

## Montreal Swimming Pools' Water Quality and Its Impact on Public Health During Summer 2006

Drasko Pekovic\*, Marie N Chou, Zana Zarkovic, Pierre Filteau and Guy Tellier

Head of Building Environmental Laboratory, Institute of BioMedical Research, Canada

**\*Corresponding Author:** Drasko Pekovic, Head of Building Environmental Laboratory of the Institute of BioMedical Research, 2550 Bates, suite 200, Montreal, (Quebec) Canada.

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### Abstract

The present study aimed to establish the water quality profile of 73 of Montreal's outdoor public swimming pools during the summer of 2006, and the profile's impact on public health. The water of these pools was tested three times: twice during July and once at the beginning of August for microbiological and physicochemical quality, according to the existing norms around the world. Results obtained indicated nonconformity of 69 (95.4%), 70 (95.9%) and 62 (98.4%) swimming pools in one or more of the parameters analysed, during first, second and third samplings, respectively. The nonconformity consisted of the absence or low levels of chlorine, of microbial contamination and of toxicity due to high levels of chlorine and other pollutants. According to some local medical clinics, this precarious situation had a significant impact on the health of swimmers. Partial official statistics of health conditions of Recreational Water Illnesses showed that *Otitis externa*, known as "infection of swimmers", increased up to 39% during swimming season.

**Keywords:** Health impact; Recreational water illnesses; Recreational water quality; Swimming pool

**Abbreviations:** CFU: Colony Formatting Unit; RWIs: Recreational Water Illnesses; SM: Standard Method; TAC: Total Aerobic Count; TNC: Too numerous to be Counted, UNT: Unit Nephelometric Turbidity; UTC: Unit True Color; WHO: World Health Organization

### Introduction

Swimming pools, as recreational facilities, have attracted human interest since ancient civilization. Bellis reported that as early as 3000 B.C., the first pool existed in the palace of Mohenjo Daro of India [1]. According to the same author, ancient romans and greeks had given an important place to swimming pools in their private and social life. In the 19<sup>th</sup> century, the Kingdom of England added to the swimming pools competition sport facilities. In the province of Quebec, the construction of public swimming pools began just in the middle of last century. Despite long experience, little is known on the maintenance of water quality in the past. Even today, adequate control of swimming pool water quality remains an important technical and scientific challenge.

Among all the natural liquids, water seems to support the strongest general microbial growth and aquatic parasite amplification, in addition to contaminants coming from the bodies of swimmers and cosmetic products [2]. Chemicals used for maintenance of the quality of water and environmental contaminants are also part of health risk factors [3].

It is well known that the inadequate water quality of swimming pools may have an important impact on human health through the world [4]. Thus, most of developed countries have established legislation on etiological and epidemiological follow up of so called Recreational Water Illnesses (RWIs). These studies show that the cutaneous infections and the otitis can be caused by *Pseudomonas aeruginosa*, the respiratory infections by the adenoviruses, and the gastro-intestinal infections by the hepatitis A virus or aquatic

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intestinal pathogens [5]. Infections of the urinary tract and the central nervous system were also reported [6]. Brewster, *et al.* and Hildebrand, *et al.* have described the outbreak of *Escherichia coli* in a children's padding pool [7,8]. Some scientists considered staphylococci as an indicator of swimming pool pollution, while others reported the impact of these micro-organisms on the health of swimmers [9,10]. A previous study also reported the presence of *Clostridium difficile* in swimming pools [11]. The presence of different *Legionella* species in swimming pools and the impact on human health was also reported [12,13]. They observed an increase of Legionnaires' disease during the summer in northern states. The impact of enterovirus on the health of swimmers has not been documented.

The contamination by the aquatic parasites *Giardia* and *Cryptosporidium* are of importance for the public health due to their resistance to chlorine [14,15].

In addition to microbial pollution, the chemicals, which are used as disinfecting agents, can also cause health problems if their concentrations are not adequately controlled. The most used one is, of course, chlorine. Chlorine is well known by its properties to cause irritations and allergic reactions of the skin and can even form dichloride, a gas which can trigger cough, headaches and vomiting when inhaled [16]. Other studies have indicated that by-products of chlorine in water have cancerogenic potential [17].

