chlorine and prevents formation of hypochlorous acid (HCIO) as a strong bactericide, such that in pH levels of over 8 and 8.5, only 21% and 12% of the chlorine will respectively be in form of HCIO which is an effective disinfectant. [16-18] In the present study, mean pH was 7.7 which complied with the standard in 85.7% of the samples. The mean pH in the present study was similar to those of the studies conducted by Zezvali et al. [20] and Ghane'ian et al. [11] with respectively 83.7% and 84.73% of compliance with standard. The results of the study carried out by Rasti et al. [19] indicated 88% of compliance with the standard. According to the results of research, in 2.8% of the cases, a pH level of lower than the standard level leads to erosion of the facilities, excessive disinfection, and irritation of the swimmers' eyes and skin. Moreover, in 11.5% of the cases, pH was over the standard level, which led to sedimentation, decrease in efficiency and cytotoxicity of chlorine, increase in turbidity and color of the water, decrease in the lifetime of filters, and irritation the swimmers' eyes and skin.

The standard temperature of swimming pools and Jacuzzis is respectively 26-28°C and 36-40°C 17, 18. In the present study, the temperature of swimming pools and Jacuzzis was respectively 10.4% and 20.8% in contrast with the standard level. The total mean temperature of the swimming pools and Jacuzzis was respectively 26.92°C and 39.43°C.

Swimming pools are proper places for the growth of pathogenic microorganisms. To control and monitor the quality of the water in the swimming pools, it is necessary to carry out examinations like HPC, total coliform, and fecal coliform. The allowed maximum level of HPC in swimming pool water is below 200 units per 100 ml. [16-18] In the present study, an average of 409.6 HPCs existed in the swimming pools, which was 21.5% in contrast to the standard. The results of the studies conducted in Urmia and Isfahan on the bacteriological quality of water in the swimming pools indicated that HPC did not comply with the standard in respectively 33.04% and 37% of the samples. The results of a study conducted on the swimming pools in Kerman showed that the level of HPC was above the standard level in 14.6% of the samples.

One of the most important activities that is effective in monitoring the quality of water in swimming pools is to control their bacteriological quality. According to the standards, the number of total coliforms should be below 500 MPN/100 ml. [20-25] In the present study, its mean and noncompliance with standards was respectively 61.9 MPN/100 ml and 4.9%.

Measuring the microbial quality of swimming pool water is mostly conducted through water fecal contamination indicator bacteria. According to the standard, the number of fecal coliform should be below 1/100 ml. [16-18] In the present study, the number of fecal coliforms in 17% of the swimming pools was in noncompliance with the standards, but it was reported to be 100% in agreement with the standards in the studies conducted by Zezvali et al. [20] and Mansourian et al. [26] that focused on the water of swimming pools in terms of fecal contamination. The nonconformity of the swimming pools regarding contamination with fecal coliforms in the studies carried out by Shahriyari et al. [24] and Nikayin et al. [21] was reported to be 11.96% and 23%, respectively. In the current study, the results of Pearson correlation test showed that there was a reverse and significant statistical relationship between the residual chlorine and HPC, and total coliform and fecal coliform. The same relationship was also reported in the experiments conducted by Zezvali et al. [20] Mansorian et al. [26] Nikayin et al. [21] Martins et al. [27] and Borgmann-Strahsen. [28] Therefore, keeping the values of a disinfectant with good residual effect like chlorine with a specified standard range can be influential in preventing microbial contamination and prevalence of many diseases communicable through the water of the swimming pools, which was referred to in the beginning of the present study. Conducting similar studies especially those dealing with the relationship between the environmental health of swimming pools and the quality of their water is necessary to preserve and enhance public health.

Conclusion

According to the results of the present study, the swimmers' health is in danger even in the best swimming pools; therefore, compliance with personal and environmental health, teaching health hints to the swimmers, constant controlling and monitoring of water quality in the swimming pools, making sure about sufficient teaching about the principles of operation and maintenance of water quality to those in charge and beneficiaries, and making sure about effective treatment of the water of the pools through a regular periodical program are necessary. Continuous disinfection and sufficient residual effect of a disinfectant like chlorine in water of swimming pools are very important factors particularly in hot months like July-August, and swimming pools should regularly and continuously be measured and evaluated. The results of the present study; however, showed that continuous presence of health authorities is effective in regular control of water quality in swimming pools; therefore, their attempts are well appreciated, and they are required to strongly continue their endeavors in the future, too.

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Conflict of Interest

All authors disclose that there was no conflict of interest.

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