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A binomial modeling approach for upscaling colloid transport under unfavorable conditions: organic prediction of extended tailing

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Transport of colloids in saturated porous media is significantly influenced by colloidal interactions with grain surfaces. Near-surface fluid domain colloids experience relatively low fluid drag and relatively strong colloidal forces that slow their down-gradient translation relative to colloids in bulk fluid. Near surface fluid domain colloids may re-enter into the bulk fluid via diffusion (nanoparticles) or expulsion at rear flow stagnation zones, they may immobilize (attach) via strong primary minimum interactions, or they may move along a grain-to-grain contact to the near surface fluid domain of an adjacent grain. We introduce a simple model that accounts for all possible permutations of mass transfer within a dual pore and grain network. The primary phenomena thereby represented in the model are mass transfer of colloids between the bulk and near-surface fluid domains and immobilization onto grain surfaces. Colloid movement is described by a sequence of trials in a series of unit cells, and the binomial distribution is used to calculate the probabilities of each possible sequence. Pore-scale simulations provide mechanistically-determined likelihoods and timescales associated with the above pore-scale colloid mass transfer processes, whereas the network-scale model employs pore and grain topology to determine probabilities of transfer from up-gradient bulk and near-surface fluid domains to down-gradient bulk and near-surface fluid domains. Inter-grain transport of colloids in the near surface fluid domain can cause extended tailing.