TRANSVERSE MIXING IN HETEROGENEOUS AQUIFERS

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Transverse mixing plays a crucial role in natural attenuation of contaminants originating from a continuous release into groundwater, e.g. by a persistent source zone. If the degradation of the contaminant requires a dissolved reaction partner, such as dissolved oxygen or nitrate, long-term supply requires mixing of the reaction partners in the direction lateral to groundwater flow. This is a comparably slow process and likely limits the overall reaction rate. Similar scenarios of reactions controlled by transverse mixing may exist in natural set-ups, e.g., determining the length of the reduced core downstream of a peat lengths within an aquifer. Local bulk transverse dispersivities αt typically range in the order of a few percent of the mean grain diameter, causing steady-state mixing-controlled reactive plumes to be very long. In two-dimensional set-ups, focussing of flow in high-permeability inclusions has been identified as major mechanism of enhancing tranverse mixing in heterogeneous aquifers.
We have derived a first-order scaling law for effective transverse mixing in 2-D heterogeneous domains, quantifying the probability that a solute particle changes streamlines. Effects of streamline meandering are corrected for. In contrast to classical spatial-moments analysis, our effective transverse mixing coefficient does not change with travel distance. We could also quantify the uncertainty of m ixing. Monte-Carlo simulations were used for validation of our a nalytical expressions.
Based on the scaling of effective transverse mixing in heterogeneous domains, we have derived expressions for the statistical distribution of concentration in steady-state transport, and for the statistical distribution of plume length in mixing-controlled reactive transport. In both cases the validity of the mean transverse mixing coefficients was confirmed. Also, in both cases the uncertinty of transverse mixing, albeit significant in magnitude, turned out to be less important than the uncertainty meandering and/or of the total volumetric flux passing through the source zone.
Transferability to realistic three-dimensional flow fields are subsject to current investigations.