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Dynamics of Transport and Deposition of BioColloids in Granular Porous Media

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A simulator of the flow of aqueous suspensions and the deposition of colloids and/or bio-colloids in granular media has been developed and applied for the prediction of the penetration rate and the distribution profile of the colloids as functions of depth, time, and the system parameters. The porous structure of the granular medium is represented as a three-dimensional network of constricted pores, thus taking into account the converging-diverging character of flow within granular formations. A Lagrangian-type simulation is used to calculate the rate of particle transport and deposition in each pore segment. Gravity and drag, as well as hydrodynamic and physicochemical interactions between suspended colloids and pore walls are considered in 3-D trajectory equations. The hydrodynamic and physicochemical interactions of the oncoming colloids with previously deposited matter are also taken into account properly during the simulation. Rates for the particles that exit the 3-D network as a function of time and system parameters are calculated, providing quantitative information on the time needed for a plume or a biocolloid source rejected accidently into the subsoil to reach any nearby aquifer or surface aqueous receptors.

Depending on the conditions, three distinct flow modes, namely downflow, upflow, and horizontal flow, are commonly encountered in groundwater transport phenomena, each having a different direction of the macroscopic flow of the aqueous suspension relative to gravity. The simulator is applied for the monitoring of the transient behavior of all three modes of colloidal transport. The loss of permeability is monitored through calculation of the pore-scale, as well of the network-scale hydraulic conductance at each time step. The simulator predicts also the changes of particle penetration rates for all modes of suspension flow operation. Numerical results for the temporal evolution of the distribution of the suspended colloids and of the profiles of the deposited population are reported based on simulations of suspension flow in a typical porous medium. Upflow suspensions of biocolloids travel for shorter distances and deposit faster than the other two types of flow, while extensive deposition phenomena occur near the entrance front of the porous medium, which may lead to pore clogging. Downward flow displays a smoother performance, allowing relatively long penetration rates. Horizontal flow operation gives somewhat slower deposition and clogging rates and leads to a two-dimensional distribution of deposited matter, which, in turn, leads to a shifting of the flow and transport transversely to the main flow direction. The overall behavior is intermediate between those of upflow and downflow operations.