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Surveillance of the physical, chemical, and microbiological quality of swimming pool water in the Hamadan province

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ABSTRACT

Swimming is considered one of the most conventional recreational activities for both leisure and exercising. Swimming pools have either public or private usage. Nevertheless, if the water of the swimming pools is polluted and is not identified on time, it could result in the transmission of various diseases to the people who use them. Therefore, the main objective of this study was to assess the health situation of swimming pools in the Hamadan province during the period of 2012–2014. This research was a descriptive-analytical (cross-sectional) study on the 19 active pools in the 8 cities of Hamadan province. A total of 120 samples were randomly taken from different parts of the swimming pools during the three-year study period. The sampling and testing procedures were performed according to standard methods. The SPSS software (IBM®) and the linear correlation test were used for data analysis. The results showed that the physicochemical parameters, such as pH and residual chlorine for 76% and 86% of the total samples, respectively, showed good compliance in pool water during the study period. In terms of microbiological parameters, the lowest and highest numbers of positive samples were observed in the years 2012 and 2014, respectively. According to the results and the unfavorable trend observed mainly in terms of microbial contamination, appropriate measures, such as through strict enforcement of sanitary standards and provision of required equipment like turbidity meter, should be undertaken in order to increase the hygiene level of swimming pools in the Hamadan province.

Keywords: Swimming pools, Physicochemical parameters, Biological parameters, Hamadan

Introduction

During recent years, the trend of using swimming pools for recreational purposes or for exercise has been growing. It is said that in industrialized countries each person uses a swimming pool at least once in his lifetime.[1] Swimming pools (SPs) can be either public or private and it is generally estimated that in the European Union (EU) and United States of America there were about 13.5 million swimming pools.[2] Due to the complexity of water chemistry, and human exposure and behavior, the potential health risks are not yet fully understood.[1] During recent years, the development of knowledge about the health risks of recreational areas, such as SPs, along with the need to remain updated with the latest control strategies has resulted in the provision of new regulations regarding health conditions, and chemical and biological quality of pools in many countries.[3] The World Health Organization (WHO) recommended guidelines, at the international level, to protect human health from monitor risks resulting from the use of recreational areas and swimming pools. The purpose of WHO behind providing these guidelines is that they are used as the base for the development of national strategies to manage risks that may occur in promenades and swimming pools. Also, they form the basis for

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the framework to ordain local regulations through decision-making.[4] Fecal contamination of the SP water is considered to be the main risk to swimmers. Microbiological contamination could be directly (intentional or because of washing the body) caused by the swimmers or indirectly caused through the contamination of water sources.[5] Non-fecal contamination caused by human wastes, such as skin waste, sputum, mucous, or vomiting, is considered as a potential source of pathogenic, non-fecal microorganisms.[4] Studies conducted in this context showed the spread of diseases, which includes the Shigella spp., *Escherichia coli O157:H7*, *Pseudomonas aeruginosa*, Leptospira, *Giardia lamblia*, *Cryptosporidium parvum*, adenovirus, and the Norwalk virus. In the study conducted by Una Ryan et al., it was shown that the lack of national and international standards or guidelines, poor adherence and understanding of regulations by governing staff, patron behavior, and a low level of public knowledge and awareness are the main key barriers that limit swimming pool-associated outbreaks of cryptosporidiosis.[6] Other studies also reported that recreational and competitive swimmers or swimmers training in chlorinated indoor pools suffer from ocular, skin, and upper and lower airway symptoms.[7] Swimming pool atmosphere has adverse health effects on lifeguards as well.[8] Short-term exposures can also induce significant alterations in lung permeability, such as airway inflammation, epithelial damage, and re-modelling, similar to that seen in the airways of asthma patients. [9, 10] In most cases of diseases, one of the main reasons was improper water disinfection. Since chlorine and chlorine compounds are the most common disinfectants used to disinfect swimming pools and drinking water, having a proper residual of chlorine to achieve this purpose was considered as an acceptable solution.[5] To assess the water quality of pools and health hazards caused by swimming in contaminated pools, several studies have been conducted all over the world. For example, Goshorn et al. (1922) studied the chemical quality of swimming pools in terms of chloride, nitrate, nitrogen, ammonia nitrogen, nitrate nitrogen, and nitrogen as urea in SPs.[11] The results showed that swimming pools used only by women are more polluted than pools for men. Papadopoulou et al. (2008) studied the microbiological quality of swimming pools in Greece. The results showed that 67% of the water samples complied with the relevant standards, but in 33% of cases at least one of the microbiological parameters was beyond the permissible limits.[12] Florentin et al. (2010) studied the health related effects of disinfection by-products in the pools that were disinfected with chlorine and its compounds. The results showed that the risk of disinfection by-products could not be the reason that disinfection of swimming pool water to control pathogens content be overlooked.[2] The study conducted by Pasquarella et al. on the behavior of swimmers and their knowledge on how to use the pool showed that wrong behavior among swimmers is because of both lack of awareness about health risks and limited understanding of the common pool regulations.[13] Hence, it is necessary to train them and provide more health information. In another study Dallolio and her colleagues studied the sanitary conditions of swimming pool water in Bologna, Italy.[3] The results showed that in 65% of the cases that the standards of swimming pools in the country had not been met, only one parameter exceeded the limit. It was also shown that due to appropriate operation of water disinfection systems, pH and residual chlorine values were within the optimal ranges and hence, microbiological contamination (enterococci) was observed in less than 2% of the total samples only. Barikbin et al. conducted a study to evaluate the quality of SP water in Birjand and observed that in most cases the evaluated parameters of pH, free residual chlorine, alkalinity, turbidity, and temperature were acceptable and within the desirable limit.[14] However, biological indexes in 25% of the cases were beyond the standard values, but positive *E. coli* was not found in the samples.

