Clay colloids and viruses cotransport through vertically oriented porous media

ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΑΤΡΩΝ UNIVERSITY OF PATRAS

Technical University of Crete

COLL2015_0683-P255

Vasiliki I. Syngouna[1], and Constantinos V. Chrysikopoulos[2]

[1]Environmental Engineering Laboratory, Civil Engineering Department, University of Patras, 26500 Patras, Greece
[2]School of Environmental Engineering, Technical University of Crete, 73100 Chania, Greece

Introduction

Previous experimental observations have shown that flow direction can significantly influence colloid deposition (Chrysikopoulos and Syngouna, 2014). However, the effect of flow direction on the cotransport of clay colloids and viruses has not been previously explored. The present study examined the effect of flow direction on the cotransport of clay colloids and viruses in vertical water-saturated columns packed with glass beads. A steady flow rate was applied in both vertical upward (VU) and vertical downward (VD) directions. Bench scale experiments were performed to investigate the interactions between viruses and clays during their simultaneous transport (cotransport) in porous media. Also the synergistic effects of suspended clay colloids and flow direction on the attenuation and transport of viruses in porous media was examined.

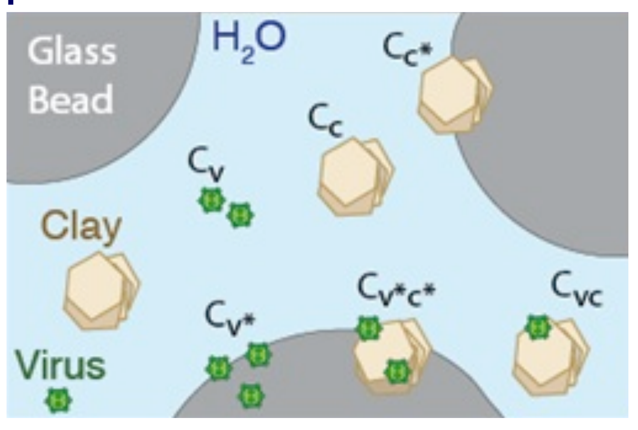


Figure 1. Schematic illustration of the various concentrations employed in the cotransport experimental study.

Notation

- C_c : suspended clay particles
- $C_{Total\text{-}v}$: total virus concentration
- C_v: suspended viruses
- C_{vc}: viruses attached onto C_c
- C_{c^*} : clays attached onto glass beads
- C_{v^*} : viruses attached onto glass beads
- $C_{v^*c^*}$: viruses attached onto Cc*
- C_{v0} : influent (initial) virus concentration
- C_{c0} : influent (initial) clay concentration

Materials and Methods

Bacteriophages

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

ΦX174: a somatic single-stranded DNA phage with effective particle diameter ranging from 25 to 27 nm

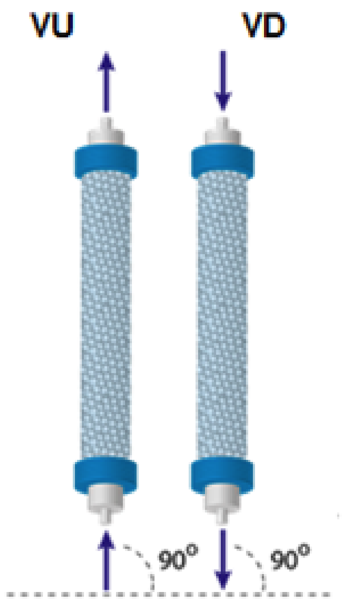
Clays

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)

Experimental Set Up

- Glass column
  - Length 30 cm
  - Internal diameter 2.5 cm
- Glass beads
- Flow rate of Q=1.5 mL/min
- pH=7.0±0.2
- vertical upward (VU) and downward (VD) flow directions



Analysis of Experimental Data

⊙ Collision efficiency, α [-]
(Rajagopalan and Tien, 1976)

$$\alpha = -\frac{2d_c \ln(RB)}{3(1-\theta)\eta_0 L} \qquad RB = \frac{M_{r(i)}}{M_{r(t)}}$$

