

# Direct Visualization of Reactive Transport: Mixing at the Pore-Scale and at the Darcy-Scale

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We have designed laboratory experiments to study two basic problems in hydrogeology: (1) How do chemicals mix so that they react in natural porous media and, (2) What model best describe solute spreading in the subsurface? These questions are intimately related because Darcy-scale spreading, pore-scale mixing, and chemical reaction may profoundly affect one another.

We have developed methods that accurately image changing concentrations during reaction in porous media experiments using colorimetric chemical reactions. These methods enable us to distinguish product from reactants and quantify their concentrations throughout experimental porous media chambers by their different light absorption (e.g. a green product formed from clear reactants). The results show that the conventional coupling of chemical reaction equations with transport equations developed for conservative solutes may either over predict or under predict the degree of chemical reaction. In some cases, incomplete mixing, at both the pore-scale and the Darcy-scale (from cm size heterogeneity), segregate reactants so that the rate of reaction is over predicted by conventional coupling of transport and chemical reaction equations. In other cases chemical reaction creates density fingering, further mixing the reactants, and greatly enhancing reaction. Density gradients develop under conditions of slow flow because diffusion coefficients differ between reactants and products. We will discuss how processes that mix or segregate solutes depend on the spatial texture of hydraulic conductivity.