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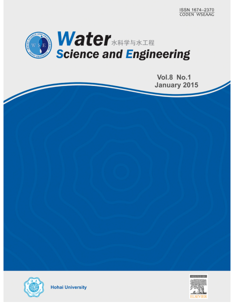

Experimental and theoretical study of coupled influence of flow velocity increment and particle size on particle retention and release in porous media

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Experimental and theoretical study of coupled influence of flow velocity increment and particle size on particle retention and release in porous media

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Abstract

Experimental and theoretical studies were carried out to investigate the coupled influence of flow velocity increment and particle size on the retention and release of particles in porous media. Particle release was examined through measurement of changes in effluent particle concentrations, and particle retention was assessed through measurement of the final spatial distribution of particles remaining in the soil columns after the experiments. Particle release curves were simulated using a convection-dispersion model that includes the instantaneous release of the line source. Fitted model parameters were used to gain insights into the mechanisms that control particle retention and release. When the flow velocity increment was 0.0435 cm/s, the peak concentration of particles decreased with increasing flow velocity until the latter approached a critical level, beyond which the particle concentration increased. Particle wedging and fouling were considered the primary mechanisms that controlled particle retention and release beyond the critical particle velocity. In experiments with large flow velocity increments, small particles exhibited lower particle mass fraction than large particles as particle wedging and fouling increased with particle size. The range of longitudinal dispersivity decreased with an increasing particle size and flow velocity increment. Moreover, the mean particle velocity increased with the mean interstitial fluid velocity. The mean particle velocity profile was highly sensitive to the particle size at low velocity increments. In general, particle release rates increased with both flow velocity and velocity increment. The mass of the released particles provides further evidence that particle wedging and fouling are the major factors that control particle release in sand columns.

Keywords: Particle; Porous media; Retention; Release; Hydrodynamic force

1. Introduction

The retention and release of particles in porous media have profound effects on many important processes occurring in the subsurface zone. These processes affect clogging, structural changes of subsurface porous media, particle-facilitated transport of contaminants, and soil formation (Reddi et al., 2000; Tomlinson and Vaid, 2000; Blume et al., 2002; Sen and Khilar, 2006; Natarajan and Kumar, 2011; Bradford et al., 2013, 2014; Pazmino et al., 2014; Engström et al., 2015; Sasidharan et al., 2016). For example, contaminants are transported into the subsurface zone directly by dissolution in the fluid phase or indirectly by association with the particle surfaces (Grolimund et al., 1996; Karathanasis, 1999; Missana et al., 2008; Bradford et al., 2013). Soil permeability can be either decreased by clogging of pore necks with fine particles, or increased by the washing out of the fine particles that leads to widening of the pore size (Blume et al., 2002). Furthermore, the transport of contaminants associated with particles is either facilitated or retarded by the mobile particles (Blume et al., 2002; Sen and Khilar, 2006; Bradford et al., 2013).

To explain how particle retention and release contribute to contaminant transport in porous media, we first of all need to understand the mechanisms of particle transport and deposition. Mechanisms of particle retention and release in porous media involve wedging, straining, fouling, and attachment to solid surfaces (Sen and Khilar, 2006; Torkzaban et al., 2008; Bradford et al., 2013; Raychoudhury et al., 2014). The ratio of the particle size to pore constriction size is

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