⊙ Mass recovery of $C_{Total-v}$, C_v, M_r [-]

$$M_r(L) = \frac{\int_0^\infty C_i(L,t)dt}{\int_0^{t_p} C_i(0,t)dt}$$

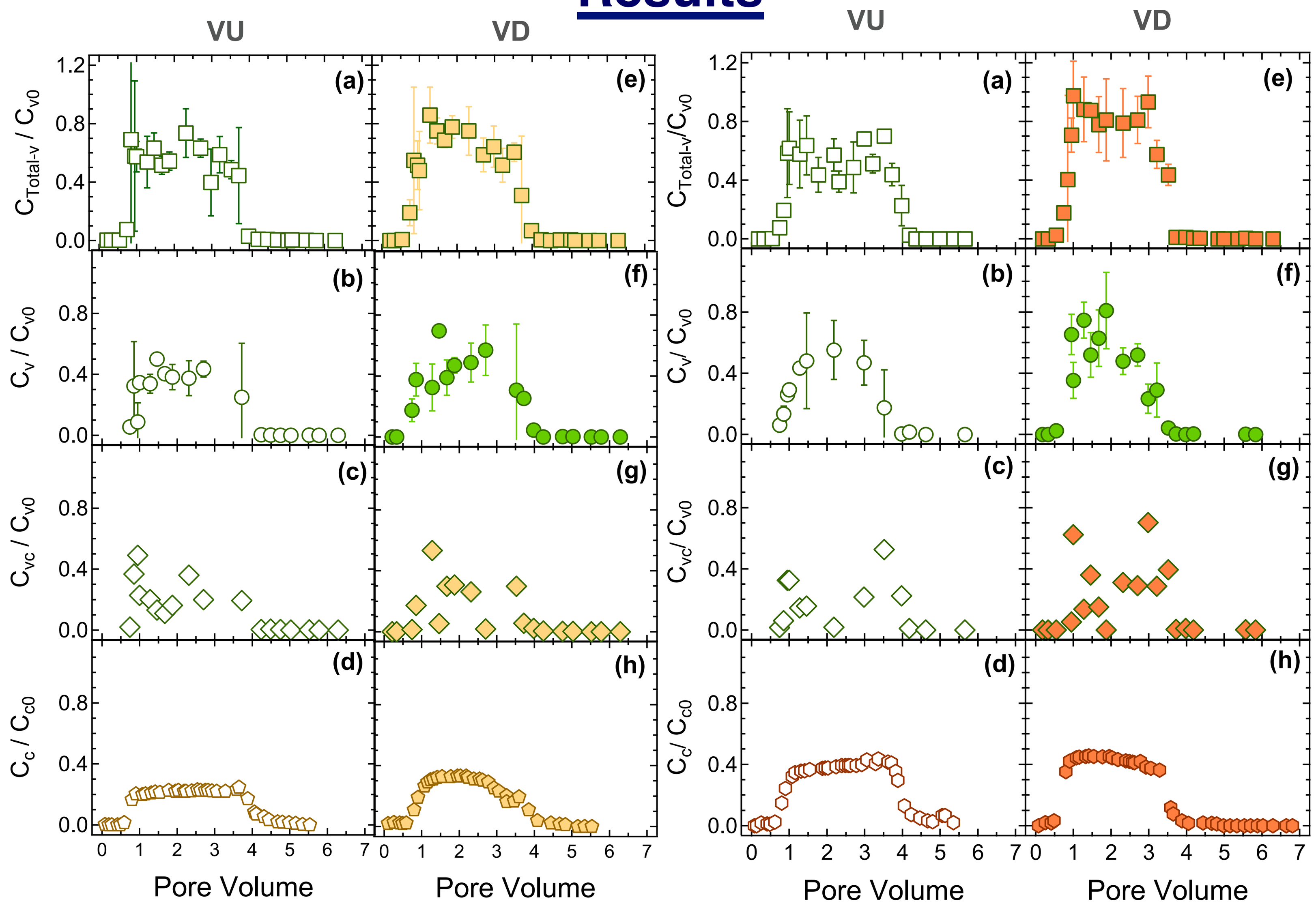
⊙ Produced mass of C_{vc}, M_p [-]
(Syngouna and Chrysikopoulos, 2015)

$$C_{vc} = C_{Total-v} - C_v$$

⊙ First normalized temporal moment
(James and Chrysikopoulos, 2011)

