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Interpretation of numerical transport tests with single and dual porous medium approaches

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Preferential flow paths (PFP) in alluvial sediments influence the fate of contaminants in ground water and render the application of the classical Fickian approach doubtful. In order to improve the comprehension of this remark and its practical effects, numerical experiments of conservative solute transport were performed on three blocks of alluvial sediments from the Ticino basin (Northern Italy), described by Zappa et al. (doi:10.1016/j.jhydrol.2005.10.016). The volume of each block is about $6\,\mathrm{m}^3$ and the conductivity field is assigned on cubic voxels with side equal to $2\,\mathrm{cm}$. Flow modelling was conducted with a conservative finite difference scheme and convective transport with particle tracking (Vassena et al., doi:10.1007/s10040-009-0523-2). The numerical experiments simulate the evolution of a tracer plume which is instantaneously injected through the incoming face and travels along a longitudinal average flow bounded by lateral no flow boundaries. The interpretation of the results is conducted by fitting the cumulative breakthrough curve (BTC) obtained from the analytical solution of the 1D convective-dispersive equation to the numerical test data, through the calibration of the Darcy's velocity and the dispersion coefficient. Results for the classical single porous medium (SPM) case show some discrepancies due to the presence of PFP, which could be taken into account if a dual porous medium (DPM) is considered. In particular the domain is modelled as the superposition of two porous media, characterised by high and low conductivity. Most of the DPM models developed earlier neglect the flow rate in the low K porous medium and include a possibly linear mixing between the two media. Here the flow in the low K porous medium is taken into account, but mixing is neglected.

The fit between cumulative BTC obtained from numerical test data and analytical solutions was conducted with the Levenberg-Marquardt algorithm, supported by the analysis of the uniqueness of the inverse problem, which is very critical for the DPM approach, since five parameters have to be calibrated (the Darcy's velocities and the dispersion coefficients for both media and the fraction of solute mass travelling in the high K medium).

The DPM model permits to improve the fit of the cumulative BTC but it requires the calibration of several parameters. The tests clearly show that the improvement of the results is particularly important for those blocks where PFP are more evident. Furthermore the DPM model often reduces the differences between the temporal moments of the BTC computed from the analytical solution and from the numerical experiment data.