Chemical disinfection of combined sewer overflows

In Copenhagen, a significant number of harbour bathing areas are occasionally closed for recreational activities, due to the discharge of untreated combined sewer overflows (CSOs). A CSO event occurs when the designed capacity of the combined sewer system is exceeded during major rainfall events. A CSO, a variable mixture of wastewater and rainwater, is discharged into the nearby surface water, which renders surface water unusable for recreational activities, such as bathing. This is because the microbial water quality of receiving waters is not of a suitable quality as mentioned in the EU directive 2006/7/EC. Nordic countries have a short summer season, and the frequent closures of harbour bathing areas in prime weeks for recreational activities are due mainly to the discharge of untreated CSO. Disinfecting a CSO in the existing CSO structure, before discharging it to the surface water, would be a quick way to maintain limits on the indicator bacteria of 500 MPN Escherichia coli (E. coli) per 100 mL and 200 MPN Enterococcus spp per 100 mL in the receiving waters. Disinfecting CSO has not been practiced before in Denmark, but it would increase the usability of surface waters for recreational activities. The occurrence of a CSO event, and its quality and quantity, is unpredictable, so the disinfectants employed for such a task should be robust, in order to treat water varying in quality. The present thesis provides a solution to designing a CSO disinfection system, without changing CSO overflow structures. An overview of the chemical disinfection of a CSO, from the batch scale to the full-scale, was studied, and disinfection efficiency was evaluated by calculating the removal of bacteria from a CSO and quantifying disinfectants during treatment. Residual toxicity was studied for a preliminary risk assessment of disinfectants entering the aquatic ecosystem in the receiving water’s post-disinfection discharge.

Performic acid (PFA) and peracetic acid (PAA) are used to disinfect CSO water, in order to reduce the number of indicator bacteria. Moreover, PFA and PAA do not form toxic by-products when they react with the ammonia present in the CSO. Disinfectant dose and contact time in the present study were designed by disinfecting a laboratory-simulated CSO with different wastewater concentrations. Degradation kinetics of PFA and PAA in the simulated CSO as well as the disinfection efficiency were studied. PAA degradation in the simulated CSO was slower compared to the degradation of PFA, the latter of which, at a dose (1-8 mg/L) and with 10 minutes’ contact time, efficiently removed 4.2 logs of E. coli and 3 logs of Enterococcus spp from the simulated CSO. Furthermore, the ecotoxicity of the residual disinfectants PFA, PAA and chlorine dioxide (ClO2), and their degradation products hydrogen peroxide and chlorite, in relation to organisms in the aquatic ecosystem was studied. With the help of ecotoxicity data, a preliminary environmental risk assessment of PFA, PAA and ClO2 for CSO disinfection was done, to ensure the safety of the aquatic ecosystem in the receiving waters. This assessment could also be used to obtain permission from authorities for full-scale disinfection. Based on the maximum allowable concentration quality standards for the freshwater and predicted residual concentrations of PFA, PAA and ClO2, a minimum dilution factor (590 times for PFA, 138 times for PAA and 707 times for ClO2) is needed for discharge into the surface water, to avoid the risk of toxic effect in the aquatic environment, albeit the rapid degradation of PFA and ClO2 in water will not have an acute toxic effect, and lower dilution factors may also be safe for the receiving waters. PFA and PAA were applied for the full-scale disinfection of CSO in two different Danish CSO structures. In the first CSO event, 2-8 mg/L PFA with 20 minutes’ contact time efficiently reduced E. coli and Enterococcus spp below the limit mentioned in EU directive 2006/7/EC, when treated CSO was diluted into the Øresund strait. In the second CSO event, however, low PFA (1-4 mg/L) failed to reduce the number of E. coli and Enterococcus spp bacteria below the limit mentioned in the EU directive, even after dilution, entering the Øresund. PAA was used for full-scale disinfection when CSO was pretreated with chemical coagulation and through the HydroSeparator to remove suspended solids. During the CSO event, 10 mg/L PAA reduced Enterococcus spp from 105.5 MPN per 100 mL to 103.7 MPN per 100 mL with 10 minutes’ contact time. Microbial profiles, made by measuring Enterococcus spp before and after a CSO event, revealed that the numbers of Enterococcus spp post-disinfection were almost the same as pre-existing Enterococcus spp in the first recipient. To summarise, frequent closures of recreational areas can be minimised by chemically disinfecting CSOs before discharging into surface waters.

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