Engineering scalar transport in porous media via chaotic advection

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**ABSTRACT:**

Many activities in the terrestrial subsurface need to recover/emplace scalar quantities (dissolved phase concentration or heat) from/in volumes of saturated porous media. Application examples include solution mining, remediation of contaminant plumes, or harvesting geothermal heat energy. Transient switching of the pressure at different wells can intimately control subsurface flow, generating a range of “programmed’’ flows. In a simplified model of an aquifer subject to balanced injection and extraction pumping, chaotic flow topologies have been predicted theoretically and verified experimentally. Mixing enhancement due to chaotic advection and kinematic confinement of aquifer volumes are key features of the chaotic dynamics. We show theory and data from two types of experiments. First we use a Hele-Shaw cell to visualize and quantitatively confirm the simplest examples of the theory of transport in open chaotic flows of constant permeability. Second we use a 1 meter tank filled with glass beads of different sizes and emplace synthetic salt “deposits”. Data indicates a doubling of salt extraction rate from particular stirring protocols over the rate obtained with a steady flow. Other flow protocols clearly demonstrate confinement of the salt concentration, which can be released and reconfined as we turn particular stirring protocols on and off. Understanding these phenomena may form the basis for new efficient technologies for many applications in porous media scalar transport.