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How does the wetting dynamics affect capillary trapping in heterogeneous soil: Neutron imaging study

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The wetting dynamics of the water infiltration into a porous soil system has a strong influence on the amount of entrapped air inside the soil. Simultaneously, a higher volume of entrapped air obstructs a water flow in the medium. This effect is more noticeable in soils with preferential pathways because the soil matrix has a higher capillary forces and therefore the air is accumulated in preferential pathways.
In the presented study, two experiments were conducted on the same sample. The first experiment was performed under the constant water level condition (CWL) and the second experiment was carried out under the constant water flux condition (CWF) at the top of the sample. The sample was composed of coarse and medium coarse fractions of sand and fine porous ceramics. Materials were packed into the quartz glass column of the inner diameter of 29 mm. The coarse sand represented a highly conductive region connected from the top to the bottom of the sample with the exception of three thin (2-3 mm) separation layers made up of the medium coarse sand. Three discs of fine ceramics formed slow flow regions. Infiltration experiments were monitored by neutron radiography at two different beamlines to produce two-dimensional (2D) projections. The CWL experiment was monitored at NEUTRA station with an acquisition time of 16 seconds per projection and the CWF experiment was visualized at BOA station with an acquisition time of 0.25 seconds per projection. Both stations are located at the Paul Scherrer Institut, Switzerland. The acquired radiograms of the dry sample were subtracted from all subsequent radiograms to determine the water thickness in projections. From series of corrected radiograms taken at the different angles three-dimensional (3D) image was reconstructed for steady state stage of the CWL experiment and for the entire CWF experiment. Then the series of 3D images mapped the wetting of the porous system over the corresponding phase of infiltration process.
The results show a higher steady state infiltration rate during the CWL experiment. In this case, the air was mostly pushed out from the sample by the moving wetting front. The infiltration rate was continuously decreasing during the infiltration up to the value of steady state infiltration rate. When the wetting front has reached the bottom of the sample the air was moving from matrix domain to preferential domain. Infiltration rate was still higher than during CWF. On the contrary, during the CWF the water infiltrated into the fine ceramics first and then into the medium coarse sand attracted by forces that were stronger in comparison to the coarse sand. Due to this effect a significant amount of air was trapped in preferential pathways, and consequently blocked the water flow primarily due to the presence of medium coarse sand regions.