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Air Bubble Presence and Colloidal Particle Transport in Porous Media

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1. Introduction

Colloid transport in the subsurface environments has significant attention in recent years because the colloids can be contaminant itself or play the role of contaminants carrier. Colloids are generated from chemical and/or physical perturbations in the natural porous matrix or changes in hydraulic system such as pumping or injection of water at high rates. Colloids can also be introduced into the porous medium from the land surface through rapid infiltration of rainfall or injected into subsurface as tracer for an experiment (Keller and Sirivithayapakorn, 2004, Ryan and Elimelech, 1996).

Many researches have been investigated the role of air-water interface in transport of contaminant in porous media, however most of them focused on continuous air-water interface and mass balance equation rather than discrete air-water interface, i.e. air bubble and force balance equation. By setting up the force balance equations for particle-bubble interaction, many questions in transport of colloids in porous media in the presence of discrete air phase such like capture mechanisms, bubble entrapment in pore body, critical size of bubble to retard or facilitate the colloid transport, etc. can be solved.

Understanding the role of moving bubble in particle transport in porous media is essential for improving the effectiveness of filtration, and enhancing flexibility of particle transport control.

2. Basic Theories

One of the important considerations on particle behaviors is formation of a cluster when the bubble dissolves. Formation of particle cluster may cause changes in hydrodynamic system by clogging at the pore throat.

Colloids travel through the water-filled paths of the porous medium by advection and dispersion and are immobilized from the pore water by film straining, air-water interface capture, and deposition onto soil-water interfaces. One dimensional advection-dispersion equation (ADE) describes the movement of pore water colloids (DeNovio, Saiers, and Ryan, 2004).

$$\frac{\partial C}{\partial t}+\frac{\partial \Gamma_{STR}}{\partial t}+\frac{\rho_c}{S_w}\left[f_{air}\frac{\partial \Gamma_{AWI}}{\partial t}+f_{soil}\frac{\partial \Gamma_{SWI}}{\partial t}\right]=A_L v\frac{\partial^2 C}{\partial z^2}-v\frac{\partial C}{\partial z}$$

where C is the pore water colloid concentration; Γ_{STR} , Γ_{AWI} , and Γ_{SWI} are immobile-phase colloid concentrations for removal by film straining (STR), air-water interface capture (AWI), and soil-water interface deposition (SWI); t is time; ρ_c is the ratio of colloid mass to its effective cross-sectional area; S_W is water saturation; f_{air} is the air-water interfacial area per unit void volume; f_{soil} is the soil-water interfacial area per unit void volume; A_L is the longitudinal dispersivity; V is the average pore water velocity; and Z is the coordinate parallel to flow.

3. Methodology

Particles present on soil-water interface and in the fluid as suspended form in water saturated porous media. The presence of bubble in the water saturated system affects on the transport phenomena and behaviors of the particles. The moving air bubbles carry the particles attached on their surface if the buoyancy is still big enough to keep the bubble rising, or retard when the total mass of the particles produces gravitational resistance which is equal to or exceeds the buoyancy.

Force balance equation, population balance equation, and one dimensional advection-dispersion equation describe effects of moving bubble on the behaviors and transport of the particles in porous media.

4. Conclusion

Particle attachment on air-water interface has received great attention in many years. However the past researches focused mainly on continuous air phase or trapped air bubble in the pore. To perform more effective research on the subsurface environment regarding contaminant transport along with air bubbles, the following aspects must be examined and understood.

Bubbles catch the particles in the fluid while they pass the pore and the particles attached on the bubble surface may cause changes the behaviors of the bubble. The changes of bubble behaviors include reduced velocity, and increased residence time in the pore. Moving bubble can enhance particle transport by carrying them on their surface or help the particles form a cluster by giving chance to aggregate when they dissolves.

To define the roles of bubble for the particle transport the critical conditions for bubble and particle to affect each other is investigated.

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