COTRANSPORT OF VIRUSES AND CLAY PARTICLES IN UNSATURATED POROUS MEDIA

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Summary

Suspended clay particles in groundwater can play a significant role as carriers of viruses, because, depending on the physicochemical conditions, clay particles may facilitate or hinder the mobility of viruses. This experimental study examines the effects of clay colloids on the transport of viruses in variably saturated porous media. All cotransport experiments were conducted in both saturated and partially saturated columns packed with glass beads, using bacteriophage MS2 as a model virus, and kaolinite (KGa-1b) and montmorillonite (STx-1b) as model clay colloids. The various experimental collision efficiencies were determined using the classical colloid filtration theory. The experimental data indicated that the mass recovery of viruses and clay colloids decreased as the water saturation decreased. Temporal moments of the various breakthrough concentrations collected, suggested that the presence of clays significantly influenced virus transport and irreversible deposition onto glass beads. The mass recovery of viruses, based on total effluent virus concentrations, was shown to reduce in the presence of suspended clay particles. Furthermore, the transport of both suspended and attached onto suspended clay-particles viruses was retarded, compared to the conservative tracer. Under the unsaturated conditions both clay particles hindered the transport of MS2.

Materials and Methods

Bacteriophage

MS2: an F-specific single-stranded RNA phage with effective particle diameter ranging from 24 to 26 nm

For the separation of viruses adsorbed onto clay particles from suspended viruses in the liquid phase, centrifugation was used as described in Syngouna and Chrysikopoulos (2013).

Clays

Kaolinite (KGa-1b): a well-crystallized kaolin from Washington County, Georgia

Montmorillonite (STx-1b): a Ca-rich montmorillonite, white, from Gonzales County, Texas

The <2 μm clay colloidal fraction was separated by sedimentation and then was purified (Rong et al., 2008)

Electrokinetic measurements

The zeta potentials were determined to be -40.4±3.7 mV for MS2, -26.03±2.77 mV for KGa-1b, and -20.5±0.8 mV for STx-1b (Chrysikopoulos and Syngouna, 2012).

Experimental Set Up

- Plexiglass column
  Length 15.2 cm
  Internal diameter 2.6 cm
- Uniformly wet-packed

- Glass beads 2mm
- Flow rate of Q=1.5 mL/min
- pH 7.0±0.2
- Saturation level: 82-100%
- Water potential: constant

Cotransport Experiments

C_c : Suspended clay particles
$C_{Total\text{-}v}$: Total viruses
C_v: Suspended viruses
C_{vc}: Viruses attached onto C_c
C_{c^*} : Clays attached onto glass beads (SWI)
C_{v^*} : Viruses attached onto glass beads
C_{vc^*}: Viruses attached onto C_c*
$C_{v^\Diamond}$: Viruses captured in air-water interface (AWI)
$C_{c^\Diamond}$: Clay colloids captured in AWI
$C_{vc^\Diamond}$: Viruses attached onto $C_c^\Diamond$

In the column effluent:

