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Original Research

Microbiological quality of the water of recreational and rehabilitation pools: a 2-year survey in Naples, Italy

M. Guida [a], F. Gallè [b], M.L. Mattei [a], D. Anastasi [b], G. Liguori [b,*]

[a] Department of Biological Sciences, University of Naples 'Federico II', Naples, Italy
[b] Department of Studies of Institutions and Territorial Systems, University of Naples 'Parthenope', Via Medina n. 40-80133, Naples, Italy

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SUMMARY

Objectives: To analyse and compare the microbiological quality of the water in rehabilitation and recreational swimming pools in Naples, Italy.

Study design: A 2-year survey investigated the microbiological quality of the water in seven recreational and rehabilitation pools, and the findings were compared with local guidelines.

Methods: For each facility, water was sampled at the intake point and at two points inside the pool. Total microbial contamination and *Pseudomonas aeruginosa* contamination were evaluated.

Results: Microbial mesophilic contamination and *P. aeruginosa* contamination were found in all seven pools. Microbial mesophilic contamination was more common in recreational pools (3–4.2% samples were above threshold values), probably due to the greater number of bathers. *P. aeruginosa* was more common in intake water than water inside the pool [mean values of 19.3 and 22.5 colony-forming units (cfu)/ml in recreational and rehabilitation pools, respectively]. A longer period of contact with chlorine and the dilution process may have led to lower levels of *P. aeruginosa* in the pool water (range 2–15 cfu/ml).

Conclusions: There is a need to improve disinfection and cleaning procedures, with consideration given to the different uses and daily bather loads of each pool type. There is also a need to monitor water quality and to increase users' knowledge and awareness of the risks.

Introduction

Swimming is often recommended because of its potentially beneficial effects on the joints and on people's general sense of well-being. A large variety of people attend swimming pools for athletic, recreational or medical activities. In these environments, the elderly, pregnant women, babies, people with handicaps or movement disabilities and athletes can be predisposed to contracting infections.[1] Several types of opportunistic or pathogenic micro-organisms can be introduced to the water via direct or indirect human contamination, and can grow to a point at which they may cause cutaneous, gastrointestinal or respiratory diseases in the bathers.[2] Swimming pools are often associated with outbreaks of waterborne infections.[3,4] Many interventions can be engaged to improve the microbiological quality of water in swimming pools; however, the paucity of application of these systems or their deficiency in relation to bather turn-over, together with elevated microbial resistance to disinfectants, can predispose the users to infection hazards.[2,5]

Pseudomonas aeruginosa, an aerobic ubiquitous Gram-negative rod, can be released in the water from bathers' skin through desquamation or the surrounding environment. It grows well in the warm, moist environment provided by pools, is resistant to inadequate disinfection treatment, and is often implicated in pool-associated infections and outbreaks.[3,6–9] *Pseudomonas* tends to accumulate in filters and areas that are poorly cleaned, and can live in a biofilm which is a source of nutrients for its growth and provides protection against exposure to disinfectants.[10,11] It can cause different types of infection, especially in immunocompromised patients. In hot tubs, the primary health effect associated with the presence of *P. aeruginosa* is folliculitis; otitis externa and infections of the urinary tract, respiratory tract, wounds and cornea have also been linked with the use of hot tubs. In swimming pools, the primary health effect associated with *P. aeruginosa* is otitis externa, although folliculitis dermatitis, conjunctivitis and pneumonitis have also been reported.[2]

This report presents the results of a survey undertaken in seven recreational and rehabilitation pools in Naples, Italy to analyse the

* Corresponding author. Tel./fax: +39 081 547 47 90.
E-mail address: giorgio.liguori@uniparthenope.it (G. Liguori).

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microbiological quality of the water, particularly contamination due to *P. aeruginosa*.

Methods

Between 2006 and 2007, a total of 409 water samples were collected from four recreational pools and three rehabilitation pools in Naples. One-litre sterile bottles were used to sample water at the intake point and at two points in the pool, i.e. 40–50 cm from the edge and 20–30 cm from the surface, as recommended by regional guidelines.[12] Sampling was undertaken on a monthly basis before the pools opening time.

For each sample, microbiological parameters were evaluated on the basis of their corresponding guidelines (total microbial count at 22 °C and 37 °C: UNI EN ISO 6222:2001; *Escherichia coli*: UNI EN ISO 9308-1:2002; *Enterococcus* spp.: ISO 7899-2:2000; *Staphylococcus aureus*: UNI 10678:1998).[13]

P. aeruginosa detection was performed as described by the UNI EN 12780:2002. One-hundred millilitres of each sample were filtered with a sterile 0.45-μm Ø membrane, which was incubated at 36 ± 2 °C for 44 ± 4 h on *Pseudomonas* agar base/CN-agar (Oxoid CM0559, SR0102). Blue-green, fluorescent colonies were counted and expressed as colony-forming units (cfu) per 100 mL. The recommended threshold values are ≤1 cfu/100 ml for water inside the pool and ≤0 cfu/100 ml for intake water.

