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# Impact of flow conditions on pore-scale solute mixing: experiments in heterogeneous 2D porous media

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Solute mixing mediated by flow in porous media plays a significant role in controlling reaction rates in subsurface environments. In many practical cases, incomplete mixing—inhomogeneous solute concentrations—occurs at the pore-scale, limiting local and thus upscaled reaction rates, and renders their prediction based on effective dispersion coefficients derived from dispersion models (or by assuming Taylor-Aris dispersion) inaccurate. We perform solute transport experiments in transparent, quasi-two-dimensional, soil analog models to investigate the relationships between pore-scale solute dispersion and mixing under different flow conditions. We use Fluorescein as a conservative tracer and record its fluorescence intensity in monochrome images at fixed time intervals. We convert the fluorescence intensity to solute concentration fields based on a calibration curve obtained with various homogeneous solute concentrations and subsequently compute concentration gradients. Our images provide evidence for incomplete mixing at the pore-scale and show strong gradients transverse to the overall flow direction. We fit the mean longitudinal concentration profile to an analytical solution of the advection-dispersion equation and compute the effective longitudinal dispersion coefficient. Based on the lamellar mixing theory, we also infer an effective diffusion coefficient relevant to the mean concentration gradient's dynamics. By comparing these two diffusion/dispersion coefficients in saturated flow conditions, we show that while their values are similar at low Péclet, their scaling behaviors as a function of Péclet are different. Hence, as pointed out by several previous studies, modeling reactive transport processes requires accounting for a mixing behavior driven by a diffusive process that cannot entirely be described by the solute dispersion coefficient. We extend this work by varying the saturation degree in the experiments and our samples' structural heterogeneity to investigate how flow desaturation and porous medium structure impact solute mixing.