Geophysical Research Abstracts, Vol. 7, 06074, 2005
SRef-ID: 1607-7962/gra/EGU05-A-06074

The effects of pore-scale biomass distribution and morphology on biodegradation rates in contaminated groundwater

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Recent laboratory and modeling studies indicate that in groundwater, biodegradation occurs primarily along plume margins, where one or more nutrients mix with contaminants through transverse dispersion. Biomass growth is concentrated along this mixing zone, and it affects water flow and mass transfer. The goal of this work is to determine if biomass morphology along a transverse mixing zone must be resolved in order to accurately predict bioremediation. A pore scale biomass growth model was developed and calibrated to an experiment where biomass growth occurred along a transverse mixing zone between lactate (electron donor) and tetrachloroethene (electron acceptor) in model 2D porous media. Fitted biomass growth parameters were used to determine the steady biomass distribution and morphology as a function of average water velocity and biodegradation rate constants. Overall contaminant degradation rates were calculated 1) using biomass developed from the pore-scale biomass growth model, and 2) assuming biomass was uniformly distributed in pores and did not affect water flow paths. Modeling results indicate that water velocities are reduced in pores along the transverse mixing zone that contain biomass. This allows more time for contaminants in pores adjacent to biomass to diffuse and mix, but it reduces the total mass flux of solutes to these pores. Near the inlet, the substrate degradation rate for developed biomass is less than that for uniform biomass because substrates are not mixed across a sufficient number of pores in the transverse direction; this occurs because biomass is only present near the transverse centerline of pores. The length of this incomplete mixing region increases with increasing flow rate and decreasing reaction rate. Hence, biomass morphology and distribution are important features for incomplete mixing conditions. For larger scale models, both biomass morphology and

the local flow field are unresolved, so a suitable value for the transverse dispersion coefficient must be determined. In the well-mixed region, good agreement with pore scale degradation rates is achieved with continuum models.