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Article · January 2011

DOI: 10.1504/IJEE.2011.039454

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Microbiological water quality and sampling policy of public swimming pools

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Abstract: Water samples collected from 100 public swimming pools in the West Bank of the Palestine by health inspectors. The samples were tested for microbiological quality for the years 2003, 2004 and 2005. The overall of unaccepted tested swimming pool water samples were as follows: 35.8% for total *Coliforms* (TC), 24.4% for faecal *Coliforms* (FC), 36% for Heterotrophic Plate Count (HPC), 39.3% *Enterococci* (Ente), and 28% for P. *aeruginosa* (Pa), 24.3% for *Staphylococcus aureus* (Sa), and 6.7% for Salmonella (Sal). Therefore, it is necessary to allocate more attention to swimming pool monitoring and evaluation studies to prevent pollution of the swimming water.

Keywords: hygiene; microbiological; Palestine; swimming pools; water quality.

Reference to this paper should be made as follows: Al-Khatib, I.A. and Ghannam, R.S. (2011) 'Microbiological water quality and sampling policy of public swimming pools', *Int. J. Environmental Engineering*, Vol. 3, No. 2, pp.192–204.

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environment, and the indication of sources of water, air and soil pollution and adapting methods for the limit of their pollution, and the control of environment and water quality, and the use of scientific analytical methods for the treatment of environmental pollution.

1 Introduction

The main tasks in pool water management involve keeping the water clean, safe and free from pathogens. Generally it is assumed that if these factors are properly managed, the pool is safe to swim in. However, if there is a large bathing load in the pool, or faecal contamination, higher doses of chlorine (super-chlorination) may be required (Charles et al., 1999; Gunther et al., 2005). Maintenance of pools is essential; skill and knowledge are prerequisites (Griffiths, 1994a, 1994b; Tamminen, 1996).

A great number of infectious diseases may be transmitted by swimming pools and other relevant recreational facilities if not properly designed, constructed, operated and maintained. In addition, chemicals used for water treatment and disinfection purposes may, either by their nature or after reaction with water ingredients, present certain toxicological hazards to those in contact with the water (bathers) (Rigas et al., 1998; Helen et al., 2001).

Bathers contaminate the water with large amounts of micro-organisms. From the skin alone hundreds of millions of bacteria are rinsed during swimming. Other sources are saliva, as well as the flora of intestines and genitals. These micro-organisms can cause various illnesses; for example, eczema, infections of ears or the gastro-intestinal tract (WHO, 2003a, 2003b), in addition to diarrhoea and skin, and upper respiratory infections (Borgmann-Strahsen, 2003). During one incident at an Atlanta water park, seven children suffered kidney failure and one child died from swimming in water contaminated with *E. coli*. The regular and proper use of a sanitiser in the water will destroy the vast majority of these organisms before they have a chance to strike (Brown, 2009). Disinfection of swimming pools should control the organisms responsible for all of these infections (Anipsitakis et al., 2008; Esterman et al., 1984).

Bacteria, viruses and other microbes exist naturally on most surfaces that are exposed to air, including water. Although many are harmless, some of these contaminants may cause infection and disease (Kaydos-Danielsa et al., 2008). Pools and spas are particularly vulnerable to illness-causing bacteria and germs introduced into the water by swimmers and spa users (WHO, 2003b; UK Department of the Environment, 1987).

Pathogenic micro-organisms may be sustained in poorly chlorinated pools. Pathogenic bacteria such as *Staphylococcus, Streptococcus, Pseudomona aeruginosa, Mycobacterium marinum, Klebsiella, Yersinia* and *Legionella* can all be found. Consequently, it is not always sufficient to assume that a pool is safe based purely on compliance with chlorine guidelines. Microbiological testing of swimming pool waters may give a better indication of how safe it is to swim (Emu Ltd., 2006; Al-Khatib et al., 2000).

Staphylococcus aureus and other staphylococci have been considered better candidates for evaluating the hygienic quality of swimming pools for several reasons (Tolba et al., 2008). They are consistently shed from the skin, mouths, noses, and throats of bathers and are opportunistic pathogens that cause a variety of infections, including boils, carbuncles, skin rashes, and eye infections (Papadopoulou et al., 2008; Robert and Michael, 1986).