Therefore, the aim of this study is to evaluate the physical, chemical, and microbiological quality of swimming pools, which included microbiological parameters like

Total Coliform (TC), Fecal Coliform (FC), *Pseudomonas*, *Streptococcus*, Heterotrophic Plate Count (HPC), and *Staphylococcus*, chemical parameters of pH and free chlorine residual, and physical parameters like turbidity in the Hamadan province during 2012-2014.

Materials and Methods

Sampling

This cross-sectional study was conducted in a descriptive-analytical way on 19 active swimming pools in the 8 cities of Hamadan province. A total of 120 samples were randomly taken from different parts (i.e. deep, semi-deep, shallow, and Jacuzzi) of the swimming pools during heavy service loads between 10 am to 12 pm, and also in different seasons during three years, according to standard methods.[14–16] The parameters that were studied, along with their units, are shown in Table 1.

Table 1. The studied physical, chemical, and biological parameters along with standard values

Parameter	Unit	Standard value
pH	unitless	7.2-8
Residual chlorine	mg/L	1-3
Turbidity	NTU	0.5
TC	MPN/100mL	0
FC	MPN/100mL	0
P. aeruginosa	cfu/mL	<1
HPC	cfu/mL	200
Streptococci	colony/100mL	100
Staphylococci	colony/100mL	50

The water samples for microbiological quality assessment were taken bottles using containing 3% sodium thiosulfate (0.4 ml) to neutralize the free residual chlorine, from a depth of about 30 cm and a distance of about 40 cm from the edge of the pool, between 10 am to 12 pm. Samples maintaining the cold chain (temperature less than 4 ºC) were placed in a cold box and were transferred to the regional reference laboratory of the Deputy of the Health department for analysis.

Measurement and data analysis

The pH and free chlorine residual parameters were measured at the sampling point using the Palin test kits based on the DPD colorimetric method, and a pH meter (Metrohm AG, Herisau, Switzerland), respectively.[14, 15] Turbidity was measured in the laboratory using a Turbidimeter (model 2100P). Microbiological parameters of the study, including TC and FC, were measured according to the multiple-tube fermentation (MTF) method. The heterotrophic plate count method, which uses a plate count agar medium, has been used to estimate the HPC bacteria of the water samples. Other biological parameters were identified accordingly using appropriate methods, such as the search and enumeration method for *Pseudomonas aeruginosa (P. aeruginosa)*, which is an opportunistic pathogen that has higher resistance to disinfection procedures. Thus, it can be found in recreational water using a membrane filter (MF) procedure with a Strymayd agar culture and Acetamide broth as well as ammonia gas production in the probable and verification steps, respectively. To perform the search and enumeration method for the *Enterococcus faecalis* (gastroenteritis Streptococcus), after evaporation using a membrane filter in KF, Streptococcus agar medium was used in a probable step and Zayd esculin bile agar culture was used in the verification step. To detect the *Staphylococcus aureus (S. aureus)*, membrane filter method in mannitol salt agar was used.[15] The obtained data was analyzed using Excel, a statistical software package SPSS 16.0 (SPSS Inc., Chicago, IL), and descriptive statistics.

