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Particle transport in a saturated porous medium: Pore structure effects

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Abstract

This paper presents an experimental study of the transport of suspended particles (SP) in a saturated porous medium, aimed at delineating the effects of pore structure on particle transport and deposition rate. Two porous media (silica gravel and glass beads) and silt SP were used. Breakthrough curves (BTCs) were well described by an analytical solution of the advective-dispersive equation with a first-order deposition kinetic. The recovery rate of suspended particles is higher in the glass beads even if the porosities are similar. This study shows the importance of pore distribution in transport processes of suspended particles. ***To cite this article: A. Benamar et al., C. R. Geoscience 339 (2007).***

Résumé

Transport particulaire en milieu poreux saturé : effets de la structure porale. Cette étude expérimentale concerne le transport et la cinétique de dépôt des matières en suspension (MES) dans un milieu poreux saturé. Elle met en évidence les effets de la structure porale sur le transport et le dépôt des MES. Deux milieux poreux (gravier siliceux et billes de verre) et des MES de limon sont utilisés. Les courbes de restitution sont bien décrites par la solution analytique de l'équation d'advection–dispersion, avec une cinétique de dépôt de premier ordre. Le taux de restitution des particules est plus important dans les billes de verre, même si les porosités sont voisines. Les résultats montrent l'importance de la distribution porale dans les processus de transport des MES. ***Pour citer cet article : A. Benamar et al., C. R. Geoscience 339 (2007).***

Keywords: Porous media; Suspended particles; Transport; Pore structure; Deposition; Beads

Mots clés : Milieu poreux ; Particules ; Transport ; Structure porale ; Dépôt ; Billes

1. Introduction

Mobile particles in soils and groundwater aquifers can act as carriers for strongly sorbing chemicals and may enhance contaminant transport. The transport mechanisms of colloids in saturated porous media have been studied in great detail. The knowledge and understanding of the colloid-associated contaminant transport in porous media have increased substantially over the last decade [8,9,13]. However, a limited number of experimental studies have been published to date on the transport and deposition of particles in

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natural porous media. Understanding the fate and transport of suspended particles in porous media has a great implication on the reduction of the risk of drinking-water-supply contamination. Mobile particles in groundwater aquifers and soils can serve as carriers for contaminants and thereby facilitate contaminant transport [15]. They also contribute to develop internal erosion in dykes and petroleum wells clogging. Owing to their large size and density, the role of suspended particles on solute transport has only recently attracted significant attention [2,6,7,12,19]. During major floods, erosion of alluvial soil causes the occurrence of significant turbidity. Turbid water travels through the alluvium and can reach water supply wells. The alluvial aquifer might be of interest for the understanding of the water pollution risk.

Various restrictions on the movement of suspended particles such as clogging, mechanical straining and filtration were studied. During the flow of the suspension through the medium, particle transport and capture result from several forces and mechanisms depending on particle size, pore distribution, and flow rate. For larger particles, typically more than 10 μm, hydrodynamics, gravity and inertial effects are dominant, while all forces and mechanisms can contribute for smaller particles whose size is ranging between 0.1 and 10 μm [7]. This paper presents an experimental study of the transport of suspended particles (SP) in saturated porous media, aimed at delineating the effects of hydrodynamic and gravity forces on particle transport and deposition rate. This study addresses transport and deposition of suspended particles in two porous media that are different in pore geometry under water-saturated flow conditions. We investigate the various mechanisms governing the process of particle transport, with emphasis on the role of particle deposition. A short-pulse technique was used for measuring particle deposition rate coefficient and collision efficiencies in the two porous media. Suspended particles were injected under saturated flow conditions into a horizontal laboratory column packed with gravel or glass beads. Many experiments were conducted with different flow rates. Particle breakthrough curves (BTCs) were measured on-line using fluorescence and turbidity (dynamic technique) sensors. These curves were well described by the analytical solution of the advection–dispersion equation with a first-order deposition kinetics. The laboratory tests performed with different flow rates and column materials showed that hydrodispersive parameters derived from 1D advection–dispersion models depend on the flow rate and the pore geometry of the porous media.

2. Materials and methods

The column setup used to determine particle transport and deposition rate (Fig. 1), described in a previous paper [2], consisted of a water (pH 6.8) reservoir with constant liquid height, a pump controlling the steady-state flow rate, a pulse injection loop, a Plexiglas column (355 mm length and 89 mm inner diameter) packed with the porous medium, and a detection system for particles and fluorescein connected to a PC for data acquisition. A numerical flowmeter was included between the pump and the column. The particle detection system consists of a turbidmeter previously calibrated for the concentration range used. Some samples of the suspension are analyzed at the outlet column using a Coulter Multisizer particle counter. Two porous media (gravel and glass beads) with quite similar porosity but differences in pore distribution are used alternatively to fill the laboratory

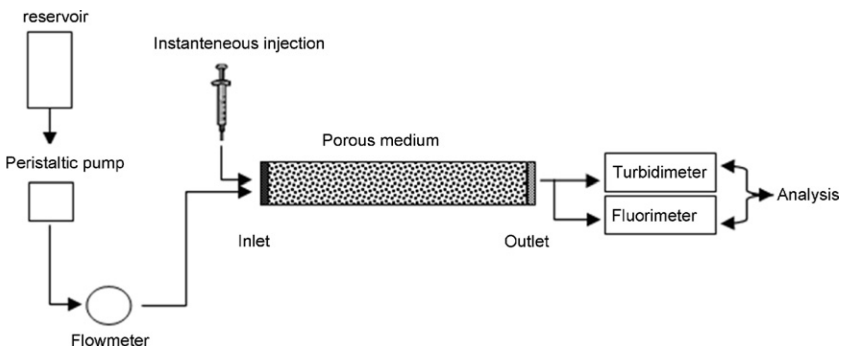

Fig. 1. Schematic drawing of the experimental setup.

Fig. 1. Représentation schématique du dispositif expérimental.