# Modeling of Colloid Transport Under Transient Conditions

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## Introduction

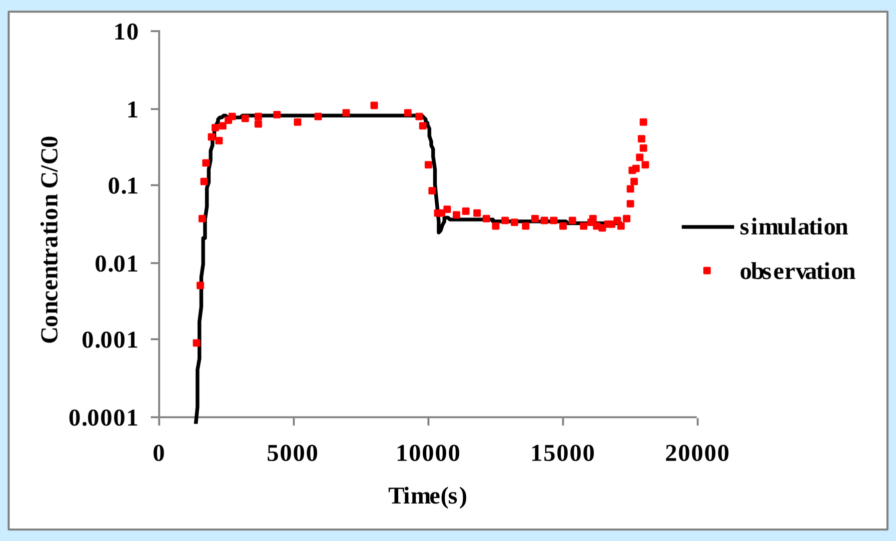
- Mobilized colloids can facilitate contaminant transport in the vadose zone and groundwater ;
- Colloids remobilization was encountered in unsaturated porous media during the processes of drainage and imbibition events;
- Previous research found that detachment of colloids under transient conditions is highly dependent on the changes in volumetric content.

## Objective

Investigate the validity of Cheng and Saiers' detachment model(2009) further by simulating experiments of Torkzaban et al.(2006).

## Description of Experiments

Virus transport experiments were conducted by Torkzaban et al.(2006). They carried out several experiments at different saturations. In some experiments, the column was allowed to be drained to residual water content in unsaturated experiments. In some others, the column was resaturated and then drained to residual water saturation. In both cases,



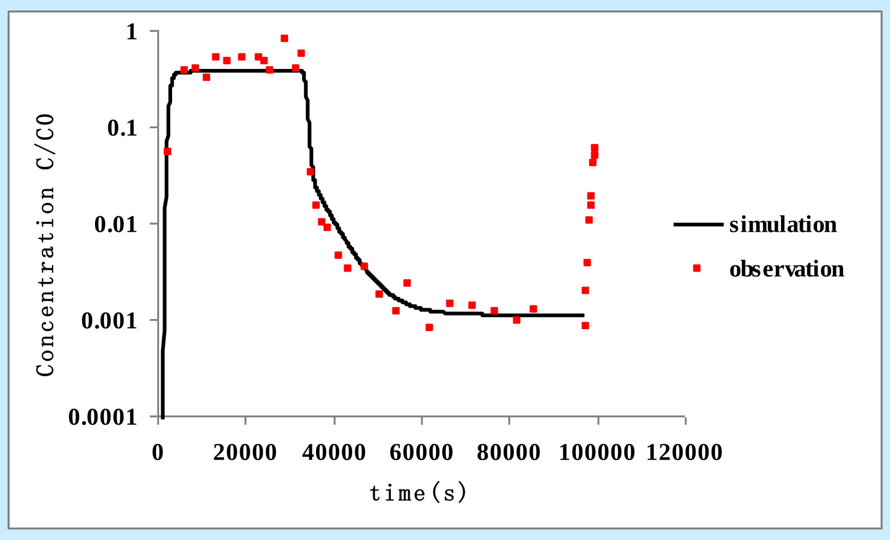




Figure 1. Colloid concentration breakthrough curves on semi-log scale. Left: saturation 100% followed by drainage; Right: saturation 50%, followed by resaturation and drainage.

a sudden increase was observed with the arrival of drying and wetting fronts. Simulation of such phenomenon can be done only if detachment process is made a function of changes in water content.

