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Quantitative microbial risk assessment for an indoor swimming pool with chlorination compared to a UV-based treatment

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Aims
Most swimming pools use residual disinfectants like chlorine for disinfection. The use of chlorine has several drawbacks: some waterborne-pathogens are chlorine resistant and disinfection by-products (DBPs) may be formed which are associated with various health risks. Therefore, an alternative treatment was developed which consists of biological sand filtration, ultra-filtration and UV-disinfection. The goal of this study was to compare the microbial risks for bathers in a UV-disinfected pool compared to a chlorinated pool with the use of a quantitative microbial risk assessment.

Methods
In this microbial risk assessment, the microbial release was calculated from multiple factors such as pool content, number of simultaneous swimmers, duration and frequency of swimming, ingestion of pool water, the hygienic behaviour of swimmers and the actual release of microbial cells per swimmer. The concentration of faecal bacteria was calculated from shedding experiments and known pathogen concentrations in faeces. The Dutch illness probability (283/1000) was used to calculate the number of infected bathers, which were all assumed to sheds 10^8 faecal pathogens per g faeces. The used reference pathogens were *Campylobacter jejuni*, *E. coli* O157:H7 and *Salmonella enterica*. The removal of pathogens by treatment with UV-disinfection was set to 5-log units, every 4 hours, while during chlorination these 5-log units are known to be achieved in 30 seconds. The dose-response relationship for *E. coli* and *S. enterica* was simulated with a beta-Poisson distribution and for *C. jejuni* a hypergeometric function was used. The yearly risk of infection was calculated separately for each of the bacterial pathogens and a normal range sensitivity analysis was done.

Results
The average bacterial cell concentration during opening hours in a UV-based swimming pool were the highest for *C. jejuni* (3.1×10^{-3} cells L^{-1}) > *S. enterica* (9.5×10^{-4} cells L^{-1}) > *E. coli* (7.2×10^{-4} cells L^{-1}). These calculated pathogen concentrations were about 180 times higher than calculated pathogen concentrations in a chlorinated swimming pool in which the averaged concentration was 4.0×10^{-6} cells L^{-1} for pathogenic *E. coli* cells. Based on the average pathogen concentration during opening hours, the yearly risk of infection was calculated to be 9.8×10^{-8} for the chlorinated swimming pool and 1.8×10^{-5} for the UV-based swimming pool treatment. The yearly risks of infection of a UV-based treated swimming pool were the highest for *C. jejuni* (1.7×10^{-3}) > *E. coli* (1.8×10^{-5}) > *S. enterica* (3.5×10^{-7}). The simulated yearly risk of infection was found to be most sensitive for the number of bathers releasing pathogens.

Conclusions
The yearly risks of infection of *E. coli* and *S. enterica* in a UV-based treated swimming pool were lower than the drinking water guidelines (10^{-4}), but for *C. jejuni* it was higher. For a more complete picture of the health risks, the effects of disinfection by-products should also be taken into account in future risk assessments, as is the effect of other pathogens like *Pseudomonas*, *Cryptosporidium* and *Giardia*. UV-based treatment might be a good alternative for chlorination for some specific types of swimming pools.