$$C_{Total\text{-}v} = C_v + C_{vc}$$

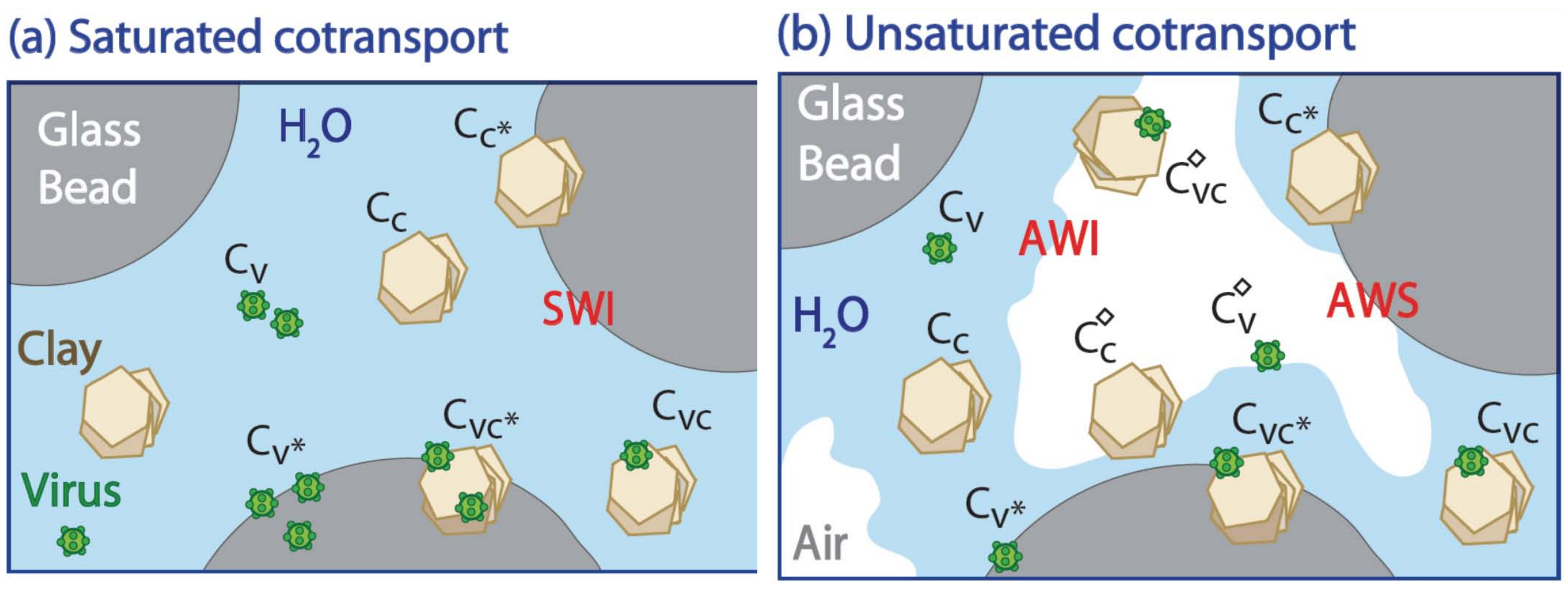
Colloid Filtration Theory

Experimental attachment efficiency (Kretzschmar et al., 1999):

$$\alpha_{exp} = -\frac{2}{3}\frac{d_c}{L(1-\theta_m)\eta_0}\ln\left[\frac{C_{ss}}{C_0}\right]$$

where:

- θ_m [-] is the moisture content
- d_c [L] is the mean collector diameter
- C_0 [M/L^3] is the influent colloid concentration
- C_{ss} [M/L^3] is the effluent colloid concentration (steady state conditions)
- η_o is the single-collector contact efficiency (Tufenkjii and Elimelech, 2004)



