Geophysical Research Abstracts
Vol. 16, EGU2014-12656, 2014
EGU General Assembly 2014

Insights and questions raised from a multi-tracer plot-scale sprinkler experiment with time-lapse 3D GPR in a structured forested soil.

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Stable isotopes appear as ideal tracer commonly applied in preferential flow analyses. At the same time, central assumptions about signature mixing and propagation are founded on effective parameters merging advective and diffusive flow domains. However, in structured soils conditions are often far from well-mixed and some established assumptions may need to be reconsidered.
We conducted a multi-tracer sprinkler experiment at a forested hillslope in the Attert Basin in Luxembourg with prevailing geogenic and biogenic preferential flow structures. At plot scale of 1x1 m^2 we sprinkled two plots with 50 mm and one plot with 30 mm Brilliant Blue and Bromide enriched water for 1 hour. The experiments were accompanied by a high resolution 3D time-lapse GPR (Ground-Penetrating Radar) survey scanning 3x3 m^2 before, directly after sprinkling and before excavation one day after sprinkling. Soil moisture was monitored with a TDR tube probe. Soil profiles were excavated and recorded for dye flow paths and for one medium resolution Bromide profile. In addition one core for pore water stable isotope analysis was taken before the sprinkling as reference and at each plot after sprinkling.

We present the results with focus on the found evidence of preferential flow and the signals of the different tracers - especially the stable isotopes. While all other methods clearly show that only minor proportions of the soil took part in the infiltration process and that the sprinkler water has largely advectively propagated to the saprolite layer at about 80-100 cm depth, the stable isotopes signals from the cores indicate more intense interaction between the soil matrix and macropores, especially in the top 50 cm. This leads to the question of how the isotope signal could mix well, when most of the pore-water did not directly interact with the infiltration-water. Further questions arise to the use of tracers in general, due to the known limitations of excavation itself and rather coarse sampling with sizes 1-2 orders of magnitude larger than most preferential flow structures - thus blurring the signal. Moreover, considerable uncertainty arises where intense staining may be due to slow water movement or large quantities of infiltrated water. Here time-lapse GPR provides promising insights identifying patterns and states. Moreover, we will discuss whether the use of multiple tracers instead of just one leads to additional information and better understanding of subsurface processes.