Contrarily to what happened in most of the developed countries, in Canada, including the province of Quebec, the follow up of RWIs is not part of epidemiological surveillance and the impact of swimming pools on public health has received little attention by the authorities and the related scientific studies seem to be nonexistent [18].

The present study was designed to establish the microbiological quality of water from 73 of Montreal's open public swimming pools and the impact on the health of swimmers during the summer of 2006.

### Materials and Methods

#### Water sampling

The three consecutive water samplings took place in the middle and end of July and the beginning of August. Each of three samplings per swimming pool was carried out at different periods of day and in presence of fluctuating number of swimmers. The volume of 1000 ml of water was taken from each swimming pool and transported in thermo-stable conditions to the laboratory for analyses. All analyses have been carried out according to standard methods (SM) [19]. For the first and third samplings, only 72 and 63 swimming pools were collected, respectively, due to the fact that the authorities of some of these installations refused access to the sampling team or confiscated samples that were already taken. The second samplings were successful in all 73 of Montreal's swimming pools.

#### Physicochemical Analysis

The physicochemical parameters tested have a direct link to the microbiological flora of the swimming pools studied.

#### The Total and Free Chlorine

Chlorine is recognized as effective disinfecting agent against bacteria. However, its activity against the aquatic parasites is considered as inadequate and its antiviral potential remains unknown. In the province of Quebec, only chlorine was recognized by the Ministry of Environment as a disinfecting agent for the swimming pools in 2006.

Total chlorine is defined as the sum of free and combined chlorine. Combined chlorine results from the interaction of the hypochloric acid with organic and inorganic matrices. In order to maintain suitable quality of the water, the free chlorine level must be at least twice that of the combined chlorine, as recommended by Dadswell [16].

Measurements of free and total chlorine were carried out according to method diethyl-p-phenylene-diamine (SM-4500) by means of the kit HACH.

### **pH**

The pH has been chosen as indicator of microbial contamination, as well as chlorine microbial effectiveness. It has been reported that low pH value may reduce levels of chlorine. Contrarily, high pH reduces its effectiveness. The pH was measured according to protocol SM-4500 H<sup>+</sup>.

### **Alkalinity**

The alkalinity is part of present study due to its importance on destruction of aquatic pathogens by chlorine which is less efficient or nonexistent at Ph levels greater than 5. The analytical method used was SM-2320.

### **Turbidity**

The value of this test in the present study is to evaluate the content of microbial flora, epithelial cells and others body waste, as well as environmental contaminants in water. The measurement of turbidity was carried out according to method SM-2130.

### **Odours**

Odours can be indicators of both microbiological and chemical contaminations of water that affect the comfort of swimmers. The members of the sampling and laboratory testing team evaluated the intensity and variety of odours olfactorily.

### **Colour**

The colour of water was measured by the visual comparison method SM-2120.

### **Microbiological Analysis**

#### **Heterotrophic Plate Count**

The analysis of total bacterial flora is a sensitive and a reliable method of evaluation of the microbiological quality of swimming pool water and might be an indicator of global swimming pool maintenance. The culture of the aerobic heterotrophic bacteria was carried out according to method SM-9215C.

#### **Fecal Aquatic Pathogens**

The Montreal swimming pool policies do not require obligatory shower prior entering swimming pools. In addition, the water of some swimming pools is in direct contact with the adjacent padding pool. These conditions give importance to the analysis of fecal aquatic pathogens in the present study.

#### **Total Coliforms**

The analysis of the total coliforms was carried out according to method SM-9222B. The fecal staphylococci and fecal streptococci (group D of Lancefield) were analyzed according to method SM-9213B and SM-9230C, respectively.

#### ***E. coli***

This analysis was not required by the provincial regulation in 2006. However, it is employed in the present study as an indicator of presence of the fecal matter in swimming pools without chlorine in the water. *E. coli* was analysed by the method SM-9222D.

#### ***C. difficile***

This species is also analyzed as an indicator of the presence of fecal matter in the water [20]. However, its impact on the health of swimmers has not been documented.

#### ***P. aeruginosa***

The enumeration of *P. aeruginosa* was carried out according to method SM-9213E.

#### **Legionella**

In the present study, Legionella was also considered as an indicator of the prolonged absence of chlorine, since is not part of regulatory quality control testings. For the research of Legionella, the water samples were also filtered according to the method SM-9260J.

