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Investigating the quasi-steady state flow instabilities by non-invasive methods

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Preferential flow in structured soils may be accompanied by significant temporal variation of quasi saturated hydraulic conductivity. These effects are often ascribed to changing fraction of the entrapped air and they are not considered in standard theory.

We were able to reproduce variation of quasi steady state flow during ponded infiltration experiment on one small undisturbed sample of coarse sandy loam and to visualize the process by neutron imaging (NI). Two main flow irregularities were detected during recurrent ponding experiment: (1) outflow rates during the first infiltration run, which was started in dry soil, were gradually decreasing, while the boundary condition remained unchanged during the experiment, and (2) the outflow rate at the beginning of second infiltration was even lower that at the end of first run and remained relatively steady.

Series of NI tomography images of the sample taken during quasi steady state stage of the first infiltration run showed air trapping in many of large pores and cavities in the sample. 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 visible entrapped air from images calculated and plotted against the quasi-saturated hydraulic conductivity of sample. The increase of entrapped air bubbles volumetric fraction by only 0.005 was accompanied by decrease of quasi-saturated hydraulic conductivity 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 air comes probably from the soil matrix where residual air encapsulated during the primary fast breakthrough of gravitational water near the edges of large pores is being gradually replaced by water attracted to fine pores by strong capillary forces. The trapped air may thus restrict the preferential flow pathways and cause overall lower infiltration and outflow flux rates. When the same experiment was repeated on undisturbed sample of the same soil but taken from more compact part of soil without presence of continuous preferential pathways, the described effect didn't occur. This shows close connection between preferential flow and temporal variations of quasi-saturated hydraulic conductivity.

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