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Deep and near-surface solute redistribution during evaporation leads to high-concentration spots and loops of solute mass fluxes

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We present magnetic resonance imaging (MRI) data of solute transport in a heterogeneous porous medium during a cycle of infiltration and evaporation. The solute plume (aqueous solution of Gd-DTPA) was visualized using a strongly T_1 weighted spin echo sequence. During infiltration solute was preferentially transported downwards in coarse-grained zones, whereas during evaporation solute moved from coarse- to fine-grained zones deeper in the sample and from fine- to coarse-grained zones near the sample surface. This 'solute mass loop' was predicted by a 3D coupled unsaturated flow and solute transport model based on Richards' and advection-dispersion equation. Observations of dye and salt tracer distributions at the sample surface confirm that near-surface redistribution can lead to high concentration spots in coarse-grained zones.

The accumulation in coarse-grained zones is opposite to the perception that accumulation would take place primarily in regions with a finer soil texture which support a higher evaporation. We propose that as long liquid water flow to the soil surface is sustained to coarse- and fine-grained zones, flow will redistribute and accumulate solutes towards locations with lowest water potential. These locations correspond to regions with low hydraulic conductivity, which can be either fine- or coarse-grained regions, depending on the pressure conditions. A 2D model is used to examine the impact of this transport cycling on solute breakthrough curves.