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Fate and Transport of Toxoplasma gondii Oocysts in Saturated Sandy Porous Media: Experimental Tests and Mathematical Modeling

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Understanding the transport of biocolloids in groundwater is essential for assessing the potential risk to human health and preventing the spread of diseases that are a result of the groundwater contamination. Toxoplasma gondii is a biocolloid that exists prevalently in the environment and has been found in groundwater sources. Currently, there is a lack of research concerning the fate and transport of the pathogen in porous media, and little is known about the effects that groundwater chemistry has on the properties of the oocyst. The purpose of this research is to characterize and model the transport and retention of T. gondii in saturated silica-sand columns in the presence of ligands and surfactants at different concentrations. Surfactants, or surface active agents, are chemicals used as detergents, emulsifiers, foaming agents, cleaning agents, and are employed for both household and commercial use. Ligands are ions that bond to metals and organic molecules, and are generated by plants and microorganisms, which then make it into the soil system and ground water below. Both ligands and surfactants are known to affect flow properties in porous media and the interactions between surfaces, such as the interaction between biocolloids and sand grains. Therefore, we chose to investigate the effects that an anionic surfactant, a nonionic surfactant, and two different ligands have on the fate and transport of T. gondii. A total of 20 column experiments were conducted including replicates as follows: 4 with anionic surfactant, 4 with nonionic surfactant, 4 with citric acid, 4 with tannic acid, 2 KBr tracers, and 2 with just a background salt to act as controls. All of the columns contained fine sand as the dominant grain size and each was run with a specified saturated flow rate from the bottom of the columns in order to analyze the change from solution and disregard change as a result of a variation in the pore velocity or gravity settling. In order to model the flow and retention we employed the classic clean-bed colloid filtration model, and implemented sources for both adsorption and desorption of the particles, which has been shown to occur with other biocolloids including oocysts. We implemented both Sodium dodecylbenzenesulfonate (SDBS) and Triton X-100 as our anionic and nonionic surfactants since both are commonly found in groundwater and have commercial and residential use. We utilized Citric acid and Tannic acid as our ligands due to their presence in groundwater. The columns were inundated with two different concentrations of the surfactants and the ligands prior to the injection of T. gondii oocysts followed by 5 more pore volumes of the initial solution. The molecular biological methods used for the detection and enumeration of T. gondii oocysts in the effluent samples included DNA extraction and qPCR. The study compares the breakthrough of T. gondii with surfactant, with ligands, control, as well as the breakthrough of a bromide tracer. Each approach was modeled in addition to the experimental testing and we compared our results to previous microbe transport studies.