## Mathematical Model

One-dimentional colloid transport governing equation:

$$\frac{\partial \theta C}{\partial t} = \frac{\partial}{\partial x}(\theta D \frac{\partial C}{\partial x}) - \frac{\partial qC}{\partial x} - \mu_l \theta C - \gamma_s - \gamma_a$$

where $C$ [pfu L$^{-3}$] is the number concentration of colloids in water; $D$ [L$^2$T$^{-1}$] is the dispersion coefficient; $q$ is dary velocity; $\theta$[-] is water content. $\gamma_s$ and $\gamma_a$ are adsorption rates to SWI and AWI.

Colloid adsorption to the solid-water interface (SWI):

$$\frac{\partial \rho_b S}{\partial t} = \gamma_s - \mu_s \rho_b S = \theta k_{att}^{s} C - k_{\det}^{s} S - \mu_s S$$

where $S$ [pfu M$^{-1}$] is the concentration of colloids adsorbed to SWI given as the number of colloids per unit mass of soil; $\rho_b$ [ML$^{-3}$] is the soil bulk density.

Colloid adsorption to the air-water interface (AWI):

$$\frac{\partial a S_a}{\partial t} = \gamma_a - \mu_a a S_a = \theta k_{att}^{a} C - k_{\det}^{a} a S_a - \mu_a a S_a$$

where $S_a$ [pfu L$^{-3}$] is the concentration adsorbed to AWI, given as the number of colloids per unit volume of air; $a$[-] is air content which is the volume of air per unit volume of the soil; $\mu_l$ [T$^{-1}$]and $\mu_s$ [T$^{-1}$] are the inactivation rates in the water and at the solid grains respectively; $k_{att}$ [T$^{-1}$] and $k_{det}$ [T$^{-1}$] are attachment and detachment coefficients.

Cheng and Saiers' detathment model as a function of changes in water content under transient conditions:

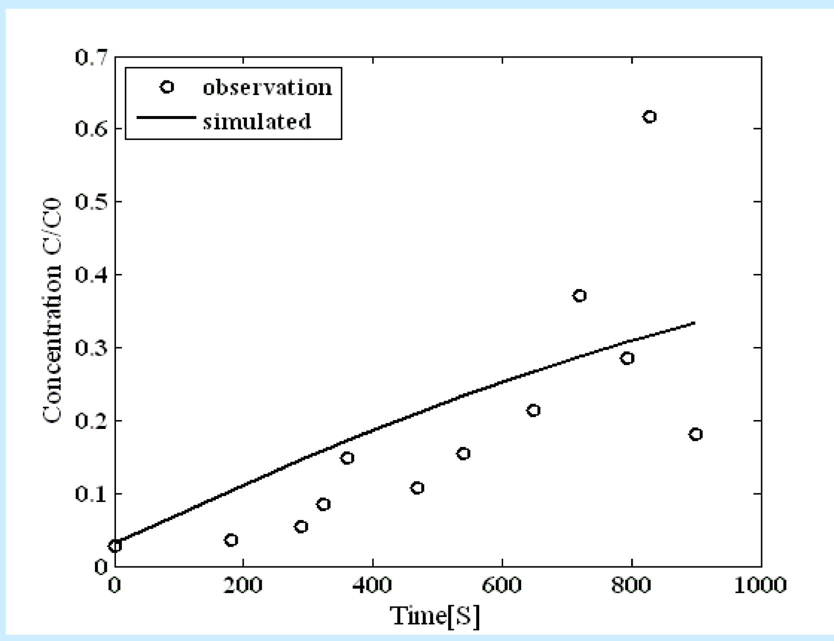
$$\frac{\partial S_i}{\partial t} = \frac{\theta}{\rho_b}\frac{1}{N_C} k_{att} C - k_{\det}^{s} S_i - \mu_s S_i - k_{\det}^{i} S_i$$