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### Toxicological Analysis

In the city of Montreal, renewal of water in public swimming pools is not practiced. Thus, it might be supposed that toxicity increases during a swimming season due to excessive use of chlorine, human body waste, microbial toxins and environmental pollutants. The water toxicity was tested by "Toxi-Chromo test". This test is not part of any of existing norms and obtained results have been compared to the results for the drinking water.

### Impact on public health

In the absence of official follow up of RWIs, the impact of the water from swimming pools on health has been evaluated by the professional experience of private medical clinics, which have treated affected swimmers, as well as partial statistical data which were obtained from the "Regie de l'assurance maladie du Quebec".

Only statistics coming from invoicing by private clinics have been considered. Other pertinent statistics such as treatments by hospitals or by CLSC (Local community services center) remain unavailable in the province of Quebec.

The following health conditions have been evaluated:

- a. *Gastroenteritis* of microbial origin,
- b. *Gastroenteritis* of aquatic parasites origin,
- c. *Otitis externa* known as swimmers infections,
- d. *Conjunctivitis* and
- e. Mucosal and skin reactions to the chlorine.

The incidence of these conditions during the swimming period from July to August has been compared to their incidences of previous months in 2006.

## Results

### Physicochemical Results

#### Chlorine

According to the provincial legislation of last year, the norm for free chlorine is between 0.6 and 1.2 mg/L. During the first and the second samplings, 57 (79.2%) and 62 (84.9%) of swimming pools had water with inadequate levels of free chlorine. By the third sampling, the number of non conforming swimming pools dropped to 49 (77.8%). The free and total chlorine values varied between 0.00 and more than 3.50 mg/L at the time of 3 samplings.

#### pH

The values of pH varied from 6.40 to 7.95 during the 3 samplings. The provincial norm for pH values is between 7.4 and 7.8. Only 12 swimming pools obtained results of pH values within the norms during the 3 testings. In contrast, 7 swimming pools obtained non-conforming results in all 3 testings. Nonconforming pH levels have been identified in a total of 54 (75.0%) swimming pools in the first sampling and in 47 (64.4%) and 35 (55.6%) swimming pools during second and third samplings, respectively.

#### Alkalinity and Color

All the swimming pools were in conformity with the norms for alkalinity (minimum of 50 mg/L of calcium carbonate), and color (0-15 UTC).

#### Turbidity

The turbidity of water remained stable in three populations of tested samples. The results generally range between 1.0 and 1.7 UNT while the provincial norms require between 0 and 5 UNT. Only one swimming pool obtained a value of turbidity of 8.5 UNT at first testing period.

### Odour

The norm for odour of chlorine in swimming pools was fixed at medium. Non-conformity was observed for 47 (65.3%) swimming pools during first sampling with either too strong or too weak odour. The results remained almost the same for the two other samplings with 58 (79.5%) and 40 (63.5%) swimming pools having inappropriate odour.

### Microbiological Results

#### HPC

The total enumeration of the heterotrophic bacteria resulted in incidence, which varied between zero and "Too numerous to be Counted" (TNC) colonies per ml. The distribution of the non-conforming results was as follows: 16 (22.2%) at the time of the first sampling, 31 (42.5%) and 27 (42.9%) at the time of the second and the third samplings. TNC incidence was obtained in 11 (15.3%), 28 (38.4%), and 22 (34.9%) by the first, second and third samplings, respectively. These results indicate negligence in water chlorination. The WHO norms require less than 200 colonies per ml.

#### Total Coliforms

This group of bacteria has been isolated from the water of many swimming pools during the three samplings. At the first sampling, only 8 (11.1%) swimming pools were contaminated, this number increased to 32 (43.8%) during the second sampling and dropped to 19 (30.2%) by the last sampling at the beginning of August. The current norms in Quebec require an absence of total coliforms/100 ml of water.

#### Fecal staphylococci and fecal streptococci

Fecal staphylococci have been isolated from water samples of 5 (6.9%) swimming pools at first samplings and 10 (13.7%) at second sampling. However, only one (1.6%) of the swimming pools contained fecal staphylococci at the last period of sampling.

The contamination with fecal streptococci was found in 8 (11%) of the studied swimming pools during the first sampling, while this rate decreased to 7 (9.6%) by the second sampling. The analyses of the third set of samples showed no presence of fecal streptococci.

