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Transport and removal of spores of Bacillus subtilis in an alluvial gravel aquifer at varying flow rates and implications for setback distances

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To minimize the risk of waterborne disease outbreaks, drinking water wells should have a sufficiently large setback distance from potential sources of contamination, e.g. a nearby river. The aim of this study was to provide insight in regards to microbial contamination of groundwater under different hydraulic gradients, which can vary over time due to changes in river stage, season or pumping rate. The effects of these changes, and how they affect removal parameters, are not completely understood. In this study, field tracer tests were carried out in Vienna, Austria to evaluate the ability of subsurface media to attenuate *Bacillus subtilis* spores, used as a surrogate for *Cryptosporidium* and *Campylobacter*. The hydraulic gradient between injection and extraction was controlled by changing the pumping rate (1, 5 or 10 l/s) of a pumping well at the test site. Attachment and detachment rates were determined using a HYDRUS-3D model and setback distances were calculated based on the 60-day travel time, as well as a quantitative microbial risk assessment (QMRA) approach. It was shown that scale must be taken into consideration when determining removal rate (λ), which is crucial for the calculation of setback distances, and that the effect of flow rate becomes more important at lower removal rates.