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Cryptosporidium parvum in Small Watersheds: Transport in Streams and Streambed Sediments

The protozoan pathogen *Cryptosporidium parvum* is a leading cause of waterborne disease. Due to its small size (5um), low specific gravity (1.05 g/cm^3), and negative surface charge, *C. parvum* oocysts are generally considered to move through watersheds from their source to drinking water reservoirs with little attenuation in the stream channel. However, the transport of the oocysts in surface waters may be mediated by interactions with suspended sediments and by subsurface filtration and removal in streambed sediments. Using settling column and flume experiments, we show that C. parvum oocyst attachment to several inorganic and organic sediments under varying water quality conditions may drastically influence the effective in-stream settling velocity of *C. parvum* oocysts. Water chemical conditions including ionic strength, ion composition, and pH did not have a significant effect on oocyst attachment to suspended sediments. To assess subsurface (streambed or aquifer) transport, we conducted a series of laboratory studies on sand columns with various length, flow velocity, ionic strength, pH, and grain surface properties. We show that classic colloid filtration theory is a reasonable tool for predicting the initial breakthrough, but it is inadequate to explain the significant tailing observed in the breakthrough of *C. parvum* oocyst through sand columns (or, equivalently, through streambed sediments). We discuss the application of the Continuous Time Random Walk approach to account for the strong tailing that was observed in the subsurface transport experiments. The CTRW is generalized transport modeling framework, which includes the classic advection-dispersion equation (ADE), the fractional ADE, and the multi-rate mass transfer model as special cases. Within this conceptual framework, it is possible to distinguish between the contributions of pore- scale geometrical (physical) disorder and of pore-scale physico-chemical heterogeneities (e.g., of the filtration, sorption, desorption processes) to the transport of *C. parvum* oocysts.

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