Monte Carlo Simulations to Calibrate and Validate Stochastic Tank Experimentsof Macrodispersion of Density-Dependent Transport in Stochastically Heterogeneous Media

Bettina Starke and Manfred Koch

Department of Geotechnology and Geohydraulics, University of Kassel, Germany
Email: Bettina.Starke@gmx.de , kochm@uni-kassel.de

To calibrate and validate tank experiments of macrodispersion in density-dependent flow within a stochastically heterogeneous medium performed in a 10m long, 1.2m high and 0.1m wide Plexiglas tank at the University of Kassel over the last few years, numerous Monte Carlo simulations using the SUTRA density-dependent flow and transport model have been performed. Objective of this ongoing long-term study is the analysis of the effects of the stochastic properties of the porous medium on the steady-state macrodispersion, particularly, the transversal dispersion. The tank experiments have been set up to mimic density dependent flow under hydrodynamically stable conditions (horizontally stratified flow, whereby saltwater is injected horizontally into freshwater in the lower half of the tank).

Numerous experiments with saltwater concentrations ranging from $c_0 = 250$ (fresh water) to $c_0 = 100000$ ppm and three inflow velocities of u = 1,4 and 8 m/day each are carried out for three stochastic, anisotropically packed sand structures with different mean K_g, variance σ^2, and horizontal and vertical correlation lengths λ_x , λ_y for the permeability variations.

For each flow and transport experiment carried out in one tank pack, a large number of Monte Carlo simulations with stochastic realizations taken from the corresponding statistical family (with predefined K_g, σ^2, λ_x , λ_y) are simulated under steady-state conditions. From moment analyses and laterals widths of the simulated saltwater plume, variances σ_D^2 of lateral dispersion are calculated as a function of the horizontal distance x from the tank inlet. Using simple square root regression analysis of $\sigma_D^2(x)$, an expectation value for the transversal dispersivity $E(A_T)$ is then computed which should be representative for the particular medium family and the given flow conditions.

One issue of particular interest concerns the number N of Monte Carlo simulations required to get an asymptotically stable value $E(\sigma_D^2)$ or $E(A_T)$. Although this number depends essentially on the variance σ^2 of the heterogeneous medium, increasing with the latter, we find out that N = O(100), i.e. an order of magnitude less than what has been found in previously published Monte Carlo simulations of tracer-type macrodispersion in stochastically heterogeneous media.

As for the physics of the macrodispersion process retrieved from both the experiments and the Monte Carlo simulations, we find reasonable agreement that, as expected, deteriorates somewhat as the density contrast and the variance of the permeability distribution of the porous medium increase. Another aspect that will be discussed in detail is the different degree of sensitivity of the lateral macrodispersion to the various parameters describing the flow and the porous medium.