Results and discussion

Transport experiments

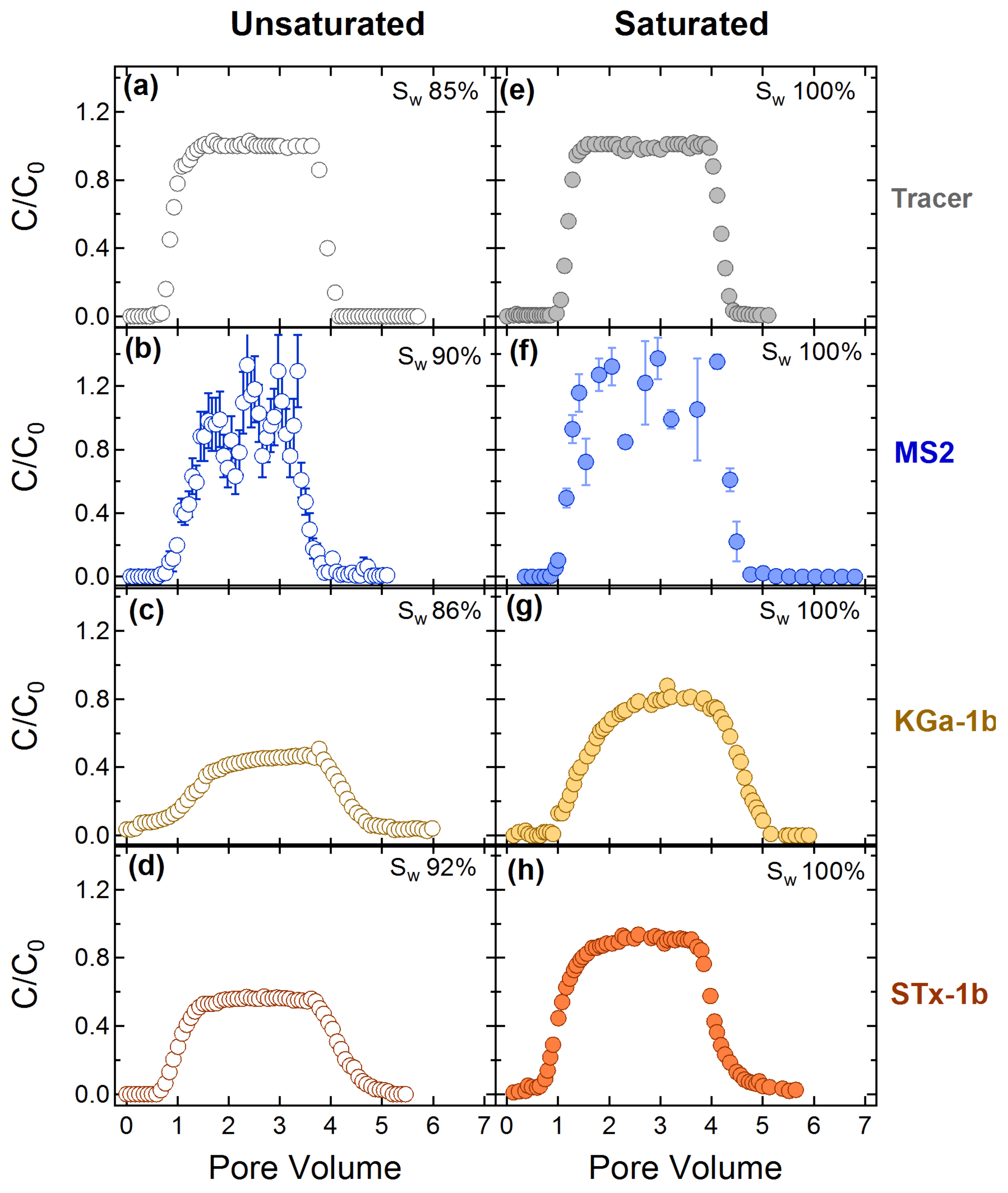


Figure 1. Experimental data of tracer, MS2 virus and clays (KGa-1b, STx-1b) breakthrough in unsaturated (a,b,c,d) and saturated (e,f,g,h,) columns packed with glass beads.

Cotransport experiments

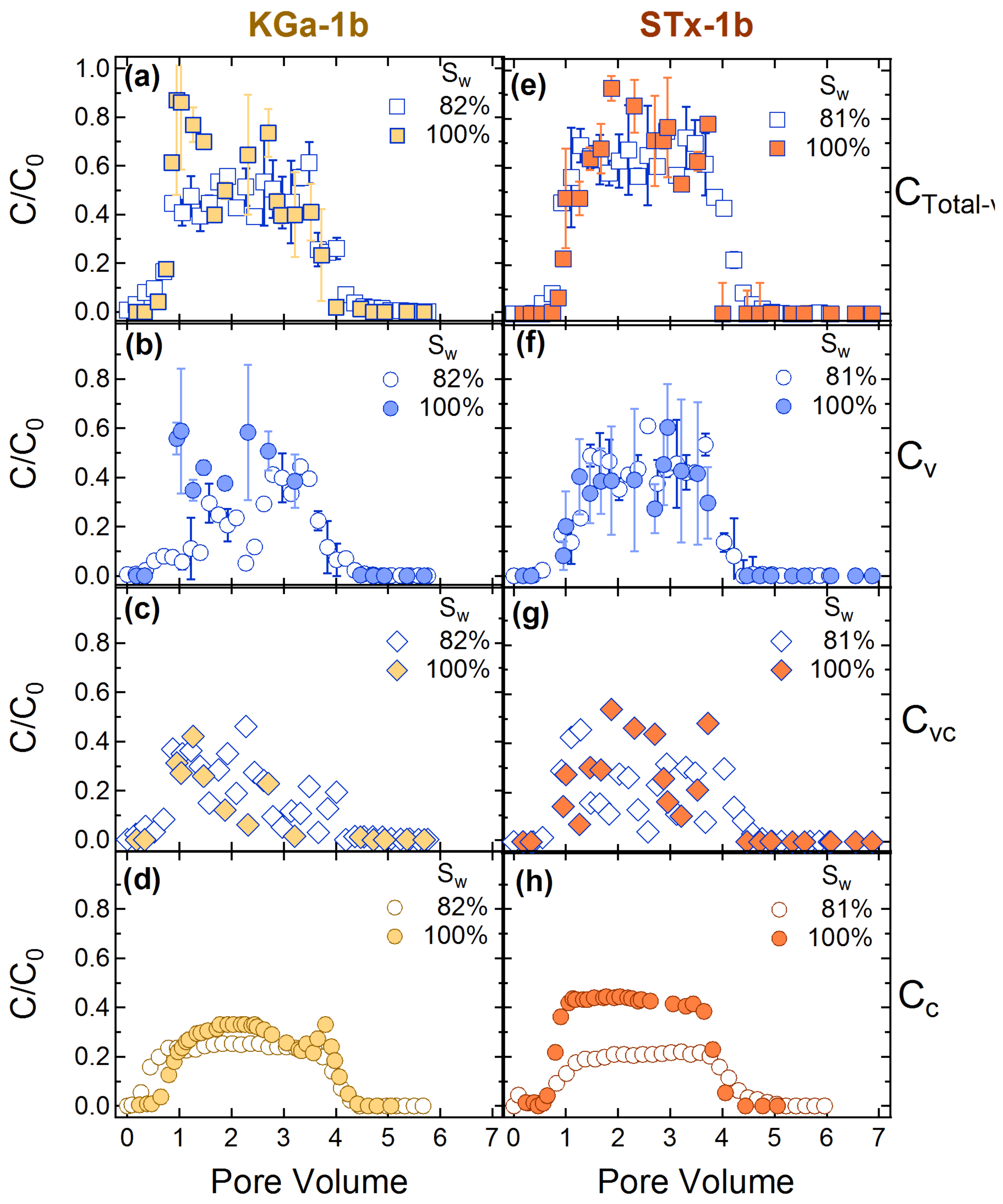


Figure 2. Experimental data for the cotransport of (a,b,c,d) MS2-KGa-1b and (e,f,g,h) MS2-STx-1b in both saturated (filled symbols) and unsaturated (open symbols) columns packed with glass beads.