Results and Discussion

The results of the measured parameters during the study period are shown in Table 2–4. The values given in the tables are the averages of the measured values of the parameters in the shallow, semi-deep, and deep points of the swimming pools. In the case of *S. aureus*, it should be noted that its measurement is taken into consideration from 2012. Unfortunately, turbidity was not regularly measured during 2012-2013 and hence, the results are not reported. Variations of the studied parameters

As it can be seen in Table 2, in terms of mean values for the measured parameters in 2012, 15.8% of the samples for pH, 10.5% of the samples for residual chlorine and TC bacteria,

Table 2. Mean value of the assessed parameters in each swimming pool during 2012

Parameters / SP No.	Mean values (percent of violation from standards or guidelines)*								
	pH	Residual chlorine	Turbidity	TC	FC	*P. aeruginosa*	*Fecal Streptococci*	HPC	*S. aureus***
1	6.6 (100)	1.5 (0)	0.57 (33)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	***
2	7.4 (0)	2.0 (0)	0.84 (100)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	***
3	7.4 (0)	2.0 (0)	1.80 (100)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	***
4	7.6 (0)	1.5 (0)	0.71 (100)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	***
5	6.8 (100)	2.0 (0)	0.64 (100)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	1.5 (0)	***
6	7.23 (0)	2.0 (0)	1.25 (100)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	***
7	7.27 (0)	3.0 (33)	0.63 (100)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	3.7 (0)	***
8	7.63 (0)	1.17 (35)	1.32 (100)	108 (50)	2 (33)	51 (50)	125 (50)	284 (50)	***
9	7.4 (0)	1.0 (0)	***	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	1.0 (0)	***
10	6.98 (55)	1.89 (0)	1.33 (67)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	2.0 (0)	***
11	7.4 (0)	0.93 (32)	***	2 (35)	0.0 (0)	0.0 (0)	0.0 (0)	1.0 (0)	***
12	7.0 (100)	1.5 (0)	0.73 (100)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	1.0 (0)	***
13	7.0 (100)	2.0 (0)	0.52 (100)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	***
14	8.0 (0)	5.0 (100)	1.73 (100)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	2.0 (0)
15	7.2 (0)	1.5 (0)	***	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.5 (0)	0.0 (0)
16	7.4 (50)	1.17 (18)	0.84 (100)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	1.0 (0)	***
17	7.18 (50)	1.82 (0)	1.28 (100)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	33.0 (0)	***
18	7.2 (25)	1.62 (8)	1.2 (100)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	5.0 (0)	***
19	7.0 (100)	1.5 (0)	1.01 (100)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	19.0 (0)	***
Average	**7.25**	**1.84**	**1.02**	**5.78**	**0.1**	**2.68**	**6.58**	**18.56**	**-**

* Measurement units: pH: no unit; Residual chlorine: mg/L; Turbidity: NTU; TC and FC: MPN/100mL; *Pseudomonas aeruginosa* and HPC: cfu/mL; *Fecal Streptococci* and *Staphylococcus aureus*: colony/100mL.
** This parameter was sporadically measured in 2011, but measured on a regular basis during the next years.
*** Not measured or data not available.