The American Public Health Association (APHA) (1999) provides standards for total and faecal *Coliforms*, Enterococci with the addition of Salmonella and others. According to Palestinian Guidelines for Construction, Maintenance and Operation of Public Swimming Pools (Al-Khatib et al., 2000), throughout any year, 95% of samples should not contain any *Coliform* organisms in 100 ml, no sample should contain *E. coli* in 100 ml, No sample should contain more than 10 *Coliform* organisms in 100 ml and *Coliform* organisms should not be detected in 100 ml of any two consecutive samples.

For Palestinian people, swimming pools represent a major recreational place and have proven to be a sound financial investment, so that recently there has been an increased interest in the construction and operation of swimming pools in the West Bank of the Palestine. The reason is that there is no marine water easily accessible.

In this study, the bacteriological quality of water from swimming pools is ascertained, focusing on water quality – whether this water is safe to swim in or not – in the West Bank of the Palestine swimming pools. The main causes of water contamination are identified. The analysis contained in this paper is based on the results of laboratory tests that the Ministry of Health completed on collected samples of water from swimming pools. The presence of some of the classical bacteriological indicators of water contamination, including total *Coliforms,* faecal *Coliforms,* Heterotrophic Plate Count (TC-FC-HPC) (CFU/100 ml), *Enterococci* (Ente) (CFU/250 ml), *Pseudomonas* (Pseud) (CFU/500 ml), *Staphylococcus* aurus (Sa) (CFU/250 ml), and Salmonella (Sal) (+/–/1) in Palestinian swimming pools is the main focus here.

2 Materials and methods

During the bathing season from April to October 2003–2005, swimming pool water samples were collected from 100 swimming pools representing all 99 outdoor and one indoor swimming pool in the West Bank of the Palestine. Only the indoor swimming pool remains open all year round, and the others open during the hot period only. The samples were collected by the inspectors of the Environmental Health Department of the Palestinian Ministry of Health for routine inspection. From each swimming pool, different number of samples was collected. Three hundred and fifty eight (358) samples were examined for total *Coliforms*, 402 samples for faecal *Coliforms*, 328 samples for HPC, 328 samples for *Enterococci*, 353 samples for *Pseudomonas*, *325 samples* for *Staphylococcus aureus*, and 15 samples for Salmonella.

Decisions regarding whether water samples were deemed acceptable or not acceptable for swimming were based on the Palestinian microbiological standards (Al-Khatib et al., 2000). The standard methods for the examination of water and wastewater, published by American Public Health Association (1998), were used as a reference for sample testing.

Bacteriological samples were analysed by the membrane filter technique, using 0.47 mm diameter, 0.45 µm pore size filters (S-Pak sterile membrane Filter, HAWG047S1, Millipore, Billerica, USA) as specified in Standard Methods (APHA, 1998) to determine the following parameters: Total Heterotrophic Plate Counts (THC) per 1 ml at 20 and 36°C (Plate Count Agar Cat. No. 1.05463, Merck KGaA, 64271, Darmstadt, Germany), total coliforms (TC) per 100 ml at 36°C (m-ENDO Agar LES, Cat. No 11.11277, Merck KGaA, 64271, Darmstadt, Germany), faecal coliforms (FC) per 100 ml at 44°C (m-FC Agar, Cat. No. 1.11278, Merck KGaA, 64271, Darmstadt, Germany), Faecal Streptococci (FS) per 100 ml at 36°C (D-Coccosel Bile Esculin Agar Selective isolation of enterococci N51 025, BioMerieux, Marcy – l Etoile, France), *Staphylococcus aureus* (SA) per 100 ml at 36°C (Chapman Agar. *Staphylococcus* Selective Agar, Cat. No. 1.05469, Merck KGaA, 64271, Darmstadt, Germany), *Pseudomonas aeruginosa* (PS) per 100 ml at 30°C (*Pseudomonas* Selective Agar Base. Cetrimide Agar, Cat. No. 1.05284, Merck KGaA, 64271, Darmstadt, Germany).

The presence of Salmonellae was ascertained by filtering at least one litre of pool water through a 0.45 µm membrane. Filtration was followed by pre-enrichment in Buffered Peptone Water (CM1049, Oxoid Ltd., Hampshire, England) followed by enrichment in Rappaport-Vassiliadis Broth (CM0669, Oxoid Ltd., Hampshire, England), and culture on Desoxycholate Citrate Agar (XLD) (CM0035, Oxoid Ltd., Hampshire, England), and Salmonella–Shigella Agar (SS) (CM0099, Oxoid Ltd., Hampshire, England).

