SWIMMING poolNEWS

EFFECT OF REDUCED CHLORINE CONCENTRATIONS ON DBP FORMATION IN WARM WATER POOL AT GLADSAXE SPORT CENTRE, DENMARK

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Based on the new decree for operation of pool water facilities issued by Danish authorities, it is expected that a large number of Danish public swimming pools will soon change operational practice to lower chlorine levels than applied today. As shown by experimental operation of the warm water pool at Gladsaxe Sport Centre this mode of operation will expectedly reduce the formation of chlorinated disinfection by-products significantly.

Background

The practice for operation of public swimming pools varies significantly from a global as well as a European perspective. Several European countries have a long tradition for operating swimming pools at lower pH and significantly lower content of free chlorine than the existing practice in Denmark, without any negative impact on the hygienic quality of pool water. The reason for this is that the proportion of the active species for disinfection of chlorine (HOCl) is increased by lowered pH why it is possible to lower the total free chlorine content without loss of disinfection capacity. The distribution of chlorine species as a function of pH is illustrated in Figure 1. The figure clearly shows that the proportion of active component HOCl increases significantly when the pH is lowered for example from 7.3 to 6.7. It is thus possible to maintain the disinfection pressure at a combined reduction of free chlorine and pH.

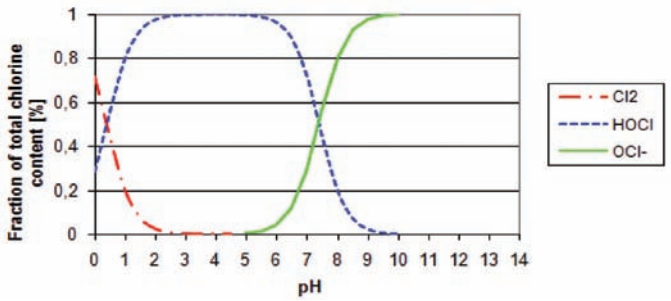

Figure 1 Distribution of chlorine species as a function of pH. HOCl is the active component.

The mechanisms for the formation of chlorinated disinfection by-products in pool water are very complex and still poorly understood, but there seems to be consensus that the formation rate of chlorinated disinfection by-products is expected to increase at higher concentrations of chlorine.

Based on the chemistry of chlorine it thus seems obvious to investigate whether a change of the Danish practice for operating swimming pools in the direction of lower content of free chlorine, combined with lowered pH will lead to lower content of chlorinated disinfection by-products in pool water, thereby increasing the comfort and reducing health nuisance for the bathers. Thus, an experimental project has been conducted to illustrate this possibility. The project has been funded jointly by the Danish Association for Swimming Pool Technology and the Danish Environmental Protection Agency.

Figure 2 Warm water pool - Gladsaxe Sport Centre

Gladsaxe Sport Centre – warm water pool

The study was conducted in the warm water pool at Gladsaxe Sport Centre. The warm water pool at Gladsaxe Sport Centre consists of a traditional warm water basin connected to a small wading pool in parallel on the same water treatment plant. The basin is shown in Figure 2. The volume of the warm water basin represents the vast majority of the total basin volume.

Data for warm water pool are:

- **Volume: 50 m³**
- **Turnover time: 30 minutes**
- **Temperature: 31-33 °C**

The water treatment for the warm water pool consists of traditional coarse filtration, sand filtration, side stream activated carbon filtration and inline chlorine electrolysis for chlorine dosage. In addition, UV treatment has been implemented in side stream to lower the combined chlorine content. The UV plant was turned off during the experimental operation because it was chosen to investigate the effects of the lowered pH and chlorine concentrations on the formation of chlorinated disinfection by-products on a traditional water treatment plant with a configuration similar to the majority of the water treatment plants in the Danish swimming pools.

Experimental Program

During the experiment the warm water pool was operated in a Phase 1 with low levels of free chlorine (set-point to 0.4 mg/l) and reduced pH (set-point 6.7) and subsequently in a Phase 2 with typical content of free chlorine (set-point 1.5 mg/l) and usual pH (set-point 7.3). Figure 3 shows the on-line logging data for free chlorine and pH for the period around the transition between the two phases.

Over the two experimental phases, the operational staff ensured logging of online data for free chlorine and pH, and

furthermore conducted three daily manual measurements of free and combined chlorine. In addition, a sampling program for ongoing monitoring of trihalomethanes (THM) and microbiological parameters was conducted.