Table 3. Mean value of the assessed parameters in each swimming pool during 2013

Parameters / SP No.	Mean values (percent of violation from standards or guidelines)*								
	pH	Residual chlorine	Turbidity	TC	FC	*P. aeruginosa*	*Fecal Streptococci*	HPC	*S. aureus***
1	7.4 (100)	2.0 (0)	***	3.0 (33)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
2	7.15 (0)	2.37 (0)	***	1.0 (25)	1.0 (12.5)	0.0 (0)	0.0 (0)	0.0 (0)	58.0 (25)
3	7.3 (0)	2.33 (0)	***	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
4	7.2 (0)	3.0 (0)	***	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
5	***	***	***	***	***	***	***	***	***
6	7.4 (0)	2.6 (0)	***	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
7	7.0 (0)	1.0 (0)	***	8.0 (100)	0.0 (0)	0.0 (0)	0.0 (0)	3.7 (0)	0.0 (0)
8	7.4 (0)	3.5 (100)	***	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	267(68)	0.0 (0)
9	6.8 (90)	2.75 (0)	***	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
10	***	***	***	***	***	***	***	***	***
11	7.5 (0)	1.88 (34)	***	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
12	6.96 (60)	1.85 (0)	***	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	126 (20)	0.0 (0)
13	7.8 (100)	2.0 (0)	***	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	250 (50)	0.0 (0)
14	7.7 (0)	1.04 (43)	***	5.0 (22)	1.0 (12)	7.0 (12)	0.0 (0)	168 (44)	11.0 (12)
15	7.7 (0)	0.84 (60)	***	2.0 (14)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
16	7.0 (50)	3.0 (0)	***	3.0 (50)	0.0 (0)	0.0 (0)	0.0 (0)	37 (17)	0.0 (0)
17	6.82 (67)	1.83 (65)	***	2.0 (23)	1.0 (12)	28.0 (39)	0.0 (0)	298 (39)	85 (45)
18	7.27 (25)	1.7 (33)	***	0.0 (0)	0.0 (0)	1.0 (8)	0.0 (0)	5.0 (0)	19 (27)
19	6.9 (50)	1.35 (25)	***	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	33.0 (8)	25 (8)
Average	7.26	2.05	-	1.41	0.176	1.2	0.0	69.35	11.65

* Measurement units: pH: no unit; Residual chlorine: mg/L; Turbidity: NTU; TC and FC: MPN/100mL; *Pseudomonas aeruginosa* and HPC: cfu/mL; Fecal *Streptococci* and *Staphylococcus aureus*: colony/100mL.
** This parameter was sporadically measured in 2011, but measured on a regular basis during the next years.
*** Not measured or data not available.

and 5.3% of the samples for the parameters of FC, *P. aeruginosa*, *streptococcus*, and HPC bacteria have exceeded the standard and guideline values. For 2013, as shown in the Table 3, 23.5% of the samples for pH, 11.8% of the samples for residual chlorine, 41.2% of the samples for TC, 17.6% of the samples for FC, *pseudomonas aeruginosa*, and HPC bacteria, and 11.8% of the samples for *S. aureus* bacteria have exceeded the standards and guideline values. Moreover, no positive samples were observed for *streptococci*. According to the results given in Table 4, in 2014, 31.2% of the samples for pH, 18.7% of the samples for residual chlorine, 81.2% of the samples for TC, 25% of the samples for FC, 43.7% of the samples for *P.aeruginosa*, and 12.5% of the samples for *staphylococcus* bacteria have exceeded the standard and guideline values. A positive point of view for the 2014 results (similar to 2013) was that there were no positive samples for *streptococcus* bacteria. Since gram-positive bacteria, such as *streptococcus* bacteria, are more resistant to chlorine than gram-negative bacteria,[17] the negative samples could be of particular importance for the mentioned years. Furthermore, given that the obtained ratio of FC/FS was <4 and that the number of *streptococcus* bacteria are less in human fecal contamination compared to heat resistant bacteria (like *E. coli*),[18] indicating the probabale animal fecal contamination.

