Paper 3.1

Review and assessment of alternative water disinfection technologies for municipal swimming pools in the Netherlands

Frank Oesterholt MSc., senior researcher KWR Water Recycle Institute, The Netherlands , Danny Traksel MSc., manager KWR Industry and Water, KWR Water Recycle Institute The Netherlands and Maarten Keuten MSc.,PhD student faculty of Civil Engineering and Geosciences, Delft University of Technology, The Netherlands.

Synopsis

Personnel and visitors of swimming pools often complain about air quality and suffer from irritation of their skin and/or mucous. Although a direct relationship has never been made, the disinfection byproducts of the use of sodium hypochlorite are believed to be responsible. In a desk study sponsored by the Dutch government, alternative disinfection methods for swimming pool water were evaluated. These methods represent the state of art of modern techniques in water treatment disinfection. Twelve methods (single techniques or combinations of techniques) were evaluated using a multi criteria analysis (MCA). Main requirement for every method was that the degree of microbiological health protection was on the same level as it is today (using classic treatment using sodium hypochlorite).

The results of the study show that the use of sodium hypochlorite is essential to reach enough residual disinfection capacity, but the amount used can be reduced by applying it in combination with other techniques. The five most promising alternative methods that came out of the MCA were: sodium hypochlorite in combination with low or medium pressure UV, sodium hypochlorite in combination with ozone or sodium hypochlorite in combination with powdered activated carbon. Another promising option is the application of chlorination using salt electrolysis.
Subsequently to this study, a pilot plant study is planned to investigate and compare the alternatives during practical dynamic swimming pool conditions.

Background

Current Dutch legislation for public swimming pools is based on the recommendation of the Dutch Health Council from 1989 which states that only free chlorine is suitable for the disinfection of swimming pool water. Dutch legislation is still based on the presence of free chlorine in swimming pool water for which minimum and maximum concentrations are specified. The use of sodium hypochlorite results in the formation of disinfection byproduct, so called DBP’s. Based on their oxidizing capability, DBP’s can be roughly divided into two main groups: combined active chlorine as a result of the reaction with ammonia and urea (chloramines, CA) and AOX (adsorbable organic halogens).

Dichloramine and especially trichloramine can cause annoyance and is often mentioned as being responsible for most of the respiratory and allergy complaints from employees and visitors of swimming pools. A recent Dutch study shows that the development of occupational asthma, due to the exposure to chloramines seems possible, although the mechanism is still unclear. The researchers conclude that there are no indications that this kind of new and specific occupational asthma caused by chloramines occur frequently and that aggravation of current asthma or allergies is the most likely explanation for higher incidence of asthma and allergies at employees of swimming pools (IRAS, 2006).

AOX is a sum parameter comprising an extensive group of organic halogens that has no longer the capability to oxidize and therefore plays no role in the oxidation/disinfection process. AOX concentrations in swimming pool water in the Netherlands can get fairly high (400 μg/l up to 2,000 μg/l; measurements; *Sportfondsenbad* 2005-2006). Although the exact composition of AOX is unknown and varies largely with water quality and hypochlorite concentration, some constituents such as chloro-acetone or chloropicrin could be very harmful to humans even at very low concentrations (Stottmeister, 1999).

These findings gave enough ground for the Dutch government to launch a study that would question the necessity of the use of sodium hypochlorite for swimming pool disinfection. Avoidance of the use or reduction of the amount of sodium hypochlorite required for proper disinfection of swimming pool water can be seen as a 'source measure' to prevent any undesired side effects. In this study a total of eleven alternative methods for disinfection of swimming pool water were listed based on literature and interviews with suppliers and experts and subsequently evaluated using a multi criteria analysis. The study was funded by the Dutch Ministry of Housing, Spatial Planning and the Environment.

Methodology

For this study the following method was used:

- Formation of a steering committee that consists of experts, specialists, suppliers, representatives of the National Platform for Swimming Pools, representatives of local government (Provinces) as they enforce Dutch legislation on swimming pools and representatives of the Dutch government.
- Performance of a literature study and interviews with suppliers and experts in the Netherlands and abroad (mainly Germany).
- Performance of a multi criteria analysis (MCA).
- Organization of a workshop in February 2007 to check and to disseminate the study results.

During the MCA, all techniques (or combination of techniques) were evaluated using the following criteria:

1. Test on microbiological effectiveness of the disinfection technique. Test 1: is it reasonable to believe that a 4 log inactivation of *Pseudomonas aeruginosa* during 30 seconds can be reached using the method? Test 2: does the method have a broad spectrum for the inactivation of human pathogens?
2. Side effects, formation of DBP's like combined chlorine, AOX and other.
3. Costs (investment costs and operational costs), based on two case studies.
4. Ease to realize/implement/operate the method.
5. Safety (transport, storage, working conditions).
6. Environmental impact.
7. Water and air refreshment requirement to prevent health complaints.
8. Ease to verify the method.

While performing the MCA, passing the test on microbiological effectiveness was compulsory to proceed. For the criteria 2 till 8 a score (1 = bad performance to 5 = good performance) was assigned for every single technique (or combination of techniques). Together with the supervising committee weight factors (for the Dutch situation) were determined for all criteria. Scores and weight factors were multiplied thus resulting in a score table (see table 1). The higher a score the better the performance of a technique in the MCA.

Research results

Table 1 gives an overview of the disinfection techniques evaluated in this study including the score in the MCA. Three methods, copper/silver ionization, hydrogen peroxide and UV/hydrogen peroxide were not included in the MCA because they have insufficient microbiological effectiveness as individual technologies.