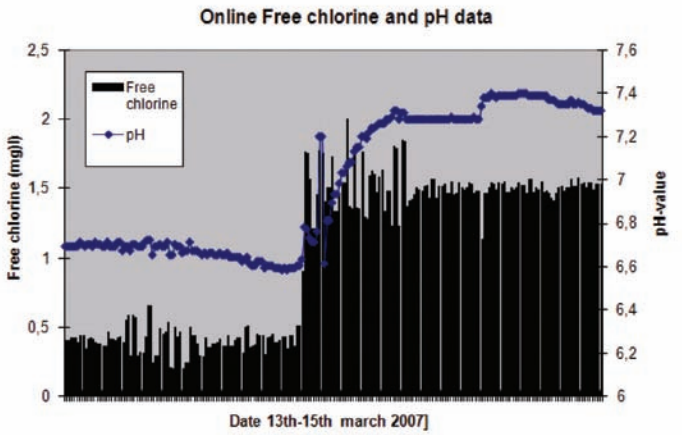

Figure 3 Illustration of on-line data for free chlorine and pH during the shift between phases 1 to 2.

The effect on the formation of combined chlorine

Figure 4 shows the concentration profile of free and combined chlorine as monitored by the operational staff three times per day through the experimental period. As shown in the figure, there was a clear increase in the content of combined chlorine from a level in the range of 0.2-0.35 mg/l through Phase 1 with 0.4 mg/l as set-point for the free chlorine content to a level of combined chlorine in the range of 0.4-0.6 mg/l for Phase 2 with a free chlorine set-point of 1.5 mg/l.

Due to a communication failure the UV plant was accidentally turned on during the shift to Phase 2 and remained on for a few days after the shift the 14th of March. The figure shows that the UV system was able to maintain the content of combined chlorine on the same low level as in Phase 1, despite the shift to higher content of free chlorine. After the UV plant was turned off again the content of combined chlorine rose to the new higher level of around 0.4-0.6 mg/l.

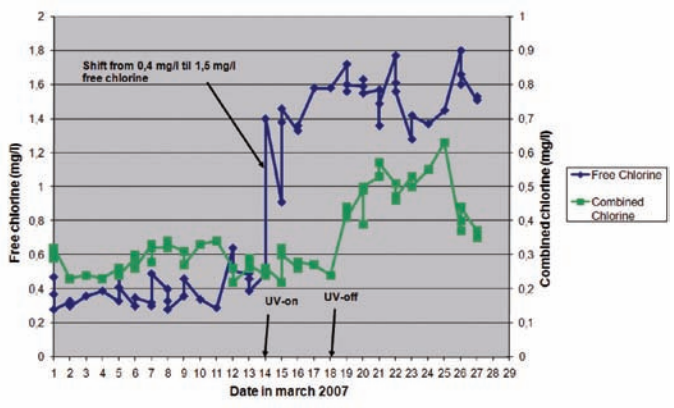

Figure 4 Concentration profile of free and combined chlorine in the pool water during the test period. The shift from 0.4 mg/l to 1.5 mg/l free chlorine takes place on the 14th of March.

The effect on the formation of THM

Figure 5 illustrates the concentration profiles for Total trihalomethanes (THM), trichloromethane (chloroform) and dichlorbrommethane in the pool water during the two experimental phases.

As shown in the figure, the concentration of THM was around 15-25 µg/l in Phase 1, with the low content of free chlorine, and rose to a level of around 40-50 µg/l in Phase 2 with a free chlorine content of 1.5 mg/l. Furthermore, it is seen that most of the THM is represented by chloroform, while the remaining THM mostly consisting of dichlorbrommethane. Thus, based on the test results of the experimental operation it can be concluded that the content of free chlorine in the studied concentration range affected the concentration of THM in the water pool significantly.

From the figure it can also be seen that the THM level in the interim period with UV treatment is similar to the level when the UV was turned off. Despite the short period with UV treatment it is still an interesting observation which is in agreement with the findings from recent and more comprehensive investigations at Gladsaxe Sport Centre; namely that no impact from the UV treatment on the level of THM could be identified.

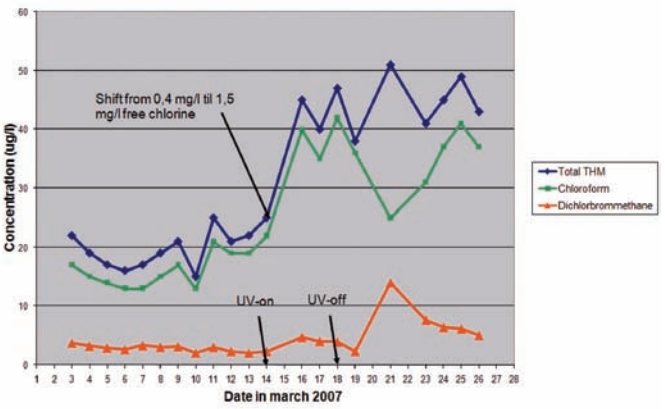

Figure 5 Concentration profile for total THM, chloroform and dichlorbrommethane in the pool water during the test period.