Biochemical identification of bacterial species was performed using API STAPH, API 20E, API NE, API STREP (Biomerieux, S.a. Marcy l' Etoile, France) in addition to stains (Gram and Ziehl–Neelsen), motility, oxidase and coagulase tests and colonial morphology. Also, P. aeruginosa strains were further O serotyped by slide agglutination (International Antigen Typing System, Sanofi Pasteur Diagnostics, Marnes-la-Coquette, France).

The bacteriological quality was considered unacceptable if any of the following applied:

- total *Coliform* > 1 CFU per 100 ml
- faecal *Coliform* > 1 CFU per100 ml
- HPC > 10^5 CFU per 100 ml
- *Enterococci*, and *Staphylococcus* aureus > 1 CFU per 250 ml
- *Pseudomonas aeruginosa* > 1 CFU per 500 ml, and Salmonella show positive in a single one litre sample.

Data obtained from the microbiological data were coded and entered into the computer using SPSS 12 (Statistical Package for Social Sciences) software. The data were analysed and tabulated.

Additionally, personal interviews in the form of a discussion with the Director of the Environmental Health Department (Atiye, 2006), Head of the water division in the

Environmental Health Department (Shabieb, 2006), and two health inspectors from the Department of Environmental Health (Yacin, 2006; Essa, 2006), who are in charge of the swimming pools' water monitoring and quality, were conducted. During these interviews, issues such as the role of the Ministry of Health in swimming pool water quality control, problems facing the health inspectors in this regard, and the cooperation of swimming pool owners and operators in water quality control, were discussed. The purpose of these personal interviews was to help in the explanation of the results and other issues related to the swimming pools.

3 Results

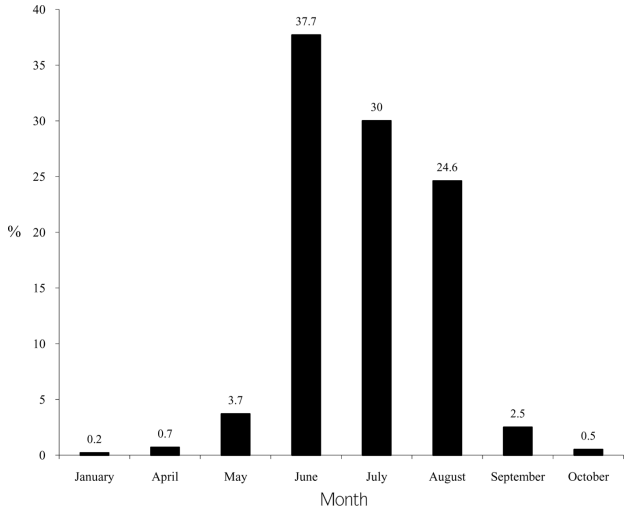
During the bathing seasons from April to October (2003–2005) several tests were carried out to determine the microbiological quality of swimming pools water in the West Bank of the Palestine.

3.1 Yearly and monthly distribution of tested swimming pool water samples

A total of 403 samples of swimming pool water were collected and tested during the three years, 2003–2005 with a percentage of 10.7%, 12.4% and 76.9% water samples for the three years, respectively.

The monthly distribution of all tested swimming pool water samples is shown in Figure 1. It can be clearly seen that highest percentages of the samples were tested during June, July and August with percentages of 37.7%, 30.0%, and 24.6%, respectively. In other months, only a few samples were tested.

Figure 1 Monthly distribution of all tested swimming pool water samples (percentage)



3.2 Number of tested samples per swimming pool

Table 1 shows the number of tested water samples per swimming pool in the three years from 2003 to 2005. The highest number of tested samples per swimming pool was 11. This number was only for five swimming pools. Samples were taken once during the three swimming seasons from 14 swimming pools.

Table 1 Number of tested samples per swimming pool

Number of swimming pools	*Number of tested samples per swimming pool*
5	11
1	10
3	9
2	8
4	7
3	6
7	5
25	4
28	3
8	2
14	1
Total 100	

3.3 Samples distribution according to the microbiological quality

Table 2 shows the yearly distribution of tested samples according to the results of the tests conducted for them, and the number of tested samples for each microbiological indicator. It can be noticed that there is a high percentage of bacterial contamination.

