Momentum dissipation during flow in soils. II. Applications

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MODELING NONEQULIBRIUM SOLUTE TRANSPORT UNDER TRANSIENT FLOW CONDITIONS WITH STEADY STATE FLOW AND TRANSPORT PARAMETERS

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The goal of this work is to determine whether mobile-immobile model (MIM) transport under transient flow conditions can be successfully described with a transport model that assumes steady flow conditions. Unsaturated, miscible displacement experiments were conducted under steady and transient flow conditions for a range of water contents and pore velocities in a medium-fine sand. Comparison of MIM parameters estimated from the steady and transient flow experiments indicate that values of mobile zone dispersion coefficients are sensitive to the flow regime. However, since solute transport is insensitive to dispersion under the experimental conditions used here, steady-state transport parameters can be used to predict the transient breakthrough data. Functions were developed to describe the dependence of the MIM parameters on system properties. These functions were incorporated into an unsaturated flow and transport simulator. Simulations were conducted under fully transient conditions and with a steady flow approach that utilizes effective pore velocities, water contents and MIM parameters. The simulations reveal that the steady flow approach sufficiently describes solute transport under transient flow conditions, except under relatively dry or highly periodic flow conditions.

QUANTITATIVE STUDY OF HYDRODYNAMIC DISPERSION TRANSIENT TIME IN HETEROGENEOUS NETWORKS

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We simulate hydrodynamic dispersion as the result of two independent physical mechanisms: advective transport and molecular diffusion. Advective transport is the deterministic passive motion of solute particles along streamlines. Molecular diffusion is modeled by a 3D random walk. By varying the molecular diffusion coefficient D_m, we simulate a broad range of Peclet numbers Pe and investigate dispersion regimes (iii) and (iv). We firstly check the validity of the method by comparing our results to Taylor-Aris' theory. In particular, we observe a linear dependence of the transient time τ with a^2/D_m (a is the pore radius). The simulated medium is a periodic arrangement of 2D square networks. Pore-scale heterogeneity is modeled by the variance of the pore size distribution. Here we quantitatively evaluate the effect of this heterogeneity levels on dispersion. In particular for τ, which defines a limit of validity of the convection-diffusion equation, the Taylor dependence on a^2/D_m observed in a single capillary, is largely obscured by heterogeneity. Finally, an important result is the continuous evolution of the dispersion process (e.g. for the law D_L/D_m proportionnal to Pe^{α}) from Taylor dispersion in homogeneous media (i.e. $\alpha = 2$) to the regime observed in experimental reviews (i.e. $\alpha = 1$).

MOMENTUM DISSIPATION DURING FLOW IN SOILS I.

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A mathematical description of infiltration in macropore soils may be obtained from the combination of fundamental conservation laws. An insight of the possible mechanisms controlling capillary and preferential flow based on the analysis of the dissipation of the linear momentum of water will be discussed. Richards' equation for flow in homogeneous soils and the kinematic wave approximation for macropore flow are regarded as the asymptotic limits of a more general kinematic – dispersive approach. Numerical solutions for infiltration in heterogeneous soils obtained with a lattice-gas model will be presented and compared with the solutions of the asymptotic limits.

STABILITY CRITERIA FOR FLOWS IN UNSATURATED SOILS

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Recent progress concerning stability criteria for flows in unsaturated soils will be reviewed. Stability criteria reflect the interplay between the nature of the background flow and the physical properties of soils. Examples of background flows are various types of steady flows and flows with time invariant moving water content profiles. The nature of the soils is expressed by the water retention and hydraulic conductivity characteristics. It turns out that soils with physical properties enabling linearization of the flow equation or the derivation of similarity solutions are also exceptional with regard to the stability criteria. For steady, one-dimensional background flows the stability criteria for various classes of soils can be exhibited in a simple diagram. Practical consequences of instabilities for agricultural and natural systems will be indicated.

LABORATORY INVESTIGATION ON WATER CONTENT DEPENDENCE OF TRANSVERSAL DISPERIVITY IN ANISOTROPIC SANDY STRUCTURES

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Evidence of macroscopic anisotropic transport behavior comes from the experimental side. Real soils show a variably pronounced tendency to spreading in one direction depending on the water saturation. We mainly focus on quantification of lateral spreading of a pulse of dye in a medium with anisotropic correlation structure under steady state conditions, for different water flow or, correspondingly, different averaged water content. We established experiments in a laboratory tank filled with three different sands arranged in a way to reproduce the same realization of a random field with two different correlation anisotropy factors. Image analysis of dye tracer experiments lead to computation of the moments of the plume at certain times under certain boundary conditions. In the cases examined the presence of capillary phenomena as well as their influence on the variance of the lateral displacement, that strongly depends on the water saturation, is evident. Quantification of the effect of these subscale phenomena on the macroscopic variables is possible only experimentally or by introducing new conceptual elements in the classical formulation of the stochastic models.

MOMENTUM DISSIPATION DURING FLOW IN SOILS II APPLICATIONS

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Richards-Equation on flow in unsaturated porous media is based on the reversible diffusion of capillary potential during transient flow, and dissipation of momentum at scales larger than an REV are negligible because momentum is thought to completely dissipate within it. However, it is our understanding that irreversible momentum dissipation at scales larger than an REV is important to explain so-called non-equilibrium flows. Field methods will be presented with those (1) momentum dissipation can be distinguished from the diffusion of capillarity, (2) momentum of flow can be estimated at various depths in the soil profile, and (3) maximum durations and penetration depths of non-equilibrated flow can be assessed with respect to the boundary conditions. Infiltration experiments revealed that significant non-equilibrium flow lasts only a few times longer than its forming water input and that only small volume fractions of soil moisture are involved in the flow process with but little interaction with lesser mobile soil moisture.

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