



An explanation for differences in the process of colloid adsorption in batch and column studies



Svantje Treumann^a, Saeed Torkzaban^{a,*}, Scott A. Bradford^b, Rahul M. Visalakshan^a, Declan Page^a

^a CSIRO Land and Water, Glen Osmond, SA 5064, Australia

^b USDA, ARS, Salinity Laboratory, Riverside, CA 92507, United States

ARTICLE INFO

Article history:

Received 16 April 2014

Received in revised form 5 June 2014

Accepted 13 June 2014

Available online 20 June 2014

Keywords:

Colloid

Bacteria

Batch

PARP-1

Column experiments

Porous media

Attachment

ABSTRACT

It is essential to understand the mechanisms that control virus and bacteria removal in the subsurface environment to assess the risk of groundwater contamination with fecal microorganisms. This study was conducted to explicitly provide a critical and systematic comparison between batch and column experiments. The aim was to investigate the underlying factors causing the commonly observed discrepancies in colloid adsorption process in column and batch systems. We examined the colloid adsorption behavior of four different sizes of carboxylate-modified latex (CML) microspheres, as surrogates for viruses and bacteria, on quartz sand in batch and column experiments over a wide range of solution ionic strengths (IS). Our results show that adsorption of colloids in batch systems should be considered as an irreversible attachment because the attachment/detachment model was found to be inadequate in describing the batch results. An irreversible attachment-blocking model was found to accurately describe the results of both batch and column experiments. The rate of attachment was found to depend highly on colloid size, solution IS and the fraction of the sand surface area favorable for attachment (S_f). The rate of attachment and S_f values were different in batch and column experiments due to differences in the hydrodynamic of the system, and the role of surface roughness and pore structure on colloid attachment. Results from column and batch experiments were generally not comparable, especially for larger colloids ($\geq 0.5 \mu\text{m}$). Predictions based on classical DLVO theory were found to inadequately describe interaction energies between colloids and sand surfaces.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

An understanding and ability to predict the transport and fate of colloids such as viruses, bacteria, protozoa, clay minerals, and engineered nanoparticles in porous media is essential for a wide variety of environmental and engineering applications (Bradford et al., 2012; Mondal and Sleep, 2013; Schijven and Hassanizadeh, 2000; Torkzaban et al., 2013). Colloid transport and fate are strongly influenced by retention in porous media (Ryan and Elimelech, 1996; Shen et al., 2008). Extensive theoretical and experimental studies

have therefore been devoted to understanding and quantifying colloid retention in porous media (reviews are given by Bradford et al., 2014; Ginn et al., 2002; Harvey et al., 2002; Jin and Flury, 2002). It has been shown that colloid retention depends on a range of physicochemical and hydrodynamic conditions (Li and Johnson, 2005; Li et al., 2004; Pensini et al., 2012; Torkzaban et al., 2008; Tufenkji and Elimelech, 2004). Batch and column experiments are the most common methods to study colloid retention in saturated porous media. These experimental techniques offer the advantage that retention can be examined under well-defined conditions. However, numerous discrepancies between batch and column results have been reported in the literature (e.g. Bales et al., 1991; Sadeghi et al., 2013; Zhao et al., 2008).

* Corresponding author. Tel.: +61 8830 38491.

E-mail address: Saeed.Torkzaban@csiro.au (S. Torkzaban).

Packed-column experiments are commonly utilized to study colloid transport and retention processes over a range of physical and chemical conditions. Analysis of colloid breakthrough curves (BTCs), and sometimes retention profiles (RPs) following completion of the experiment, are used to determine values of attachment and detachment rate constants (Harvey and Garabedian, 1991; Johnson et al., 2007; Schijven et al., 2000; Tong et al., 2005). These retention parameters are determined by fitting the solution of a mass balance transport model to experimental BTCs and/or RPs (Kim et al., 2009). The bulk of existing literature from column studies considers colloid transport to be controlled by attachment and detachment processes (Bradford et al., 2014; Schijven et al., 2000). These studies have demonstrated that the diffusion-controlled detachment rate is very slow during steady-state flow and chemical conditions (Ryan and Elimelech, 1996; Torkzaban et al., 2013). In addition to attachment, colloid straining (retention in grain–grain contacts and surface roughness) may also play a significant role in colloid retention (Bradford et al., 2013; Ma et al., 2011). However, determination of the relative contribution of attachment and straining to retention is difficult, if not impossible, from only BTC and RP information (Bradford et al., 2009). Microscopic observations have been employed to identify specific mechanisms of colloid retention, but quantitative determination of the relative contributions of these mechanisms is still not possible. Moreover, recent studies have pointed out that colloid retention in packed-bed columns is limited to only a small fraction of the solid surfaces, and blocking-type behavior is typically observed if the input colloid concentration is high and/or the colloid injection continues for a relatively long time (Brown and Abramson, 2006).