Table 2 Yearly distribution of all tested water samples for different microbiological indicators in Palestinian swimming pools (number and percentage)

	Microbiological indicators													
	TC		*FC*		*HPC*		*Ente*		*Pseud*		*Sa*		*Sal*	
Year	*Acce**	*Not acce***	*Acce*	*Not acce*	*Acce*	*Not acce*	*Acce*	*Not acce*	*Acce*	*Not acce*	*Acce*	*Not acce*	*Acce*	*Not ace*
2003	22	21	29	14	28	8	21	15	24	12	28	8	5	0
	51.2	48.8	67.4	32.6	77.8	22.2	58.3	41.7	66.7	33.3	77.8	22.2	100.0	0.0
2004	36	12	39	11	30	18	32	17	40	9	42	6	–***	–
	75.0	25.0	78.0	22.0	62.5	37.5	65.3	34.7	81.6	18.4	87.5	12.5	—	—
2005	172	95	237	73	152	92	146	97	190	78	176	65	9	1
	64.4	35.6	76.5	23.5	62.3	37.7	60.1	39.9	70.9	29.1	73.0	27.0	90.0	10.0

*Acce: accepted; **Not acce: not accepted; ***No tested samples.

The overall result of unacceptable swimming pool water samples tested for the three years of 2003–2005 is shown in Figure 2; 35.8% for the TC, 24.4% for FC, 36.0% for HPC, 39.3% for Ente, 28.0% for Pseud, 24.3% for Sa, 6.7% for Sal.

Variations in the results of swimming pool water tested for microbiological quality for the years 2003–2005 were also noted as shown in Table 2. Most of the percentages of unacceptable samples examined in 2004 are lower than those examined in 2003, but still high. For example, the percentages of unacceptable samples examined in 2003 for TC, FC, Ente, Pseud, Sa, were 48.8%, 32.6%, 41.7%, 33.3% and 22.2%, respectively and reduced to 25.0%, 22.0, 34.7%, 18.4% and 12.5%, respectively in 2004. While the percentages of unacceptable samples examined in 2005 are higher than those examined in 2004 for TC, FC, HPC, Ente, Pseud, and Sa microbiological indicators and higher than those of 2003 for HPC, Sa, Sal.

Figure 2 Distribution of all unaccepted tested swimming pool water samples for different microbiological indicators (percentage)

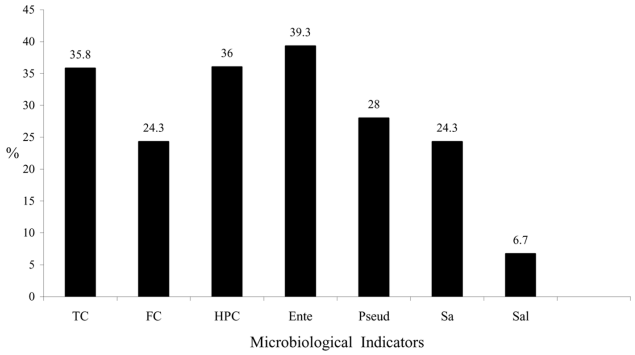


Table 3 shows the monthly variations in the results of tested swimming pool water samples. There is a noticeable variation in the results of microbiological quality indicators. The unacceptable microbiological quality reaches 100.0% for some indicators in some months, and reaches 0.0% for others.

Table 3 Monthly distribution of all tested swimming pools water samples for different microbiological indicators

	Microbiological indicators													
	TC		*FC*		*HPC*		*Ente*		*Pseud*		*Sa*		*Sal*	
Month	*Acce*[*]	*Not acce*[**]	*Acce*	*Not acce*	*Acce*	*Not acce*	*Acce*	*Not acce*	*Acce*	*Not acce*	*Acce*	*Not acce*	*Acce*	*Not acce*
January	1	0	1	0	1	0	1	0	1	0	1	0	–***	—
	100.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0	–	—
April	0	3	0	3	—	—	—	—	—	—	—	—	—	—
	0.0	100.0	0.0	100.0	—	—	—	—	—	—	—	—	—	—
May	7	8	8	7	8	7	6	9	11	4	11	2	—	—
	46.7	53.3	53.3	46.7	53.3	46.7	40.0	60.0	73.3	26.7	84.6	15.4	—	—

Table 3 Monthly distribution of all tested swimming pools water samples for different microbiological indicators (continued)

