

Microbiological quality in Finnish public swimming pools and whirlpools with special reference to free living amoebae: a risk factor for contact lens wearers?

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Abstract

To assess the possible risk of microbial keratitis associated with swimming or bathing in public pools, the microbiological quality as well as the presence of free living amoebae in 16 halogenated swimming pools and whirlpools, located in Helsinki, Finland, was determined. Five additional whirlpools situated in the ferries cruising from Finland to Sweden were included in the study. Other parameters investigated were the total bacterial count, identification of *Pseudomonas aeruginosa* and *Staphylococcus aureus*, measurement of free residual and combined chlorine, potassium permanganate index, urine, pH, and turbidity. Amoebae were detected in 41% of the pool water samples studied. Seven of 11 whirlpools and four of 10 swimming pools were shown to contain amoebae. An *Acanthamoeba* species was isolated from only one outdoor swimming pool; the other amoebae belonged to the genera *Vexillifera*, *Flabellula*, *Hartmannella*, and *Rugipes*. Although not a single verified case of *Acanthamoeba* keratitis has been found in Finland, the findings show that there is a theoretical risk of amoebic and bacterial keratitis associated with swimming or bathing in properly cleaned public pools. Consequently, we do not recommend swimming or bathing with contact lenses.

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Epidemiological evidence has indicated that bathing or swimming in polluted waters is a potential health risk.¹⁻⁴ Infections transmitted by swimming pool or whirlpool water most probably result from inadequate cleaning and/or disinfection measures.⁵⁻⁷ The microorganisms detectable in pool water originate from the skin, mucous membranes, and clothing of bathers as well as from the environment. Most agents are non-pathogenic, but some are able to cause infections.

Pseudomonas aeruginosa and *Staphylococcus aureus* most frequently cause ocular, aural, or cutaneous infections related to swimming.^{8,9} *P. aeruginosa* has caused aural and urogenital infections due to bathing in whirlpools.¹⁰ *S. aureus* and *P. aeruginosa* are also frequently found in contact lens associated keratitis.¹¹

Diseases caused by free living amoebae – for example, potentially fatal *Naegleria fowleri*

meningoencephalitis, are also often transmitted while swimming in chlorinated swimming pools.^{12,13} Certain free living amoebae are able to cause severe sight threatening keratitis, the treatment of which may last for months yet fail, making corneal transplantation necessary.¹⁴ The life cycle of *Acanthamoeba* consists of two different stages: active trophozoite and inactive cyst. The encysted form is relatively resistant to unfavourable conditions – for example, drugs and disinfectants. The trophozoite form of *Acanthamoeba* adheres to all lens types, but the encysted form does not seem to attach to gas permeable hard lenses.¹⁵ *Acanthamoebae* are able to contaminate contact lens solutions and storage cases.^{16,17} Even commercial antimicrobial lens care solutions have been found to contain *Acanthamoebae*.^{18,19} No diagnosed cases of *Acanthamoeba* keratitis have yet occurred in Finland,²⁰ although a few patients have been treated in Sweden²¹ and Norway.²² Recently also *Vahlkampfia/Hartmannella* amoebae have been isolated from both the cornea and the contact lens case of a patient with keratitis, as well as from the tap water the patient had used.²³ To clarify the risk of exposure when swimming or bathing with contact lenses we investigated the presence of amoebae in swimming pools and whirlpools in the Helsinki area and in ferries cruising from Finland to Sweden.

Materials and methods

Most of the 10 swimming pools and 11 whirlpools studied were supplied with public tap water from a single origin, the city of Helsinki. The five whirlpools on the ferries were supplied with water either from Helsinki or Stockholm. The water of Helsinki was treated by routine methods: flocculation, decantation, filtration, and disinfection by chlorine and ozone. Filtering and the use of sodium hypochlorite as a disinfectant were the principal measures used in the pools studied.

One litre water samples were drawn into sterile bottles from the surface and/or from a depth of 20 cm of each swimming pool and whirlpool for amoebal isolation. A total of 34 samples were taken, 22 from whirlpools (two from each pool), and 12 from swimming pools (two pools were examined twice). Fifty ml portions of water were centrifuged (1000 g for 10 minutes) and the sediments then centrifuged together in one batch.

