



## Risk assessment of waterborne virus in Lake Geneva: the present and the future

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The presence of waterborne enteric viruses in lake recreational water sites is not desired, as they may have a negative impact on human health. However, their concentrations, fate and transport in lakes remain poor understood. To date, the health risks posed by enteric viruses in surface water was typically assessed via monitoring of fecal indicators, such as *E. coli*, whereas a direct assessment of fate and transport of waterborne viruses is less common. In this study, we propose a coupled water quality and quantitative microbial risk assessment (QMRA) model to study the transport, fate and infection risk of four common enteric viruses, using Lake Geneva as a study site. The measured virus load in raw sewage entering the lake was characterized, fitted with different distributions and then used as the source term in the water quality simulations. A Eulerian transport model was employed to model virus transport while considering spatially and temporally varying inactivation of viruses. Eventually, the probability of infection was quantified by linking the virus concentrations at a popular beach with QMRA. The model framework was then applied to model current situations as well as future scenarios under climate change. In the simulations of year 2019, it was found that environmental stressors noticeably reduce the infection probability exerted by viruses with low background inactivation in summer, but effects in the winter are minor. Norovirus appeared to be the most abundant species and also led to the highest infection probability, which was at least 10 times greater than that of the other viruses studied. In addition, the model highlighted the role of the wind field in conveying the contamination plume and hence in determining infection probability. The simulations for the future revealed an increase of virus inactivation rates in summer times due to higher water temperature as well as increased radiation levels due to reduced cloud coverage. The enhanced inactivation in summer could compensate for the higher virus loading caused by population growth. In contrast, in winter minor temperature changes and inconsequential radiation variation would not offset the increased virus loading. However, even in the winter cases the future infection risks would not undergo significant change compared with the current situation. The proposed model framework is flexible and could be relatively easily refined and adapted for other locations and scenarios. This study highlights the potential of combining water quality simulation and virus-specific risk assessment for a safe water resources usage and management.