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Do conservative and reactive tracers take the same water flow pathways? An experimental approach

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Reactive transport modelling heavily relies on the assumption that the soil's hydraulic behavior, i.e. the solute transport volume (water content) and the water flow pathways (dispersivity), can be characterized by the use of a conservative tracer. However, there exits ample experimental evidence in the literature whether this assumption holds, mainly because of the lack of detection methods that are able to monitor solute transport with a high resolution in space and time. Time-lapse electrical resistivity tomography (ERT) supplies three-dimensional spatio-temporally resolved image data through minimally invasive measurements. ERT has proved to be a valuable tool for imaging solute transport processes in the subsurface and has the potential to resolve the above-mentioned issue. The goals of this study are to verify to what extent ERT can be used to compare flow pathways of a conservative tracer (chloride) and a reactive tracer (food-dye Brilliant Blue) in the same large soil monolith filled with an undisturbed loamy sand and eventually address the question whether they take the same flow pathways. A constant water flow field was established in the soil monolith by means of an irrigation device. The tracers chloride and Brilliant Blue were successively added to the irrigation water. The negative charge of both tracer provides an electrical conductivity contrast that can be detected by means of ERT. Time-lapse ERT provides a qualitative comparison between both tracers, by visualizing the three-dimensional transport behavior. A quantitative analysis was performed by parameterizing the voxel-scale breakthrough curves using the convection-dispersion equation, which includes retardation and sorption kinetics for the reactive tracer. At the voxel-scale, heterogeneous water flow was observed, identified by regions with different pore-water velocities. In the subsoil, these regions were aligned to soil structural features of the plough pan. We discuss the comparison of the voxel-scale retardation of the reactive tracer with the pore-water velocities, and address the question and discuss the implications to what extent both tracers take the same water flow pathways.