To study the surface contamination of the

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Table 1 Bacteriological and chemical analyses of whirlpool and swimming pool water. (Number of samples 26)

Parameter	Mean	Median	Range	Guide level
Total plate count (cfu/ml)	131	3	0-3000	<100
Combined chlorine (mg/l)	0.44	0.30	0.05-1.5	≤0.5
Free chlorine (mg/l)	0.59	0.35	<0.05-3.3	≥0.5*
Total chlorine (mg/l)	1.03	0.75	0.25-4.8	<3.0
pH	7.1	7.2	3.9-9.1	7.0-7.2
Potassium permanganate index (mg/l)	8.4	6.0	1.4-23	<10
Turbidity (FTU)	0.62	0.21	0.09-5.9	<0.4
Urine (mg/l)	0.60	0.30	<0.1-2.5	<1.0

*Whirlpool ≥ 0.5 mg/l, swimming pool ≥ 0.3 mg/l, when pH 6.5-7.2.

†Whirlpool < 3.0 mg/l, swimming pool < 2.5 mg/l.

FTU = formazine turbidity units.

pools 210 swab samples for amoebal isolation were taken from the walls of the swimming pools and whirlpools. Non-nutrient agar seeded with *Klebsiella oxytoca* was used for amoebal isolation.^{24,25} The plates were incubated in moisture for 2 weeks and examined every second day by inverse microscopy, and the amoebae characterised to genus level in the London School of Hygiene and Tropical Medicine.

Microbiological and chemical analyses were performed on 26 water samples each of 500 ml (five whirlpools were analysed twice). The disinfectant was neutralised by addition of thio-sulphate (35 mg/l) to the sample bottle. The samples were analysed for total bacterial count (plate count agar of Difco Laboratories, Detroit, Michigan, USA, at 35°C for 48 hours) and faecal coliforms (the most probable number method using lactose bromocresol purple broth at 44.5°C for 48 hours) using standard Finnish procedures.^{26,27} The presence of *P. aeruginosa* in 100 ml of water was examined, using the procedure of American Public Health Association (APHA).²⁸ The samples were also filtered for the isolation of *S. aureus*, using M-5-LSMA agar.²⁹

Other investigations included the colorimetric determination of chlorine,²⁸ measurement of pH and turbidity, using a Metrohm 605 pH meter (Herisan, Switzerland) and a Hach Model 2100 A turbidimeter (Hach Chemical Company, Iowa, USA). The potassium permanganate index was used to describe the amount of organic matter.³⁰ The water urine concentration was determined by a spectrometric method.³¹

Results

Table 1 summarises the data of the microbiological and chemical analyses. The microbiological quality of the water was good (less than 100 bacteria/ml) in 90% of the pools. *P. aeruginosa* was detected in the water of two whirlpools in which the total bacterial count was

also high. Neither faecal coliforms nor *S. aureus* were detected in the samples examined.

Amoebae were detected in 14 of the 34 samples examined (41%; Table 2). Four of the positive samples were obtained from swimming pools and seven from whirlpools. *Acanthamoeba* was isolated from only one outdoor swimming pool; the other isolates belonged to the genera *Vexillifera*, *Flabellula*, *Hartmannella*, and *Rugipes*. The majority (71%) of the amoebae were detected in pools in which the bacteriological quality of the water was good. Both samples containing *P. aeruginosa* were also amoeba positive. No amoebae were found in the swab samples from the walls of the pools.

The free chlorine concentration was below the guide level in 46% of the samples and amoebae were detected in 67% of these samples. On the other hand, amoebae could also be found in samples in which the free chlorine residue was as high as 3.3 mg/l. Free chlorine reacts with impurities in water to form combined chlorine. In 27% of the water samples the concentration of combined chlorine and the amount of organic matter (oxygen consuming substances) were elevated. Of the amoeba positive water samples 36% did not conform to the requirements and recommendations stated for good quality of swimming water. However, no correlation was seen between the degree of general quality of swimming water and the amoebal findings.