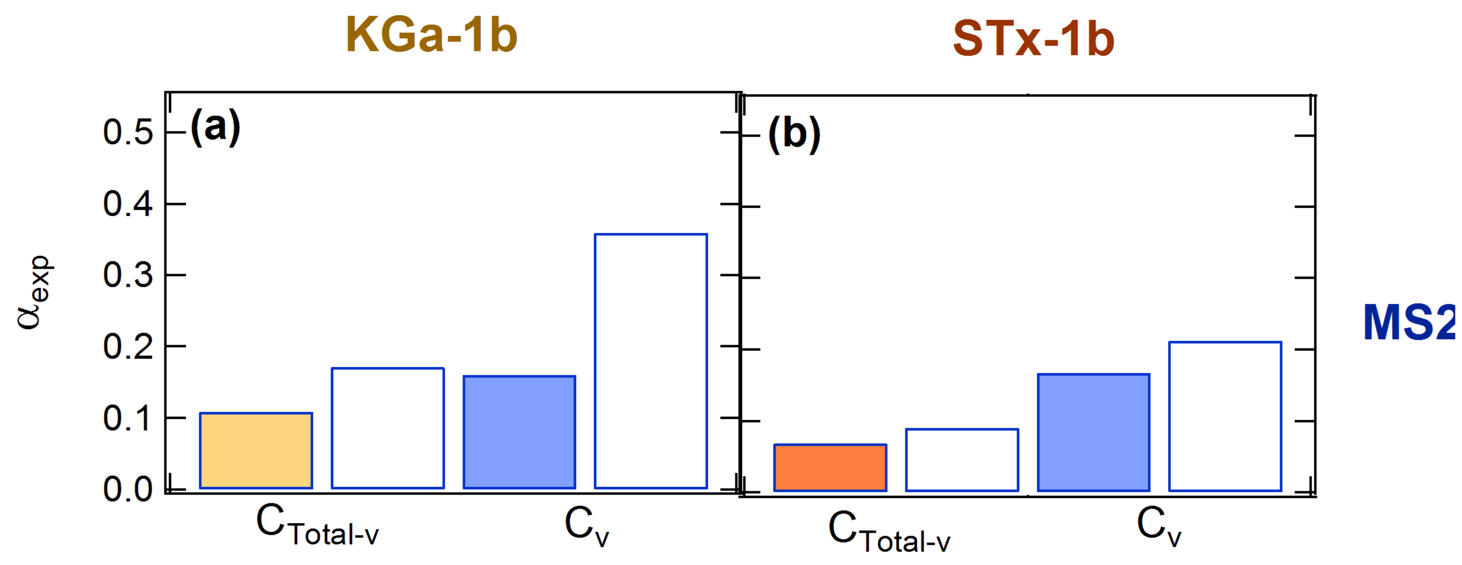


Figure 3. Experimental collision efficiencies $\alpha_{Total-v}$, based on $C_{Total-v}$ and α_v, based on C_v in the effluent in both saturated (filled columns) and unsaturated (open columns) conditions for: (a) MS2 with KGa-1b and (b) MS2 with STx-1b cotransport experiments.

References

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Conclusions

- The mass recovery of viruses and clay colloids decreased as the water saturation decreased.
- The mass recovery of both viruses was shown to reduce in the presence of suspended clay particles.
- Under saturated conditions, the transport of both $C_{Total\text{-}v}$ and C_v was retarded, compared to the conservative tracer while under unsaturated conditions the opposite was observed.
- Under unsaturated conditions both clay particles hindered the transport of both viruses.
- In the presence of STx-1b, the C_{vc}=$C_{Total\text{-}v}$-C_v values of both viruses were higher than those in the presence of KGa-1b under both saturated and unsaturated conditions.
- In the presence of both KGa-1b and STx-1b, $\alpha_{Total-v}$ and α_v values increased with decreasing saturation level.

This research has been co-financed by the European Union (European Social Fund-ESF) and Greek National Funds through the Operational program "Education and Lifelong Learning" under the action Aristeia I (Code No. 1185). This work is a collaboration between members of the BioMet Network.