The provincial standard for those two groups of aquatic pathogens from intestinal origin is also an absence/100 ml of water.

#### *E. coli*

The presence of *E. coli* was found at the time of the first sampling in 6 (8.3%) swimming pools. However, for the second and the last samplings, only 3 (4.1%) and 0 (0%) of the swimming pools contained *E. coli*, respectively. As with previous aquatic pathogens of intestinal origin, an absence of *E. coli* per 100 ml is used as a norm for the evaluation of water quality studied.

#### *C. difficile*

A total of 14 (9.7% and 9.6%) of swimming pools were found contaminated equally in the first two groups of samplings. The number of colonies varied between 2 and TNC/100 ml. In the last group of samples, no *C. difficile* was found. An absence of colonies in 100 ml of water was set as the norm by the present study.

#### *P. aeruginosa*

The incidence of *P. aeruginosa* varied between 4 and TNC colonies per 100 ml of analyzed water. During the first and the second period of samplings, the number of contaminated swimming pools was 8 (11.1%) and 4 (5.5%), respectively. No contamination by *P. aeruginosa* was observed during the last sampling. An absence of *P. aeruginosa* per 100 ml of sample was required by the provincial regulations in 2006.

### *L. pneumophila*

*L. pneumophila* was isolated from 7 (9.7%) swimming pools at the first sampling. The worst result was obtained at the second sampling showing presence of the bacteria in 19 (26.4%) of the tested swimming pools. A significant amelioration was observed by the third sampling when only 4 (6.3%) were contaminated by this bacterial species. The norms of the WHO require the absence of Legionella per 100 ml of water.

### Toxicological Analysis

The obtained values of toxicity varied between 1.00% and 3.10%. Water samples of 26 (36.1%) swimming pools displayed the toxicity level higher than 1% for the first sampling. For the second and third samplings, 31 (42.5%) and 26 (41.3%) swimming pools were found with high levels of toxicity, respectively. The toxicity of the water of the swimming pools is due, mainly, to the chlorine excess, as well as pollutants coming from swimmers bodies and microbial flora. This pollution is enhanced by the total absence of water renewal. The toxicity level of municipal drinking water is less than 1%.

### Impact on the public health

A significant augmentation was observed during the summer of 2006 of *Otitis externa* in Montreal according to the partial data obtained from "Regie de l'assurance maladie du Quebec". An average of  $2090 \pm 179$  cases of infection have been registered by private medical clinics during July and August compared to  $1502 \pm 52$  cases during the two preceding months, representing a significant increase of  $39 \pm 10$  %. Affected people treated in hospitals and by the CLSC have not been taken in account.

However, many private medical clinics have been challenged by the high incidence and steady increase of RWIs during last decade. The global results of analysed samples are summarised in the Table 1.

### Discussion

Public swimming pools became increasingly popular recreational facilities during hot summers in recent years in the province of Quebec. The majority of them are old installations respecting no norms for adequate maintenance of water conditions. The water quality was determined by an old legislation, which included basic quality control tests which are only performed occasionally. The epidemiological follow up of RWIs has not been established.

The present study, the first of its kind in Canada, aimed to determine the quality of the water of 73 open public swimming pools of the town of Montreal during the summer season by the analyses of the chemical, microbiological and toxicological properties and to determine its impact on public health by epidemiological statistical analyses.

The virological analyses, as well as the research of the aquatic parasites, were not part of the present study.

In order to obtain representative results for the swimming season, sampling and the analyses were carried out 3 times, twice in July and once at the beginning of August, which coincided with the end of the swimming season. The sampling was performed at different periods of day for each studied swimming pool and in the presence of a variable number of bathers. On the other hand, the weather conditions were similar, i.e. were generally sunny, very hot and wet.

Physicochemical analyses were employed to determine if the conditions were optimal for the maintenance of acceptable microbiological quality of water. Indeed, the activity of chlorine varies according to the pH and the alkalinity. The microbiological analyses were carried out to determine the effectiveness of disinfection of water using chlorine analyses of aquatic pathogens. The toxicological analyses were considered to determine whether polluted water might have toxic potential.

The results obtained for certain swimming pools deserve careful consideration due to the fact that sampling was carried out during a weak presence and in some occasions even in absence of swimmers.