Batch experiments are carried out by adding a quantity of solid (e.g. sand) into a solution containing a known concentration of colloids. The mixture is subsequently shaken for a sufficient period of time to reach a steady-state (equilibrium) condition. The final concentration of colloids in solution is measured and the amount of attached colloids is calculated from mass balance calculations. The apparent steady-state concentrations are used to construct equilibrium isotherms using linear, Langmuir, or Freundlich models (Yates et al., 1987). The attachment process is typically considered to be linear and reversible (Schijven and Hassanizadeh, 2000). In this case, a distribution coefficient (K_D) is calculated and converted to a retardation factor (R) that may be used in transport studies. Colloid attachment and detachment rate coefficients can also be determined from batch studies provided that the colloid concentration in the aqueous phase is measured at various times before the steady-state concentration is reached (Sadeghi et al., 2013). However, attachment and detachment rates from batch experiments have not always been consistent and reproducible due to some yet-unknown factors (Chrysikopoulos and Aravantinou, 2012; Sadeghi et al., 2013; Syngouna and Chrysikopoulos, 2010; Thompson and Yates, 1999; Thompson et al., 1998; Zhao et al., 2008). Such factors may include the type and size of the container, the presence or absence of the air–water interface in the system, the method of shaking to achieve complete mixing, and the ratio of solid and liquid phases in the container.

A potential advantage of batch experiments is that they involve less space and labor than column studies. However, results of batch studies have not been consistent with those

of column or field experiments (Sadeghi et al., 2013; Schijven and Hassanizadeh, 2000). Column experiments usually show no retardation in the BTCs, suggesting that a kinetic attachment process should be considered and that the rates of attachment and detachment are slow (Bales et al., 1991; Johnson and Elimelech, 1995; Kim et al., 2009). Batch experiments have been found to either overestimate (Sadeghi et al., 2013; Schijven et al., 2000; Zhao et al., 2008) or underestimate colloid attachment compared with that observed in column studies (Schijven et al., 2000; Torkzaban et al., 2008). This discrepancy has been attributed to the time duration of batch experiments and the selected solid/solution ratios (Sadeghi et al., 2013). Alternatively, differences in batch and column experiments may also be related to the hydrodynamic conditions, surface roughness, and pore structure. In particular, the solid phase is continuously mixed and the flow direction changes during batch experiments. This facilitates the collision of colloids to the solid phase, and possibly higher attachment rates, but also eliminates the pore structure and continuously changes the applied hydrodynamic (T_H) and resisting adhesive (T_A) torques that act on the colloids retained at roughness locations on the solid phase. Conversely, the solid phase in column experiments is stationary, and the colloids retained at surface roughness locations and grain–grain contacts will always experience a lower applied hydrodynamic torque and greater resisting adhesive torque (Bergendahl and Grasso, 2000; Bradford et al., 2009; Ma et al., 2011; Torkzaban et al., 2010a). The solid surface area associated with colloid retention is therefore expected to be greater in column than batch systems. Furthermore, the potential influence of blocking on the kinetic of colloid attachment has not been investigated in batch studies.

This study has been explicitly designed to provide a critical and systematic comparison between batch and column experiments. The aim was to investigate the underlying factors causing the commonly observed discrepancies in colloid adsorption in column and batch experiments. We examined the adsorption behavior of four different sizes of carboxylate-modified latex (CML) microspheres in batch and column experiments. The advantage of using CML microspheres is that the influence of confounding factors on retention data can be minimized; e.g., particle aggregation for engineered nanoparticles, and inactivation and growth for microbes. Our results show that colloid adsorption in batch systems should be considered as an irreversible attachment process with a blocking behavior. The rate of attachment and the fraction of the surface area contributing to colloid immobilization (S_f) were much smaller in batch than column experiments due to differences in the hydrodynamics, and the role of surface roughness and pore structure. Results from column and batch experiments were generally not comparable, especially for larger colloids ($\geq 0.5 \mu\text{m}$). We believe this study is the first to systematically compare differences in colloid retention in batch and column studies.

2. Material and methods

2.1. Colloids, sand, and electrolyte solutions

Ultra pure quartz sand (Charles B. Chrystal Co., Inc., NY) was employed as the porous media for the column and batch experiments. The median grain diameter of the sand

Download English Version:

<https://daneshyari.com/en/article/6386545>

Download Persian Version:

<https://daneshyari.com/article/6386545>

[Daneshyari.com](https://daneshyari.com)