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3D modeling investigation of vertical solute transport through fractured clayey tills

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We present a model-based investigation of the transport of tracers and pesticides through fractured clayey tills. To characterize flow and transport properties, we conducted well-controlled flow-through experiments in large undisturbed columns (LUC, diameter 0.5 m, height 0.5 m, [1]) of fractured clayey tills from two field sites in eastern Denmark. Hydraulic tests yielded matrix hydraulic conductivity and porosity values and allowed the determination of fracture hydraulic apertures. Solutes with different sorption and diffusion characteristics were injected in the LUCs at a constant and a variable flow rate: bromide as a conservative solute and tebuconazole, a pesticide that sorbs to clayey tills. Finally, preferential flow paths were made visible by injection of the dye tracer Brilliant Blue followed by segmentation of the columns.

A detailed 3D discrete-fracture model comprising the observed preferential flow through fractures and macropores, the interaction with the clayey-till matrix (advection, diffusion, sorption) and the physical setup of the LUC was used to interpret the experiments and to shed light on the transport behavior in the two columns. Different transport mechanisms prevailed; the first experiment with clayey till from about 2 m bgs was dominated by fast advective transport through larger fractures and macropores with apertures of about ~100 µm, whereas the transport in the second column from 5 m bgs was happening much slower through smaller fractures (~10 µm) and by advection and diffusion through the matrix being more prevalent. The model could reproduce the breakthrough curves from the flow-through experiments. The sorption behavior of tebuconazole to the clayey tills could be captured by introducing non-equilibrium sorption kinetics in the governing transport equation. Furthermore, the flow and transport parameters determined by the experiments and the calibrated 3D models served as basis for a modeling investigation, where the properties of the LUCs were applied to larger vertical cross sections and the leaching behavior of conservative and sorbing solutes/pesticides was analyzed under the influence of depth-varying fracture properties. This allowed us to study possible bottlenecks for vertical solute transport at the considered field sites.

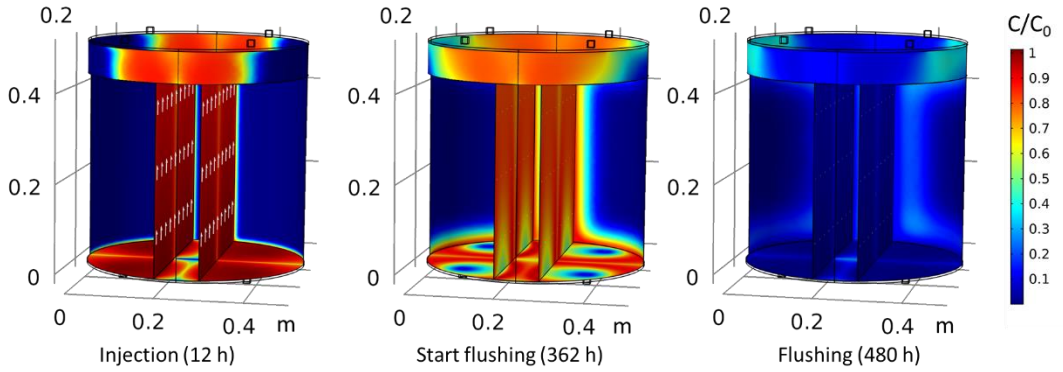

Figure 1: Example of a 3D model simulation of a LUC flow through experiment.

References

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