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Dynamics of Resident and Infiltrating Water in Porous Media: Effect of Grain Size, Initial Water Content and Flow Rate

Maxime Gouet-Kaplan, Gilboa Arye, and Brian Berkowitz
Weizmann Institute of Science, Dept of Environmental Sciences and Energy Research, Rehovot, Israel
(maxime.gouet-kaplan@weizmann.ac.il, (+972) 8 934 4124)

The dynamics between resident ("old") water and incoming ("new") water in an homogeneous, partially saturated sand column undergoing infiltration or precipitation events are examined in a series of laboratory column experiments. In such events, the old water may affect the flow pattern of the infiltrating, new water, and should be considered as an initial condition. Furthermore, infiltrating water may carry different (or similar) chemicals than the old water, which can be in chemical equilibrium with the subsurface environment. This old-new water interplay can therefore have important environmental consequences on the fate and transport of nutrients and/or pollutants toward the groundwater via the vadose zone. Previous efforts to quantify flow and transport in partially saturated media encompass a variety of soils and experimental techniques, but mostly under steady state water flow at a given unsaturated water content. Moreover, each study usually focuses on a single soil, and comparison among studies using different soils is difficult because of differences in the experimental methods. In this study, we employed sands with three different particle size distributions and four initial water contents, established by mixing a salt-free water with sand. The upper end of each soil column was irrigated with water containing a conservative tracer, at three different flow rates, while free-drainage conditions were employed at the lower end. Based on mass balance considerations, two regimes may be identified: an initial piston-like mechanism that displaces old water, followed by slow mixing/entrainment of the remaining old water. The relative contributions of these regimes appear to depend on the initial water content, grain size distribution and hydraulic conductivity. In some cases, up to one-third of the old water can remain in the system after introduction of five pore volumes of new water. A Principal Components Analysis further confirms this conclusion. If the porous medium is initially saturated, the first regime dominates, and none of the old water remains in the system. Under initial partially saturated conditions, both regimes are significant, depending on the pore-scale distribution of the initial old water. Finally, the advection-dispersion and mobile-immobile models are employed for transient water-flow conditions and tested against the measurements; the models reproduce some of the global trends but generally fail to reproduce closely the experimental results. The mechanism of preferential flow appears to explain most of the features observed.