Discussion

There are about 20 known species of acanthamoebae; at least five have been reported to cause corneal infection: *A. castellanii*, *A. culbertsoni*, *A. hatchetti*, *A. polyphaga*, and *A. rhyssodes*.³² Acanthamoebae are ubiquitous in soil, water and dust. They have been isolated from fresh-water, sea water, tap water, bottled mineral water, air, air conditioners, contact lens cases, and contact lens solutions.³³ Air, dust, and soil carried by swimmers into the water may be the sources of acanthamoebae. Contact lens wearers constitute 85% of the patients, and a history of exposure to contaminated water is common among the diseased.³⁴ Wearers of both disposable soft lenses^{35,36} and hard contact lenses³⁷ also exist among the affected individuals. *Acanthamoeba* keratitis is predominantly related to daily or extended wear soft contact lenses.³⁴

The quality of the tap water used for the filling of the pools reflects the efficiency of the water treatment process. When water samples from the home environment of 50 contact lens wearers were studied, *Acanthamoeba* species were isolated from six bathroom cold water taps.¹⁸ Also other amoebae, including *Hartmannella*, *Naegleria*, *Vahlkamfia*, *Vanella*, *Vexillifera*, *Platyamoeba*, *Filamoeba*, and *Nucleria*, were identified. Colonisation of amoebae most probably occurs in those parts of water distribution systems where the residual concentrations of disinfectant are low and water delay long. Poorly maintained and

Table 2 Frequency of amoebic contamination in whirlpools and swimming pools

Pool	Water samples (n=34)		Pools (n=21)	
	Amoeba present	Amoeba absent	Amoeba present	Amoeba absent
Whirlpool	10	12	7	4
Swimming pool	4	8	4	6
Total	14	20	11	10

old water distribution systems may also be favourable for growth in the tap water.

The mean value of total chlorine concentration of the tap water used for filling of the pools was 0.5 mg/l. Even a free chlorine concentration of 4 mg/l does not destroy the *Acanthamoeba* cysts after 3 hours of exposure.³⁸ The tap water distributed by the city of Helsinki fulfils the microbiological requirements for drinking water of directive EEC 778/80: the absence of coliform bacteria and the number of total count of bacteria less than 10/ml (at 22°C for 48 hours). The maximal allowed chlorine concentration (1 mg/l) in drinking water³⁹ is, however, not high enough to destroy the amoebae. Any contamination of the water pipelines with soil or sewage water can pollute the system with free living amoebae.

Filtering and disinfection with sodium hypochlorite are the principal cleaning measures used in the pools studied. These procedures are also unable to destroy amoebae (mainly cysts).⁴⁰ Filters retain particles suspended in water and amoebae can proliferate in the filter. Consequently, the filters should be washed regularly, using a reverse flux.

Amoebae ingest bacteria. Bacterial cocontamination may enhance amoebic pathogenicity according to in vitro and in vivo studies.^{41 42} In this study we observed no correlations between either the concentration of bacteria or the amount of organic matter and the occurrence of amoebae. Organic particles tend to accumulate as limescale on the pool walls and thus may concentrate the growth of amoebae. However, we found no amoebae on the walls of the pools.

An *Acanthamoeba* species was found in only one outdoor swimming pool in Helsinki. It is most probably introduced by a swimmer and not through the water supply. The other strains isolated belonged to the genera *Vexillifera*, *Flabellula*, *Hartmannella*, and *Rugipes*. However, most of the pools received their water from a single source. Further studies are needed to clarify if *Acanthamoeba* is more common in other parts of the country. The cleaning and disinfection methods of Helsinki are probably the best in Finland. Consequently, it is likely that the quality of water is worse elsewhere in Finland where the cleaning measures are less advanced. The finding shows that although the disinfection methods used – for example, ozonisation, may be more effective than those used in some other cities they do not completely eliminate the risk of amoebal contamination. Patients having their corneal/tear fluid infection barriers compromised – for example, by contact lens wear³⁴ or mild surface trauma,⁴³ may then have higher risks of amoebic keratitis. Contact lens soaking solutions and lens cases can serve as reservoirs for multiplication of many bacteria and fungi.^{17 44} Earlier studies have already shown the association of *Acanthamoeba* keratitis with the use of tap water or home-made saline for contact lens disinfection.⁴⁵ The elevated risk of bacterial infection associated with contaminated pool water is also

shown in this study. Consequently, contact lenses should not be worn when swimming or bathing in public pools.