$$k_{\det}^{i} = 0 \qquad for\ h > h_{si}$$

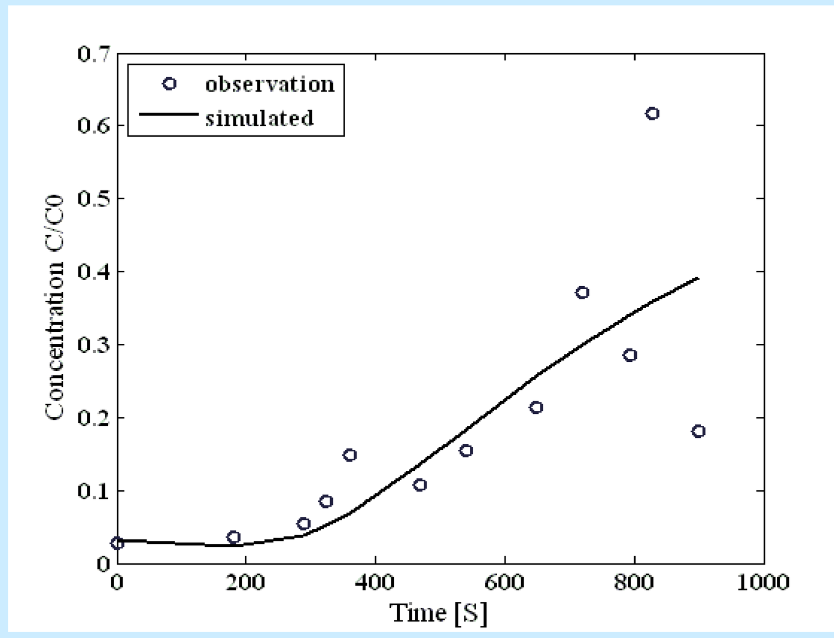
$$k_{\det}^{i} = N_d \left| \frac{\partial \theta}{\partial t} \right| \qquad for\ h \le h_{si}$$

$N_c$ is the number of compartments; $N_d$ is the empirical coefficient that quantifies colloids remobilization during drainage; $h_{si}$ is the critical entry pressure head for i compartment.

## Numerical Model Results




A

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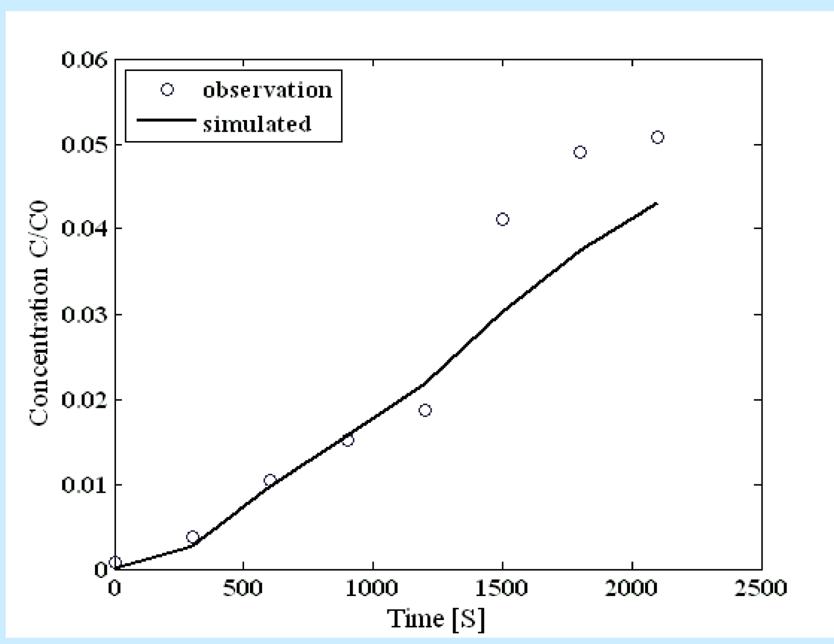


C

**A** Remobilization breakthrough with constant $k_{det}$ during drainage

**B** Remobilization breakthrough with variable $k_{det}{}^{i}$ during drainage

**C** Remobilization breakthrough with imbibition and drainage

Figure 2. Fitted and measured colloid remobilization concentration breakthrough curves during drainage and imbibition

## Conclusions

- Cheng and Saiers' model simulates drainage and imbibition column experiments, reasonably well.
- Colloid remobilization during drainage and imbibition highly depends on the changes in water content.

### Reference

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