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Experimental visualization of solutes transport in two-dimensional saturated permeable media

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Mass transport processes in groundwater flows control transport of contaminants or other dissolved substances. A good characterization of transport processes should allow, for example, the optimization of remediation systems or the prediction of natural attenuation or dilution of pollutants in aquifers. Several previous studies have highlighted the role of heterogeneity in transverse mixing processes, which may be enhanced by the convergence of streamlines due to the presence of high permeability materials. The convergence of streamlines increases the concentration gradients in the direction transverse to the flow, which results in greater transverse mixing and natural dilution. This mixing makes possible the occurrence of chemical reactions between species dissolved in groundwater of different origin.

We used image analysis techniques to characterize experiments that replicate the transport of a conservative tracer in two types of quasi 2-D homogeneous and heterogeneous saturated permeable media. The experiments were carried out in an acrylic glass tank, 85 cm long, 16 cm wide and 1 cm thick. We simulated flow conditions found in confined aquifers by imposing a vertical flow fed by a peristaltic pump that injected water at eight points at the bottom of the tank, while we controlled the outflow through the top boundary by using a constant head reservoir. We filled the tank with glass beads with mean diameter 0.05 cm to model the matrix material of the porous media and we used glass beads of 0.2 cm to create a high permeability inclusion to study the effect of heterogeneity on transverse mixing. After steady-state of flux was reached, we injected a conservative tracer (Blue Brilliant) only at the two central ports, while clean water continued flowing through the other six ports. We took digital pictures of the steady-state plume and analyzed the concentration of the tracer along perpendicular to the mean flow fringes, using a piecewise linear model to convert light intensity to concentrations in every pixel. We compared the concentrations calculated with image analysis to theoretical and numerical solutions. We also compared the estimated concentration distributions for a homogeneous and a heterogeneous experiments using as quantitative index the flow-related dilution index (Rolle et al., 2009). We conclude that in the heterogeneous case the dilution index was 1.5 times greater than in the homogeneous case, which confirms that heterogeneity due to inclusions of permeable materials can increase the transverse mixing or dilution of a conservative tracer.