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Unstable infiltration fronts in porous media on laboratory scale

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Water flow and transport of substances in the unsaturated zone are important processes for the quality and quantity of water in the hydrologic cycle. The water movement through preferential paths is often much faster than standard models (e. g. Richards equation in homogeneous porous media) predict. One type/phenomenon of preferential flow can occur during water infiltration into coarse and/or dry porous media: the so-called gravity-driven fingering flow. To upscale the water content and to describe the averaged water fluxes in order to couple models of different spheres it is necessary to understand and to quantify the behavior of flow instabilities.

We present different experiments of unstable infiltration in homogeneous and heterogeneous structures to analyze development and morphology of gravity-driven fingering flow on the laboratory scale. Experiments were carried out in two-dimensional and three-dimensional sand tanks as well as in larger two-dimensional sand tanks with homogeneous and heterogeneous filling of sand and glass beads. In the small systems, water content in the medium was measured at different times. We compare the experiments to prediction of theoretical approaches (e.g. Saffman and Taylor, 1958; Chuoke et al., 1959; Philip 1975a; White et al., 1976; Parlange and Hill, 1976a; Glass et al., 1989a; Glass et al., 1991; Wang et al., 1998c) that quantify properties of the gravity-driven fingers. We use hydraulic parameters needed for the theoretical predictions (the water-entry value (hwe), van Genuchten parameter (Wang et al., 1997, Wang et al., 2000) and saturated conductivity (Ks), van Genuchten parameter (Guarracino, 2007) to simplify the prediction of the finger properties and if necessary to identify a constant correction factor. We find in general that the finger properties correspond well to theoretical predictions. In heterogeneous settings, where fine inclusions are embedded into a coarse material, the finger properties do not change much, while the inclusions act as a storage that is filled during the infiltration process.

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