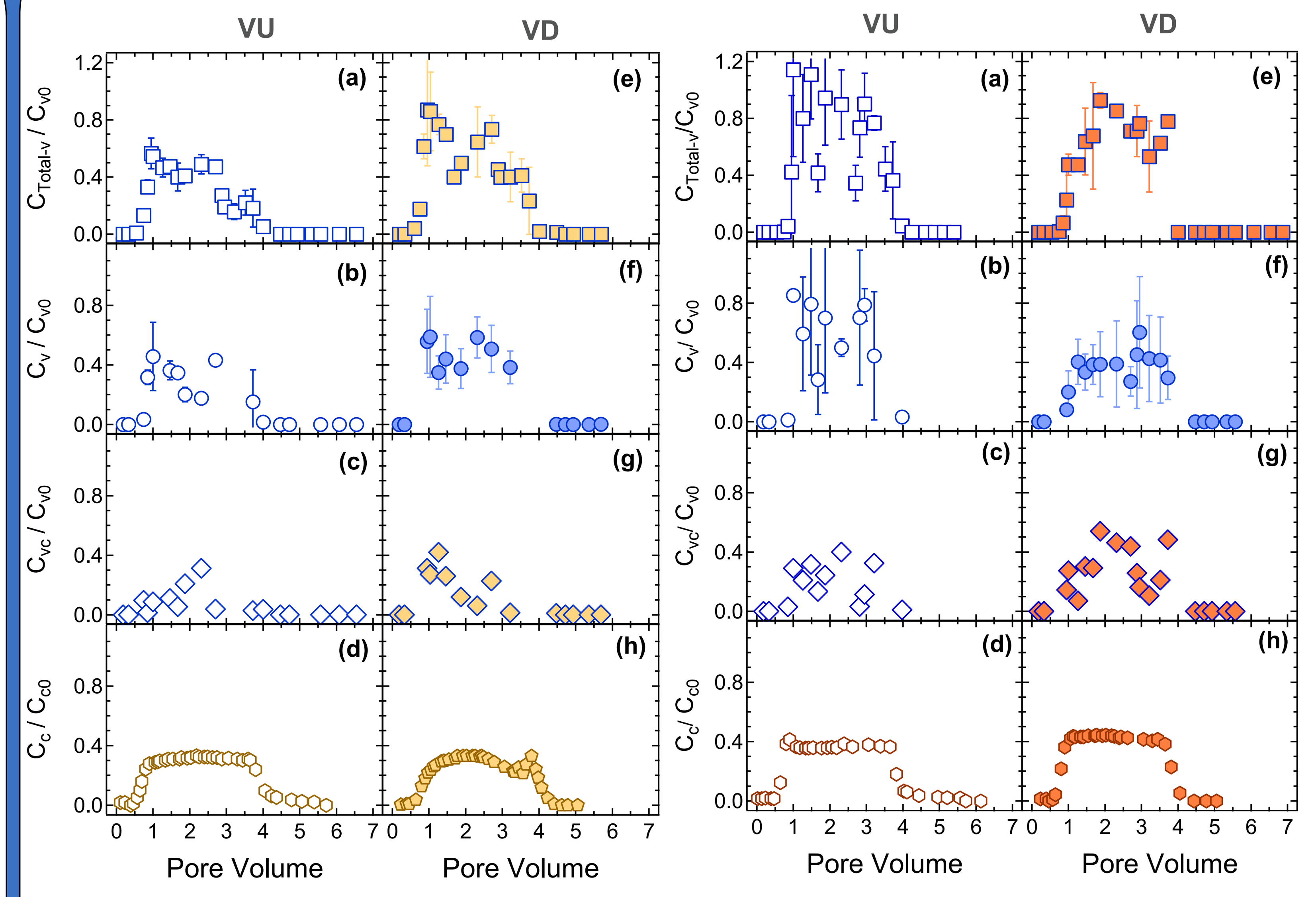
$$M_1(x) = \frac{\int_0^\infty tC_i(x,t)dt}{\int_0^\infty C_i(x,t)dt}$$

Results



Figures 2-3. Experimental data of $C_{Total-v}$ (squares), C_v (circles), C_{vc} (diamonds), and C_c (pentagons) for the ΦX174-KGa-1b cotransport (left) and ΦX174-STx-1b cotransport (right) experiments with: (a–d) vertical up (open symbols), and (e–h) vertical down (filled symbols) flow directions.

Results



Figures 4-5. Experimental data of $C_{Total-v}$ (squares), C_v (circles), C_{vc} (diamonds), and C_c (pentagons) for the MS2-KGa-1b cotransport (left) and MS2-STx-1b cotransport (right) experiments with: (a–d) vertical up (open symbols), and (e–h) vertical down (filled symbols) flow directions.