	Microbiological indicators													
	TC		*FC*		*HPC*		*Ente*		*Pseud*		*Sa*		*Sal*	
Month	*Acce**	*Not acce***	*Acce*	*Not acce*	*Acce*	*Not acce*	*Acce*	*Not acce*	*Acce*	*Not acce*	*Acce*	*Not acce*	*Acce*	*Not acce*
June	97	52	121	31	91	48	81	57	100	38	88	50	14	1
	65.1	34.9	79.6	20.4	65.5	34.5	58.7	41.3	72.5	72.5	63.8	36.2	93.3	6.7
July	71	39	88	33	57	45	66	36	81	32	91	11	—	—
	64.5	35.5	72.7	27.3	55.9	44.1	64.7	35.3	71.7	28.3	89.2	10.8	—	—
August	49	21	78	21	47	15	40	22	56	20	50	11	—	—
	70.0	30.0	78.8	21.2	75.8	24.2	64.5	35.5	73.7	26.3	82.0	18.0	—	—
September	5	5	7	3	6	3	5	5	5	5	5	5	—	—
	50.0	50.0	70.0	30.0	66.7	33.3	50.0	50.0	50.0	50.0	50.0	50.0	—	—
October	—	—	2	—	—	—	—	—	—	—	—	—	—	—
	—	—	100.0	—	—	—	—	—	—	—	—	—	—	—

*Acce: accepted; **Not acce: not accepted; ***No tested samples.

4 Discussion

The monthly and yearly distribution of acquiring swimming pool water samples posed a procedural problem. First, there was no specific schedule for water sample collection. There were some large gaps in the monthly collection of water samples from swimming pools. For example 149, 110 and 70 samples were taken during the months of June, July and August, respectively. These are the main months of the swimming season. August is considered the hottest month in the year.

The legal system currently in force is ineffective and not suitable for the situation prevailing in the Palestine today, as most of the laws were written before 1967 as part of the public health law for the Jordanian Ministry of Health. The Palestinian public health law has been worked on since the year 2000, and it is officially recognised in its final form, but still not implemented (MoH, 2000).

According to the health inspectors, water samples taken from swimming pools in 2003–2005 concentrated on only a few swimming pools in the West Bank and these are mainly located in the cities, while few of the water samples were taken from the swimming pools in rural areas due to the presence of Israeli military forces and check points at the edges of localities. All the above factors have contributed to the high percentage of bacterial contamination of swimming pool water samples. The number of tested samples in 2005 was higher than that of 2004 and 2003 because it was easier for the health inspectors to pass the Israeli check points and take samples from the swimming pools.

According to Al-Khatib et al. (2000), at least one sample should be tested on a monthly basis for all the microbiological indicators mentioned in Table 1. That means at

least 900 samples should have been tested from the 100 swimming pools during the three swimming seasons of the years 2003–2005, for the three months of June, July and August. This is in addition to daily testing of the swimming pool water for the presence of free chlorine residue and pH in the water. This procedure is very important for the health and safety of swimmers and others in contact with swimming pools.

It is worth mentioning that most of the not-acceptable results are in samples taken in the warmest months. This is due to the high water temperature and the presence more swimmers because of the holidays for students at schools and universities and for most of the employees.

Heterotrophic Plate Count (HPC) provides a general indication of pool hygiene (Ibarluzea et al., 1998). The highest percentage of HPC in Palestinian swimming pools was in May, which is considered as the starting month of the swimming season, and inspectors do not pay much attention to the swimming pools as only a few of them work during this month.

Unaccepted water samples tested for FC were present in Palestinian swimming pools with high percentages ranging from 21.2% to 100% for the different months. The faecal contamination may be due to faeces released by bathers or contaminated water sources; also, it returns the possibility of a serious defect in the pool's operating system, such as a failure of the disinfection process and/or a problem with the chemical balance of the pool (including the pH value) or the filtration system, which will require immediate attention (WHO, 2003b).

The presence of Sa with a percentage of 24.3% in all tested samples for Sa is an indicator of bad hygiene, and the presence of some swimmers with infected wounds, as Sa is an opportunistic pathogen, found in swimming pool water when bathers are present, as it is a constantly shed from the skin and nasal-oral areas of bathers.

