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Neutron imaging of recurrent ponded infiltration into heterogeneous soil

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Ponded infiltration is a hydrological process in which water remaining at the soil surface infiltrates under positive pressures into the soil profile which becomes nearly or fully saturated. For most natural sites this condition occurs only for a short period of time, mostly during extreme precipitations, still a large fraction of the total water and chemical fluxes in the soil profile are transferred during these events. Under the close-to-saturation conditions, a preferential flow may take place in heterogeneous soils. There is also the experimental evidence that a significant steady state flow rate drop may occur during a recurrent ponded infiltration indicating changes/instability of the saturated hydraulic conductivity of soil (Cislerova et al, 1988). These variations are often ascribed to a changing fraction of the entrapped air. The effect is not considered in standard theory of water flow in porous media.

In presented study we were able to reproduce variation of quasi steady state flow during ponded infiltration experiment on three small undisturbed samples of coarse sandy loam and to visualize the process by neutron imaging (NI). Two main flow irregularities typical for soil under study were detected on two soil samples during recurrent ponding experiment: (1) gradual decrease of the quasi-saturated hydraulic conductivity (Kqs) soon after the outflow appeared; (2) the Kqs was even lower that at the end of the first infiltration run and remained relatively steady. The third sample didn't produce variability of quasi steady state hydraulic conductivity.

Series of NI tomography images of the sample taken during the quasi steady state stage of the first infiltration run showed the air trapped in many of large pores and cavities in the samples affected by the temporal variations of Kqs. Furthermore, many of entrapped air bubbles increased in volume during the course of the first infiltration run. Further entrapped air redistribution has been detected during the second run. The fraction of the entrapped air visible in images was calculated and plotted against the Kqs. The increase of volumetric fraction of entrapped air bubbles by only 0.005 was accompanied by the decrease of quasi-saturated hydraulic conductivity by up to 50% of the initial value.

The experimental results support the hypothesis stated earlier (Snehota et al., 2010) that the effect of the gradual decrease of the flow rates is caused by entrapped air redistribution and gradual build-up of bubbles in preferential pathways. The trapped air may thus restrict the preferential flow pathways and cause the overall lower infiltration and outflow flux rates. When the same experiment was repeated on undisturbed sample of the same soil but taken from a more compact part of soil without continuous preferential pathways, the described effect didn't occur. The results of the NI tomography study have shown the close connection between preferential flow and temporal variations of quasi-saturated hydraulic conductivity.

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