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Bimodal breakthrough curves through dual-permeability systems: an experimental and numerical study

Jérôme Raimbault (1), Laurent Lassabatere (2), Pierre-Emmanuel Peyneau (2), Denis Courtier Murias (3), and Béatrice Bechet (2)

(1) IFSTTAR, GERS, EE, F-44340 Bouguenais, France, (2) ENTPE, University of Lyon LEHNA UMR 5023 CNRS ENTPE UCBL, Vaulx en Velin, France (laurent.lassabatere@entpe.fr), (3) Laboratoire Navier (ENPC - IFSTTAR - CNRS), Université Paris-Est, 77420, Champs-sur-Marne, France

Depending on flow conditions, dual-permeability may favor the establishment of two separate flows with two contrasting flow rates in the matrix and the fast-flow regions. In such a case (e.g. when the dual-permeability medium is saturated with water), non-reactive solutes may be carried by the water through the matrix and the fast-flow regions with two pore velocities, resulting into the transfer of two solute modes. Under other circumstances (similar flow rates in both regions and strong solute exchange between the two regions), the two modes may overlap, resulting in a unimodal shape for the BreakThrough Curves (BTCs). Consequently, when dual-permeability systems are set up into laboratory columns and submitted to flow, unimodal or bimodal BTCs may be obtained. Theoretically, the shape of the BTCs (unimodality versus bimodality) depends upon the residence time in each region, the mass of solutes transported through each region, and the solute exchange between the two regions. In this study, several experiments were conducted with saturated synthetic porous media (perforated capillary tubes embedded into sandy matrices) and the application of several flow rates to play on the relative contribution of advection relatively to molecular diffusion responsible for solute exchange between the two regions. The experimental and numerical data show that, depending on the injected flow rate and the characteristics of the systems, unimodal or bimodal BTCs were obtained. Numerical modelling is used to predict the solute BTCs as a function of input parameters (hydraulic parameters of the two regions, void ratio occupied by the fast flow region, solute exchange between the two regions) to conduct a sensitivity analysis in order to select the hydraulic parameters responsible for the BTCs bimodality. Optimization is then conducted by fitting the model to observations to derive the most likely values for the processes observed in the studied experimental systems.