Regarding the psychrophilic microbial count, the threshold values are ≤100 cfu/ml for intake water and ≤200 cfu/ml for water inside the pool. For the mesophilic count, the limits are ≤10 cfu/mL and ≤100 cfu/ml, respectively. The guidelines indicate that *E. coli* and enterococci should not be present in water samples, and the limits for *S. aureus* are ≤1 cfu/100 ml for water inside the pool and ≤0/100 ml for intake water.

For each sample, residual chlorine levels were also measured using a photometer (HI 93701, Hanna Instruments, USA) with the DPD 330.5 method. Threshold values for free chlorine are 0.6–1.8 mg/l for intake water and 0.7–1.5 mg/l for water inside the pool.[12]

Statistical analysis was undertaken in order to evaluate differences in the contamination of water from different sampling points using ANOVA, and from the two types of pools using Student's *t*-test. The level of significance was $P = 0.05$.

Data regarding the number of bathers using the pools and the type of water treatment were also collected.

Results

The characteristics of the seven facilities and the daily average number of bathers using these pools are reported in Table 1.

All the microbiological parameters of the samples complied with the threshold values of the regional guidelines, with the exceptions of the mesophilic microbial count and *P. aeruginosa*.

Table 1
Characteristics of the seven pools analysed.

Pool	Type	Volume (m^3)	No. of bathers/day	Disinfection procedure
A	Rehabilitation	45	35	Bromination/ chlorination
B	Rehabilitation	72	25	Chlorination
C	Rehabilitation	45	25	Chlorination
D	Recreational	3300	1200	Chlorination
E	Recreational	1188	1100	Chlorination
F	Recreational	600	300	Chlorination
G	Recreational	600	300	Chlorination

Table 2 shows the mean values, ranges and percentages of samples which had mesophilic microbial counts and *P. aeruginosa* levels above the recommended limits. Table 2 also shows the corresponding mean values and ranges of residual chlorine. Samples were grouped on the basis of type of facility and point of sampling.

In the recreational pools, differences in mesophilic microbial contamination were not observed between the three sampling points; however, higher levels of *P. aeruginosa* were registered in intake water compared with the pool samples.

In the rehabilitation pools, intake water showed lower mean levels of microbial contamination compared with the pool samples (5.02 vs 13.8 and 12.9 cfu/100 ml); however, this did not go above the threshold value for either the intake water or the pool samples. Conversely, *P. aeruginosa* contamination in intake water was greater than that in the pool samples (79% vs 23% and 18%). Statistical analyses did not indicate significance in these differences ($P > 0.05$).

The recreational pools showed greater mesophilic contamination than rehabilitation pools. However, *P. aeruginosa* contamination was lower in the intake water samples in the recreational pools (19.3 vs 22.5 cfu/100 ml). The pool water samples from recreational and rehabilitation pools showed similar levels of *P. aeruginosa*. Student's *t*-test did not show statistical differences between the two types of pool.

Free chlorine levels were below the recommended limit in 47 (11.5%) samples; of these, 27 (57.4%) samples (11 intake water, 16 pool water) were also positive for *P. aeruginosa* (data not shown).

No remarkable trends in microbiological contamination of samples were observed during the survey period.

Discussion

The use of swimming pools and similar recreational water environments has benefits for health and well-being. However, pools may present certain hazards that must be considered for the safety of bathers and personnel. In recent years, much attention has focused on the risk of infection associated with contamination by faecal and non-enteric micro-organisms.[2,12]

Certain population groups may be more predisposed to these hazards than others. For example, children may spend more time in recreational pools than adults, and they are more exposed to accidental ingestion of water. Immunocompromised individuals are more susceptible to waterborne infections and tend to experience more severe outcomes. Moreover, heavy exercise, such as training for competitive swimming, appears to have a depressant effect on the immune system, which may last for a week or more. It may be that competitive swimmers are at greater risk of contracting upper respiratory and viral infections than recreational water users.[1,2]

Several factors may increase the risk of contracting infectious diseases in these environments. The duration of water contact directly influences the amount of exposure to micro-organisms in contaminated water and aerosols. A high bather load, especially where there is limited water turnover, may be a significant factor in the transmission of disease. The personal hygiene of recreational water users may also alter the water quality significantly. Higher water temperatures may promote the growth of some micro-organisms.[1,2]

Chlorine is often used to disinfect swimming pools, but inadequate chlorination may lead to the colonization of spray circuits and pumps with Gram-negative bacteria, predominantly *P. aeruginosa*.[14]

P. aeruginosa contamination of water can arise from infected human or environmental sources. Since the symptoms of illnesses caused by this bacterium are primarily mild and self-limiting, the true incidence of *P. aeruginosa*-associated infections in swimming