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Numerical analysis of a neutron radiography-monitored infiltration experiment: Two-phase modeling using TOUGH2

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It has been shown in ponded infiltration-outflow column experiments that true steady state flow is often not reached in certain soils exhibiting preferential flow. Experiments often show a temporal change of flow rate that can, in the case of experiments conducted on saturated samples at constant head gradients, be interpreted as variations of saturated hydraulic conductivity. It has also been shown that these variations can be caused by slow redistribution of entrapped air in the sample. The experiment presented in this study was conducted on a small fabricated sample with axially symmetrical inner geometry of material distribution. In preparing the sample, areas of fine sand were surrounded by continuous preferential pathways composed of coarse sand. Ponded infiltration was performed on the sample while monitoring using neutron imaging was conducted to obtain spatiotemporal information about the water content distribution in the sample. Results of the experiment revealed that during the quasi-steady state stage of the experiment the saturated hydraulic conductivity gradually decreased due to the transfer of air bubbles from fine sand to coarse sand. Flow through the coarse sand became partially blocked by air bubbles and the overall quasi-steady flow rate consequently decreased by 30% during six hours of infiltration.

In an attempt to model this behavior, we simulated ponded infiltration in two dimensional (2D) domains using the EOS3 module of the numerical simulator TOUGH2 (Lawrence Berkeley National Laboratory). The main objective was to determine which types of preferential pathway patterns were prone to air entrapment and whether the air redistribution observed in the experiment could be numerically simulated. Modeling was conducted in three different 2D domains with increasing complexity of the preferential pathways' geometry. Analysis of the results confirmed that during ponded infiltration, water percolated fastest at the start of infiltration through the highly conductive regions (coarse sand). At the same time full saturation was not achieved during the steady state flow stage of the numerical experiment, which corresponds to the air entrapment in the preferential pathways seen in the neutron images. Some transfer of air from fine to coarse material was observed in the domain with the most complex preferential pathway geometry. The air redistribution visualized by neutron imaging in the column experiment was captured using numerical simulation (TOUGH2) but to a much smaller extent. A new modeling approach that simulates the behavior of air bubbles in near-saturated heterogeneous porous media more precisely is needed.