Table 4. Mean value of the assessed parameters in each swimming pool during 2014

Parameters / SP No.	Mean values (percent of violation from standards or guidelines)*								
	pH	Residual chlorine	Turbidity	TC	FC	*P. aeruginosa*	*Fecal Streptococci*	HPC	*S. aureus***
1	7.4 (0)	1.5 (0)	***	3.0 (33)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	19.0 (33)
2	7.2 (0)	1.5 (0)	***	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
3	7.6 (0)	2.0 (0)	***	2.0 (330)	0.0 (0)	51.0 (67)	0.0 (0)	0.0 (0)	0.0 (0)
4	7.6 (0)	3.0 (0)	***	6.0 (100)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	27.0 (33)
5	6.9 (50)	2.0 (0)	***	2.0 (17)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
6	7.1 (0)	2.5 (0)	***	48 (50)	1.0 (17)	3.0 (17)	0.0 (0)	164 (40)	0.0 (0)
7	6.9 (100)	1.0 (0)	***	2.0 (34)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
8	6.8 (100)	5.0 (100)	***	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
9	7.0 (50)	3.2 (34)	***	1.0 (12)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
10	7.7 (0)	2.5 (0)	***	4.0 (672)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
11	7.35 (0)	1.78 (0)	***	4.0 (45)	0.0 (0)	6.0 (12)	0.0 (0)	32.0 (12)	0.0 (0)
12	***	***	***	***	***	***	***	***	***
13	7.64 (0)	2.7 (100)	***	10.0 (40)	1.0 (20)	0.0 (0)	0.0 (0)	124 (20)	40.0 (20)
14	***	***	***	***	***	***	***	***	***
15	7.2 (0)	0.5 (75)	***	4.0 (22)	4.0 (25)	6.0 (25)	0.0 (0)	81 (27)	38.0 (22)
16	6.85 (73)	2.43 (0)	***	12.0 (54)	0.0 (0)	1.0 (6)	0.0 (0)	0.0 (0)	62.0 (40)
17	7.2 (25)	1.96 (83)	***	3.0 (47)	1.0 (7)	81.0 (27)	0.0 (0)	170 (34)	74 (28)
18	***	***	***	***	***	***	***	***	***
19	6.74 (67)	1.54 (15)	***	2.0 (24)	0.0 (0)	1.0 (5)	0.0 (0)	1.0 (0)	35 (19)
Average	7.2	2.19	-	6.25	0.44	9.31	0.0	35.75	18.44

* Measurement units: pH: no unit; Residual chlorine: mg/L; Turbidity: NTU; TC and FC: MPN/100mL; *Pseudomonas aeruginosa* and HPC: cfu/mL; *Fecal Streptococci* and *Staphylococcus aureus*: colony/100mL.
** This parameter was sporadically measured in 2011, but measured on a regular basis in the next years.
*** Not measured or data not available.

However, if there were positive samples of heat resistant bacteria as well, further investigation, in terms of sanitary conditions, would be required. pH values that deviate from the standard values (higher or lower) can cause problems, such as inefficiency of the disinfection process, corrosive characteristic of water, eye irritation and skin damage of swimmers, staining of the surfaces etc.[19] Thus, considering the results in which values outside the standard limits had been measured during the study period, more controlling measures should be adopted. Maintaining a minimum amount of residual disinfectant can prevent bacterial growth and transmission of diseases. Also, similar to pH, as the maximum allowable values can prevent health effects and damage to the swimmers skin or eyes,[5, 20] this parameter should also undergo meticulous monitoring. Another point that should be considered, as shown in Tables 2–4, is that although turbidity is an important parameter as it increases the effectiveness of disinfection,[19, 20] unfortunately, in the three samples of 2012 and for all samples taken in 2013 and 2014, this parameter was not measured mainly due to the lack of access to turbidimeter for all counties/districts. Therefore, availability of the appropriate equipment needed for turbidity measurement is suggested. The Pearson correlation analysis of turbidity and microbial contamination for the 2012 data showed positive and significant correlation (r=0.68, p<0.05) between high turbidity values and microbial contamination. This correlation was also reported in the study conducted by MacKenzie et al. [21]

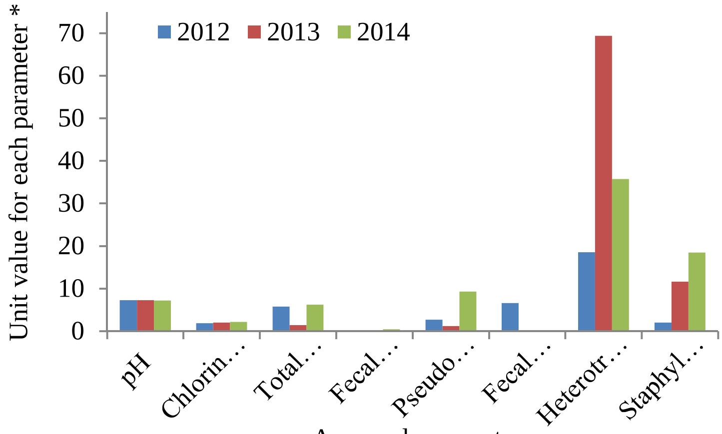

Fig. 1. Trends in the variation of parameters assessed during the study period.

