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Is solute transport in heterogeneous soils predictable?

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Solute transport experiments with a fluorescent dye were run in a sand tank ($75 \times 40 \times 5$ cm) containing an artificial packing of three quartz sands of different pore size distributions. The packing consisted of numerous layers ($0.5 \times 5 \times 5$ cm) with a 45° inclination in a random spatial configuration. Six different flow rates were applied at the upper boundary covering imbibition and drainage. When a stationary flow regime was reached for each flow rate various solute pulses were applied at different positions onto the upper surface of the structure. The tracer plumes generated from the pulses were recorded by a digital camera as they travelled through the sand bedding.

To model the experiment a textural map of the sand structure was generated from a digital image of the sand tank. For each of the three sand types the hydraulic parameters were determined from multi-step-outflow experiments. Using the textural map and assuming homogeneity of each of the sand layers the steady-state flux field for each of the boundary conditions used in the experiment was calculated using Richards' equation. The time evolution of nine solute pulses applied at different initial positions at the upper boundary of the soil was simulated using the advection-dispersion equation for every flux field.

In good agreement with the experimental observations the simulations predicted the formation of preferential pathways if the average saturation of the sand structure was low and a quasi-homogeneous transport close to saturation.

This results show that the saturation dependent behaviour of solute transport can be predicted. We analyze the preconditions for such a prediction and draw conclusions for the general predictability of solute transport in heterogeneous porous media.