Table 1. Overview of alternative disinfection techniques for swimming pool water

method	**remarks**	**end score in MCA**
sodium hypochlorite + UV (medium pressure lamps)	MP-UV in mean stream	310
salt electrolysis	anode and cathode in one chamber (production sodiumhypochlorite) stock solution: 10-15 g/l hypochlorite	305
sodium hypochlorite + UV (low pressure lamps)	LP-UV in mean stream	295
sodium hypochlorite + ozone (in bypass)	25 % bypass; 15 minutes contact time; dose 7 mg/l ozone; UV for ozone destruction.	295
sodium hypochlorite + powdered activated carbon (PAC)	dose of 2 g/m^3 PAC before sand filter. Sand fraction in filter bed 0.71 – 1.25 mm Backflush 3 times/week	295
sodium hypochlorite + tetrachlorodecaoxide (TCDO)	continuous dose of 0.20 mg/l TCDO	280
sodium hypochlorite	*stock solution: 150 g/l sodium hypochlorite*	*275 (reference method)*
salt electrolysis + membrane cell	anode and cathode in separate chambers (production chlorine gas and sodiumhydroxide) stock solution: 10-15 g/l hypochlorite	270
anodic oxidation	addition of NaCl to the swimming pool water up to 1,200 mg chloride/liter. Anodic oxidation in bypass.	270
sodium hypochlorite + nanofiltration		195
hydrogen peroxide		does not pass microbiological effectiveness test
UV/ Hydrogen peroxide		does not pass microbiological effectiveness test
copper/silver ionisation		does not pass microbiological effectiveness test

The MCA resulted in five techniques (grey section in table 1) that offer best opportunities to prevent or lower the formation of DBP's in swimming pool water disinfection. The main benefits of these five methods are summarized in table 2.

Table 2. Main benefits from 'top 5' high score in MCA

method	main benefits from MCA
sodium hypochlorite + UV (medium pressure lamps)	Dissociation of all chloramines. Possible oxidation of some AOX components. Easy to realize. Low environmental impact.
salt electrolysis	Less formation of chloramines and AOX. Easy to realize. Relatively safe.
sodium hypochlorite + UV (low pressure lamps)	Dissociation of monochloramine. Easy to realize. Low environmental impact.
sodium hypochlorite + ozone (in bypass)	Prevention of formation of di- and trichloramines. Oxidation of monochloramine and AOX. Fresh water requirement is lowered.
sodium hypochlorite + powdered activated carbon (PAC)	Removal of AOX and chloramines through adsorption. Fresh air requirement is lowered.

Workshop Results

The results of the study were made public during a workshop held at KWR Watercycle Research Institute on February 15th 2007. There was a general agreement with the study outcome. In addition to the project results, workshop attendants stated that in current situations the DBP-formation using sodium hypochlorite can be further reduced by optimizing the dosing, mixing and stock concentration of the sodium hypochlorite and by separating hypochlorite turnover and filter turnover. Improved use of sodium hypochlorite should have the same advantages and roughly the same end score as salt electrolysis in table 1.

Furthermore it was concluded that there is little known about the influence of refill water quality on DBP-formation in the swimming pool water. Finally some practical aspects, that could also be critical when it comes to DBP-formation, were mentioned such as obliged showering before swimming, prevention of cleaning water from the platform to enter the pool and proper training of personnel on the function and action of the pool water treatment installation.

Conclusions

The MCA performed in this study results in five alternative disinfection techniques or combination of techniques for swimming pool water treatment which show good opportunities to prevent the formation or reduce the presence of undesired by products during disinfection.

As each of these techniques is based on the production/addition of free chlorine, the result also shows that for sufficient microbiological disinfection (4 log removal of *Pseudomonas aeruginosa* during 30 seconds) free chlorine is essential. Three alternatives with a different disinfection strategy, copper/silver ionization, hydrogen peroxide and UV/hydrogen peroxide, did not pass the microbiological effectiveness test as individual techniques.

Prior to applying an alternative disinfection method as suggested in this study, the formation of DBP's could be reduced by optimizing the existing system based on sodium hypochlorite. Simple measures such as good and rapid mixing in combination with a lower stock concentration or separation of the filter and hypochlorite turnover could show beneficial.

Future actions

Based on the results of this study the Dutch Ministry of Housing, Spatial Planning and the Environment is planning on performing a pilot study with the five selected techniques to explore the effectiveness and possible side effects in practice. This pilot study is scheduled to start in the summer of 2009. In a preliminary study the research plan for this pilot study must be drafted including a monitoring plan and an overview of analytical methods.

References

IRAS, Institute for Risk Assessment Studies. University of Utrecht. *Influence of air quality on the prevalence of complaints among swimming pool personnel.* 2006. In assignment of the Dutch Ministry of Social Affairs. (Report in Dutch, English summary)

KWR Water Recycle Institute, *An exploratory investigation on alternative disinfection techniques for swimming pool water,* KWR report 07.023. 2007 (Report in Dutch)

Sportfondsenbad. Unpublished measurements performed in swimming pool water in 2005 and 2006.

Stottmeister, E. Zum vorkommen von Desinfektionsnebenprodukte in Schwimm- und Badebeckenwässern. UMID, WABOLU. 1999 (in German)

Acknowledgement

This research was sponsored by the Dutch Ministry of VROM (Ministry of Housing, Spatial Development and the Environment). VROM is the Dutch Ministry responsible for water quality, hygiene and safety in swimming facilities open to the public.
This research was supervised by a steering committee of representatives from the government, suppliers, research institutes and branch organizations.