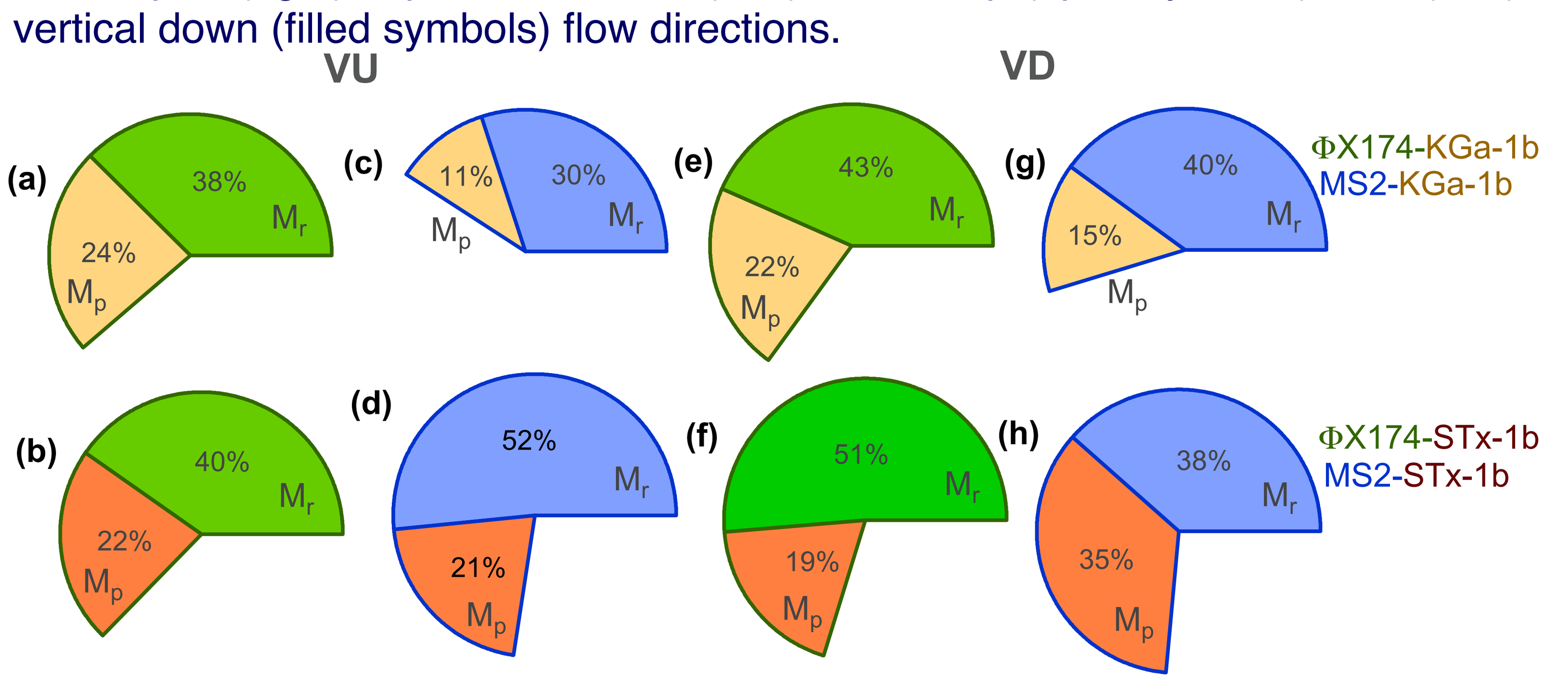


Figure 6. Calculated M_r values based on C_v and M_p values based on C_{vc} for cotransport of: (a,e) ΦX174 with KGa-1b, (b,f) ΦX174 with STx-1b, (c,g) MS2 with KGa-1b, and (d,h) MS2 with STx-1b under (a–d) vertical upward, and (e–h) vertical downward flow directions.