P. aeruginosa was detected in 28.0% of the 353 tested swimming pools water samples for Pseud. This can be explained by the presence of unclean surrounding areas for many of the swimming pools, as *P. aeruginosa* is ubiquitous in water, vegetation and soil (Highsmith et al., 1985). Salmonella was detected in only 6.7% of test samples for Sal.

From Table 3, it is difficult to see a general trend for the microbiological quality variation as a function of years, since the number of years is limited, but most of the percentages of unacceptable samples examined in 2004 are lower than those examined in 2003, but still high. The unstable political and economical situation in Palestine is reflected in the routine lives of the people. Some times, the inspectors have the power to control the sanitary conditions of swimming pools, and some times they do not have that power.

From field observations and interviews with the health inspectors and other related persons, the following are the main reasons that contribute to high percentages of swimming pool water microbiological contamination:

- Most of the swimming pools are located near residential areas, domestic wastewater cesspits, farming activities, play yards, restaurants, industrial factories, sewage effluents, livestock, domestic animals, and wildlife so that swimming pool sites form a source of pathogens that cause gastrointestinal infections, or infections of the upper respiratory tract, ears, eyes, nasal cavity and skin, (WHO, 2003b) as limited sewerage systems are available in the West Bank communities.

- Some swimming pools are not isolated from public places such as restaurants, and clubs, as there are no fences to prevent customers from entering the pools and eating there.
- Most of swimming pools have no basins for disinfection of the feet.
- The negligible experience of swimming pool owners and operators in the maintenance and operation of swimming pools. Owners of swimming pools do not follow the Palestinian and international regulations for swimming pool construction, bathing, continuous operation of filters, and use of disinfectants; and they do not ensure that the swimmers follow their instructions.
- A high percentage of swimming pools work without license from the special authorities (58% and 47% in the years 2004 and 2005, respectively). This can contribute to increasing contamination as a result of not following Palestinian and international regulations for swimming pool operation, maintenance and bathing.

Another condition that contributes to swimming pool water contamination is the inappropriate behaviour of the bathers themselves, as a high percentage of the bathers do not follow the regulations of swimming pool supervisors. Such behaviour can be summarised as follows:

- some bathers do not take a shower before entering the pool
- some of them enter the pool without changing their clothes and removing their shoes
- some swimmers spit, spout water, blow their nose while in the water
- some bathers with long hair do not wear a bathing cap when entering the pool
- not all bathers wear appropriate bathing suits
- some bathers eat and drink near by or inside the swimming pool
- public swimming pools are usually overcrowded: this can inversely influence microbiological quality of the water directly (Papadakis et al., 1997).

5 Conclusion and recommendations

It was found that health inspectors used irregular sampling procedures to ascertain swimming pool water quality. In addition, they relied on the outdated 1967 public health law for public swimming pool inspection. Several factors were found to contribute to the high percentages of unacceptable microbiological quality of swimming pool water samples collected in the three years, 2003–2005. Examples include: inadequacy of the location of many swimming pools, the infrastructure and equipment of some swimming pools, unqualified supervisors, and the fact that bathers did not abide by the swimming regulations such as taking a cleansing shower bath, using warm water and soap, and thoroughly rinsing off all soap suds before entering the swimming pool, enclosure or area.

Public inspections should serve the additional goal of ensuring awareness among swimming pool supervisors and owners about water quality and safety in order to reduce the microbiological contamination. All factors that influence the uniformity and

reliability of routine swimming pool inspections should be modified by policies and regulations designed to ensure periodic training, inspection and systematic standardisation of inspection evaluations. Activating the implementation of the new public health law that was recently approved by the Palestinian legislative council is considered a priority.

No swimming pool should be allowed to operate without an official license from the concerned authorities. Owners of swimming pools should be encouraged to keep their swimming pool water as clean and free from contamination as possible by following the regulations and implementing them in their swimming pools, and ensuring that the bathers follow their instructions.

Conducting public awareness campaigns with the community to reduce the risk of potential threats to public health by improving personal hygiene practices should be considered an important issue.

For further research, specific pools in the region should be selected and detailed studies should be conducted. Such studies should be comprehensive and take into consideration other analyses like chlorine, temperature, organic content of water, number of swimmers, types of bacteria that are present in swimming pools, etc.

Acknowledgements

The authors would like to thank the Environmental Health Department, Ministry of Health – Ramallah, Palestine, for providing them with the results of microbiological results of tested water samples from swimming pools.

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