The content of total halogenated organic matter was tentatively monitored through the experimental period. The total content of halogenated organic matter is to a large extent similar to the concentration of AOX (Adsorbable organic halogens). The parameter was monitored by rapid analysis at DHI's laboratory where the rapid analysis test kit initially was tested by measuring standards with known AOX content. The AOX content was found to increase from a typical level of 0,6-0,8 mg/l through Phase 1 with 0.4 mg/l as set-point for the free chlorine content to a level of 0,8-1,1 mg/l for Phase 2 with a free chlorine set-point of 1.5 mg/l. The parameter AOX is interesting because a relationship is likely to exist between the content of AOX and the formation of THM in the pool water.

Hygienic quality

Throughout the experimental operation the Environmental Laboratory of Copenhagen I/S took samples for standard monitoring the microbiological quality of the pool water.

A summary of the measured microbiological data for the two phases are given in Table 1. It can be seen from the table that no significant differences in the measured microbiological parameters for the two phases. In addition, the measured values were all well in compliance with national standards for the given parameters. The hygienic quality of the pool water with respect to the standard microbiological parameters was unaffected by the lower content of free chlorine.

Table 1 Summary of results of measurements of microbiological parameters through the experimental operation.

PARAMETER		NATIONAL STANDARD	0.4 MG/L FREE CHLORINE	1.5 MG/L FREE CHLORINE
Total heterotrophic plate count (HPC) (37°C)	CFU pr. 100 ml	<1.000	3-14	5-26
Pseudomonas aeruginosa	CFU pr. 100 ml	<10	<1	<1
Thermo tolerant coliforms	CFU pr. 100 ml	<10	<1	<1

Chlorine consumption and control

The dosage of chlorine in the warm water pool at Gladsaxe Sport Centre is done by inline chlorine electrolysis. The chlorine consumption could be followed from the consumption of kWh per day of the electrolysis plant. Results showed that the consumption of chlorine during the operation with low levels of free chlorine was about 30% lower than the consumption during operation at the higher level of free chlorine, so there was a significant improvement - economically as well as environmentally.

However, before shifting the operational conditions to low chlorine content it is essential to establish a robust and well functioning monitoring and dosing control system including at least reliable online measurements of free chlorine, pH and redox potential to ensure stable chlorine concentrations in the pool. For warm water pools where the load can vary dramatically and abruptly this will put increasing demands on the chlorine control system and the frequency of on-line sensor calibration etc. compared to the typical practice in Danish swimming pools today.

In addition, when switching to operate with low chlorine content, it is important to ensure that the hydraulic conditions (mixing conditions) of the pool are adequate, to avoid "dead zones" which otherwise periodically might have very low levels of free chlorine and inefficient disinfection capacity.

Conclusions

The experimental operation of the warm water pool showed that it was possible to achieve significant improvements in the water quality with respect to DBP's - and thus also improved indoor air quality - in the pool facilities by operation at a lower content of free chlorine than are used in the Danish swimming pools today.

The content of combined chlorine rose from a level around 0.2-0.35 mg/l to a level around 0.35-0.65 mg/l when the free chlorine content was increased from 0.4 mg/l to 1.5 mg/l. Similarly, the levels of THM increased from 15-25 µg/l to a level around 40-50 µg/l at the higher content of free chlorine. Throughout the experimental operation, the hygienic quality of the pool water was unchanged and remained well within the national standards at the new operating conditions with low chlorine content. Furthermore, the chlorine consumption decreased by approx. 30% by lowering the concentration of free chlorine of 1.5 mg/l to 0.4 mg/l.

Literature

1 Danish EPA (2001). AOX literature review - Description of AOX, absorbable organic halogens, with focus on swimming pool water. Grøn, C. and Dybdahl, HP; Environmental Project No. 643.

2 Danish EPA (2007). Alternatives to chlorine as a disinfectant in public swimming pools. Holm Kristensen, G., Møller Klausen, M., Arvin, E., Albrechtsen, HJ, Bisted, O., Malmgren Hansen, B. Frederiksen, E., and Kaas, P.; Environmental Project No. 1153.

3 Danish EPA and the Danish Association for Swimming Pool Technology (2007). Experimental operation of the warm water pool in Gladsaxe Sport Centre at low levels of free chlorine and reduced pH. Holm Kristensen, G., Møller Klausen, M. and Janning, K.