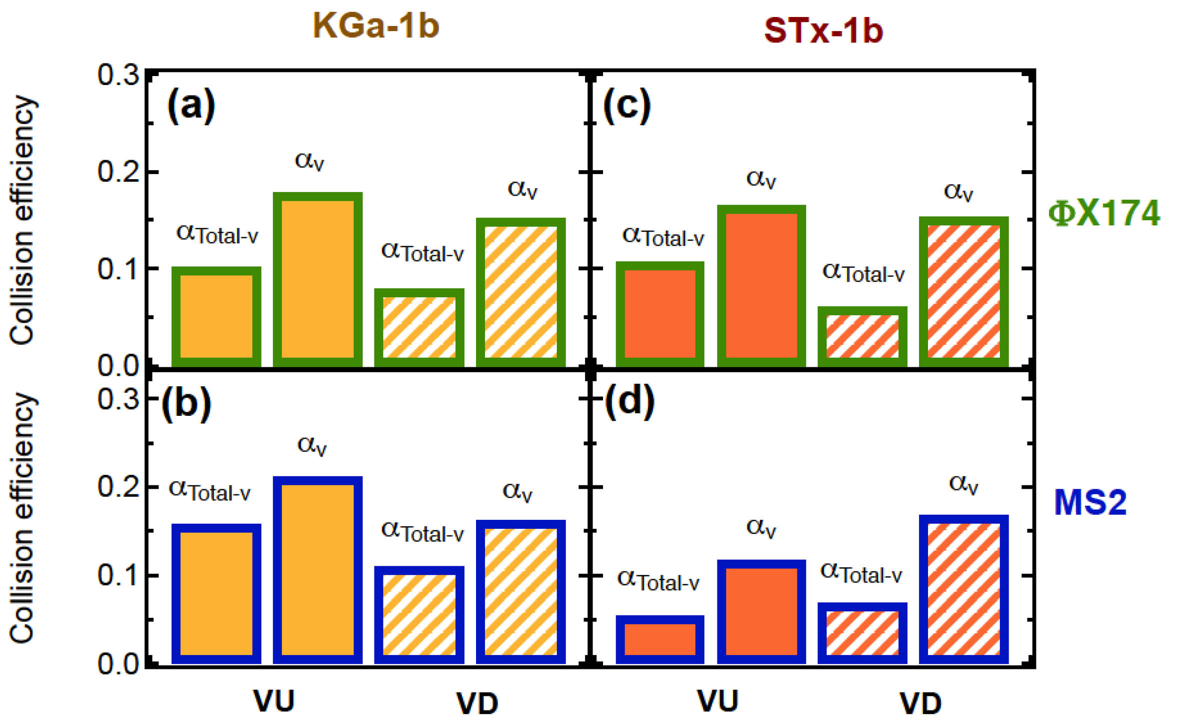


Figure 7. Calculated collision efficiency values, $\alpha_{Total-v}$, based on $C_{Total-v}$, and α_v based on, C_v, for cotransport experiments: (a) ΦX174 with KGa-1b, (b) MS2 with KGa-1b, (c) ΦX174 with STx-1b, and (d) MS2 with STx-1b under vertical upward (solid bars) and vertical downward (partially shaded bars) flow directions.

Conclusions

- ⊙ In the presence of KGa-1b, at VD flows, clay colloids hindered the transport of ΦX174.
- ⊙ In the presence of STx-1b, for both flow directions examined (VU, VD), the presence of clay colloids facilitated the transport of ΦX174.
- ⊙ In the presence of either of the two clays (KGa-1b, STx-1b) for both flow directions examined (VU, VD), the transport of MS2 was facilitated, except for the case of VD flow direction in the presence of KGa-1b.
- ⊙ In the presence of KGa-1b, the M_p values based on C_{vc} of MS2 were lower than those in the presence of STx-1b under both flow directions.
- ⊙ Similar M_p values based on C_{vc} of ΦX174 were observed in the presence of either of the clays under both flow directions examined.
- ⊙ In the presence of both KGa-1b and STx-1b, $\alpha_{Total-v}$ values were higher in VU than VD flows with the only exception of MS2 and STx-1b cotransport.
- ⊙ The calculated α_v indicated that the presence of KGa-1b increased the attachment of virus onto glass beads and clay colloids more than STx-1b.

References

1. Chrysikopoulos, C.V., Syngouna, V.I., 2014. *Environmental Science and Technology* 48, 6805-6813.
2. Rong, X., Huanga, Q., He, X., Chen, H., Cai, P., Liang, W., 2008. *Colloids and Surfaces B: Biointerfaces* 64 (1), 49–55.
3. Rajagopalan, R., Tien, C., 1976. *AIChE Journal* 22 (3), 523-533.
4. James, S.C., Chrysikopoulos, C.V., 2011. *Advances in Water Resources* 34(10),1249-1255.
5. Syngouna, V.I., Chrysikopoulos, C.V., 2015. *Journal of Colloid and Interface Science* 440, 140-150.

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.