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History of ophthalmology

The fifteenth century ophthalmologist's vade mecum

Benvenutus Grassi was probably born in the eleventh century, and wrote a practical text of ophthalmology which was popular for 500 years. For general surgeons such as Guy de Chauliac, it was the standard ophthalmological vade mecum.

Both copied manuscripts and printed copies survive, including Provençal, French, Hebrew, and English translations from the Latin. The book was modestly priced, and most barber surgeons probably owned a copy. Let us try to get the gist of what we would have learned from it, if we were apprentice ophthalmologists in the 1400s.

'Regarding anatomy, dear reader, the eye consists of two coats, filled with humours which are albuginous (like egg white) – and vitreous (like glass) respectively. The spirit of sight enters through the pupil and flies down the optic nerve.

'You will see much cataract. There are three curable and four incurable types. One is caused by excessive eating and drinking, and others by "severe headache, too much worry, weeping and wailing". Some physicians use purgation and powders, yet this is useless. Cataract is a disease within the eye and the cure must directly reach this area. (NB: Benvenutus has no use for diplomacy, referring to these practitioners as either ignorant physicians' or 'fools of quacks', depending on the translation.)

'Treat cataract by couching – purge the patient and have him sit astraddle a bench. Face him, and with a silver needle, pierce the eye coats. Hold the cataract down from exactly the length of time it takes you to say four pater noster. Postoperatively, patients must lie still for eight days while egg white dressings are applied. They must have a light diet, and *no chicken*, as this causes rushing of blood to the eyes. Do not use steel instruments. The point can break and remain within the globe, and severe pain, cold abscess, and loss of sight will result. Gold needles are good, gold having inherent power over cold and dampness (basic astrology was common knowledge among the educated, the sun being the gold planet, source of life and warmth and banisher of cold and fog).

'Ophthalmia is a disease which shows itself on the white of the eye, accompanied by

burning and discomfort. Your patient will be tormented, and will not be able to sleep or rest due to a feeling of sand in the eye. To treat him, equal parts of hyacinth extract and sarcol (the gum of a certain tree) should be mixed in a brass mortar and dusted over the eye of the reclining patient. Do not, dear friends, use nostrums which aggravate the patient's suffering. These can cause the contents of the eye to run out between the lids, followed by blindness. In chronic ophthalmia, mix one ounce each of oak fern, milkweed, and rhubarb with one drachm each of crocus, cubebs, and cinnamon. Administer morning and evening.

'Regarding fungus, you will see patients with a fleshy growth between the nose and eyes, which some call "mulberry". The swelling looks rather like lung substance, and is granular. It may involve both lids, and if you seize it with a hook it tears through. To cure it, cut it away with a sharp knife, cauterise the wound with a hot iron and dress with cotton soaked in egg white.

'Injuries from sticks, stones, and fists are common. Apply beaten albumen on a cotton pad, and do this hastily, before the ocular humours escape! Renew this four times daily, and twice during the night. Meanwhile, anoint the patient's forehead and temples with alabaster ointment. If the coats of the eye are severely lacerated, more potent cure is needed: remove the embryos from white hen's eggs, beat them in a mortar to the consistency of ointment and apply twice daily.

'Always remember that organs are preserved by agents that resemble them – the eye is a cold organ, so use cold remedies. Patients have lost their sight from use of absinthe and frankincense which are heating agents. An excellent general remedy is the juice of fennel, rue, verbena, and sage mixed with the urine of a chaste youth. This is a powerful treatment – use it and you will believe!' 'I have made much money by many of these cures,' remarks the author proudly.

Benvenutus's last piece of advice is this: do not forget the poor if you want God to give you success operating!

FIONA ROMAN