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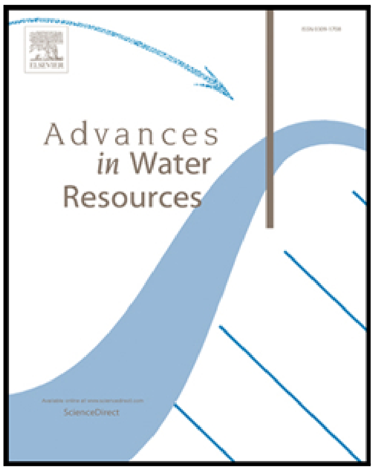

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An immersed boundary-lattice Boltzmann model for biofilm growth in porous media

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Abstract

In this paper, we present a two-dimensional pore-scale numerical model to investigate the main mechanisms governing biofilm growth in porous media. The fluid flow and solute transport equations are coupled with a biofilm evolution model. Fluid flow is simulated with an immersed boundary–lattice Boltzmann model while solute transport is described with a volume-of-fluid-type approach. A cellular automaton algorithm combined with immersed boundary methods was developed to describe the spreading and distribution of biomass. Bacterial attachment and detachment mechanisms are also taken into account. The capability of this model to describe correctly the couplings involved between fluid circulation, nutrient transport and bacterial growth is tested under different hydrostatic and hydrodynamic conditions (i) on a flat medium and (ii) for a complex porous medium. For the second case, different regimes of biofilm growth are identified and are found to be related to the dimensionless parameters of the model, Damköhler and Péclet numbers and dimensionless shear stress. Finally, the impact of biofilm growth on the macroscopic properties of the porous medium is investigated and we discuss the unicity of the relationships between hydraulic conductivity and biofilm volume fraction.

Keywords:
Lattice Botzmann method, Immersed boundary method, Biofilm growth, Porous media, Cellular automata

1. Introduction

Biofilm is a community of one or more species of bacteria or other microorganisms (fungi, algae, yeasts) associated irreversibly with a liquid or solid surface (water, biological tissues, solid substrates located in marine environments or freshwater) (Potera, 1999) and enclosed in a matrix of polysaccharide (Kalmokoff et al., 2001, Prakash et al., 2003, Smith, 2005). Biofilm is composed primarily of microbial cells and extracellular polymeric substance (EPS). The EPS plays various roles in the formation and structure of the biofilm and also, protects the cells by preventing the access of antimicrobial and xenobiotic compounds and confers protection against environmental stresses such as UV radiation, pH shift, osmotic shock and desiccation

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