

EGU2020-14230

<https://doi.org/10.5194/egusphere-egu2020-14230>

EGU General Assembly 2020

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Macropore-matrix mass transfer: reactive solute transport as quantified with Fluorescence imaging

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Preferential flow paths in soils play a major role for transport processes of heat, gas, water, and solutes and are important adsorption sites. For mass-exchange processes and water storage in soils, small-scaled soil properties, like the spatial distribution of adsorption sites and their accessibility, and the permeability are crucial. Interfaces between macropores (i.e., earthworm burrows, cracks, and root channels) and the soil matrix control the mass exchange. Water and solute transfer through the interface between bio-pores, aggregate or crack surfaces and the matrix was traced at the scale of small soil blocks (≤ 45 mm edge length) with Fluorescein (i.e., a reactive, fluorescent dye). The objectives were to visualize and quantify hydraulic transport, and sorption characteristics of earthworm-, root- and shrinkage-induced interfaces. Batch experiments were performed to calibrate the Na-Fluorescein tracer concentration versus fluorescence-intensity relationship and to derive parameters for two kinetic sorption models (i.e., Freundlich vs. Langmuir). Fluorescence imaging in the laboratory of small soil blocks was applied with a self-constructed spraying device, and with the help of the calibration, small-scaled dye-concentration maps were derived. Time- and interface-dependent positions of the wetting fronts in vertical direction were estimated with the help of the cumulative infiltration. Assuming equilibrated conditions between Na-Fluorescein in solution (calculated by multiplying the local dye-concentration and the local water content) and Na-Fluorescein sorbed to soil, the total mass transfers as a function of macropore-type and spraying time were determined. The results of the mass transfer for water and reactive solutes were characteristic for the soil structure type and depending on the composition of the macropore-matrix interface. Differences were explained by alterations in soil structure and chemical composition of the coatings. Results suggest relations between mass exchange and observable soil properties. This can be helpful for improving the numerical simulation of macropore-matrix mass transfer and inverse simulations of small-scaled hydraulic, transport, and sorption characteristics of macropore walls.