Parameters Analysed	1 <sup>st</sup> Sampling July 8-10 72 samples		2 <sup>nd</sup> Sampling July 15-17 73 samples		3 <sup>rd</sup> Sampling August 4-6 63 samples	
	Conform (%)	Non conform (%)	Conform (%)	Non conform (%)	Conform (%)	Non conform (%)
<b>Microbiological Results</b>						
HPC	56 (77.8)	16 (22.2)	42 (57.5)	31 (42.5)	36 (57.1)	27 (42.9)
Total coliforms	64 (88.9)	8 (11.1)	41 (56.2)	32 (43.8)	44 (69.8)	19 (30.2)
<i>Fecal staphylococci</i>	67 (93.1)	5 (6.9)	63 (86.3)	10 (13.7)	62 (98.4)	1 (1.6)
<i>Fecal streptococci</i>	64 (88.9)	8 (11.1)	66 (90.4)	7 (9.6)	63 (100)	0 (0)
<i>E. coli</i>	66 (91.7)	6 (8.3)	70 (95.9)	3 (4.1)	63 (100)	0 (0)
<i>C. difficile</i>	65 (90.3)	7 (9.7)	66 (90.4)	7 (9.6)	63 (100)	0 (0)
<i>P. aeruginosa</i>	64 (88.9)	8 (11.1)	69 (94.5)	4 (5.5)	63 (100)	0 (0)
<i>Legionella</i>	65 (90.3)	7 (9.7)	54 (74.0)	19 (26.0)	59 (93.7)	4 (6.3)
<b>Physicochemical Results</b>						
pH	18 (25.0)	54 (75.0)	26 (35.6)	47 (64.4)	28 (44.4)	35 (55.6)
Alkalinity	72 (100)	0 (0)	73 (100)	0 (0)	63 (100)	0 (0)
Free chlorine	15 (20.8)	57 (79.2)	11 (15.1)	62 (84.9)	14 (22.2)	49 (77.8)
Colour	72 (100)	0 (0)	73 (100)	0 (0)	63 (100)	0 (0)
Turbidity	71 (98.6)	1 (1.4)	73 (100)	0 (0)	63 (100)	0 (0)
Odour	25 (34.7)	47 (65.3)	15 (20.5)	58 (79.5)	23 (36.5)	40 (63.5)
Toxicity	46 (63.9)	26 (36.1)	42 (57.5)	31 (42.5)	37 (58.7)	26 (41.3)
Total	3 (4.2)*	69 (95.8)**	3 (4.1)*	70 (95.9)**	1 (1.6)*	62 (98.4)**

**Table 1:** Global presentation of obtained results by analyses of 73 Montreal's public swimming pools.

\* = Conform in all testing parameters.

\*\*= Non-conform in one or more parameters.

Slight improvements of the water's qualities by the third sampling are due to the warning of the managements of the swimming pools about the described ongoing studies.

Finally, the impact on the public health of the precarious conditions of a high number of Montreal swimming pools has been evaluated by partial official statistical analyses of incidence of health conditions belonging to the RWIs. Due to the quality of these data coming from invoicing by private medical clinics, only *Otitis externa* had an adequate code for statistical evaluations. Other conditions that are part of RWIs are associated with a complex code allowing no compilation of specific data. The impact of hospitalised or CLSC treated RWIs is not included in the present statistical evaluation.

However, private medical clinics in the Montreal region have noticed a significant impact of swimming pools on the health of treated swimmers and RWIs were in constant and significant progression during the last decade. In the United States, where RWI follow-up is mandatory, Beach., *et al.* [21] have reported 62 waterborne diseases and outbreaks during 2003-2004 associated with recreational water. One can consider that the similar situation may have occurred in Quebec.

## Conclusion

The results obtained during this study of the public swimming pools of the town of Montreal support the following conclusions:

- a. The majority of the cases of non conformity of water were based on the lack of free chlorine and consequently, the microbiological contamination, potentially dangerous for human health.
- b. Some swimming pools had chlorine in excess.
- c. Water of some swimming pools displayed high toxicity levels.
- d. The quality of the water of the majority of the studied public swimming pools is precarious and represents a real danger to the public health.
- e. A significant increase in Otitis externa was observed.

The elaboration of new legislation coincided with the end of the present study and has been in force since January 2007. However, it contains some unusual tolerance, such as swimming up to 30 days in microbiologically contaminated swimming pools.

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