(* Measurement units: pH: no unit; Chlorine residual: mg/L; TC and FC: MPN/100mL; *Pseudomonas aeruginosa* and HPC: cfu/mL; *Fecal Streptococci* and *S. aureus:* colony/100mL).

Moreover, according to Table 1, the maximum microbial contamination was observed in SP no. 8 (located in the city of Malayer) in 2012, where all bacteriological tests were positive. The maximum residual chlorine violations was also observed in this swimming pool. Thus, it could be due to insufficient amount of disinfectant residual.[19] During the study period, highest contamination by the microorganism coliform bacteria was observed in 2014, where 81% of the total samples were positive. Hence, appropriate surveys should be done to address the possible reasons and actions necessary to deal with the same. As also shown in the Figure 1, the highest number of positive samples of *S. aureus*, *P. aeruginosa*, and heat resistant coliforms are observed in 2014. The lowest number of positive samples of total coliforms was observed in 2013 while HPC was the highest for this year. Hence, microbial contamination of SPs may not necessarily be due to fecal contamination, but can also be due to urine excretion, body washing, or secretion of mucosa from the nose, throat, or mouth of the swimmers. Therefore, the measurement of *S. aureus* and *P. aeruginosa* can be of critical importance. Moreover, the infections that resulted from these microbial agent was through contact and not through swallowing. As seen in the Figure 1, it has an increasing trend during recent years, which implies that an increase in the health risks, such as skin and eyes infections, in swimmers can be expected.[17] Proper disinfection and existence of adequate disinfectant residuals was the main criterion behind the prevention of microbial contamination. In the study conducted by Arnau Casanovas-Massana and Anicet R. Blanch (2012) to identify the microbial populations associated with natural SPs, it was found that three out of the four natural pools that were assessed, exceeded the limits stated in the recommendations for *E. coli* or *enterococci*. But the concentrations of *P. aeruginosa* and aerobic heterotrophic bacteria were within the acceptable limits. The results of this study suggest that wildlife may be the main source of fecal contamination in the natural swimming pools.[5] Rigas et al. (1998) surveyed eleven outdoor and indoor swimming pools in Greece and found 45–91% microbiological compliance with the standards, where *S. aureus* and *P.*

aeruginosa were the predominant microorganisms.[22] The same predominant microorganisms were also reported in other studies conducted in Greece. *S. aureus* was the most frequent isolate (23%) followed by *P. aeruginosa* (18.4%), even though the compliance to the standard values was different and ranged within 63%–100 %.[23]

The results of the study conducted by Hosseinzadeh et al. in 2010 on swimming pools in the city of Hamadan showed that fungal contamination did not exist in the assessed swimming pools.[24] Regardless, physiochemical parameters including pH and chlorine residual in a few samples were exceeded the required limits, where the results of this study are in consistent with it. These researchers also confirmed fecal streptococcus infection of four SPs that were studied in the city of Hamadan in 2011.[25] Barikbin et al. also showed that *E. coli* was not found in the swimming pool that was assessed, but 15.5% of the samples had positive results for *P. aeruginosa*.[14]

Conclusion

In conclusion, the results of the study showed that, among physicochemical parameters, pH and residual chlorine have favorable conditions for about 76% and 86% of the total samples, respectively. But, favorable trends were not observed for microbial indicators. As expected, with betterment in public health status and health literacy during recent years, pollution is also decreasing, which was not observed earlier. Another point that should be mentioned is that turbidity was not measured in most of the assessed swimming pools mainly due to lack of relevant measuring equipment even though it has considerable effect on disinfection efficiency in systems that use chlorine as the main disinfectant. Also, most of swimming pools in the studied area have this kind of disinfection system. Thus, the availability of turbidity measurement equipment should be considered.

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