

Transport of *Cryptosporidium parvum* Oocysts in Saturated Porous Media

Joseph Ryan, Yumiko Abe, and Rula Abu-Dalo

University of Colorado at Boulder

Ronald Harvey and David Metge

U.S. Geological Survey

Menachem Elimelech, Garrett Miller, and Zachary Kuznar

Yale University

Outline

- Motivation for this research
- Characterization of *Cryptosporidium parvum* oocysts
- Effect of heterogeneity on oocyst transport in an intermediate-scale aquifer tank
- Effect of ionic strength and secondary minimum on oocyst deposition
- Comparison of oocyst and microsphere transport
- Importance of straining on oocyst transport

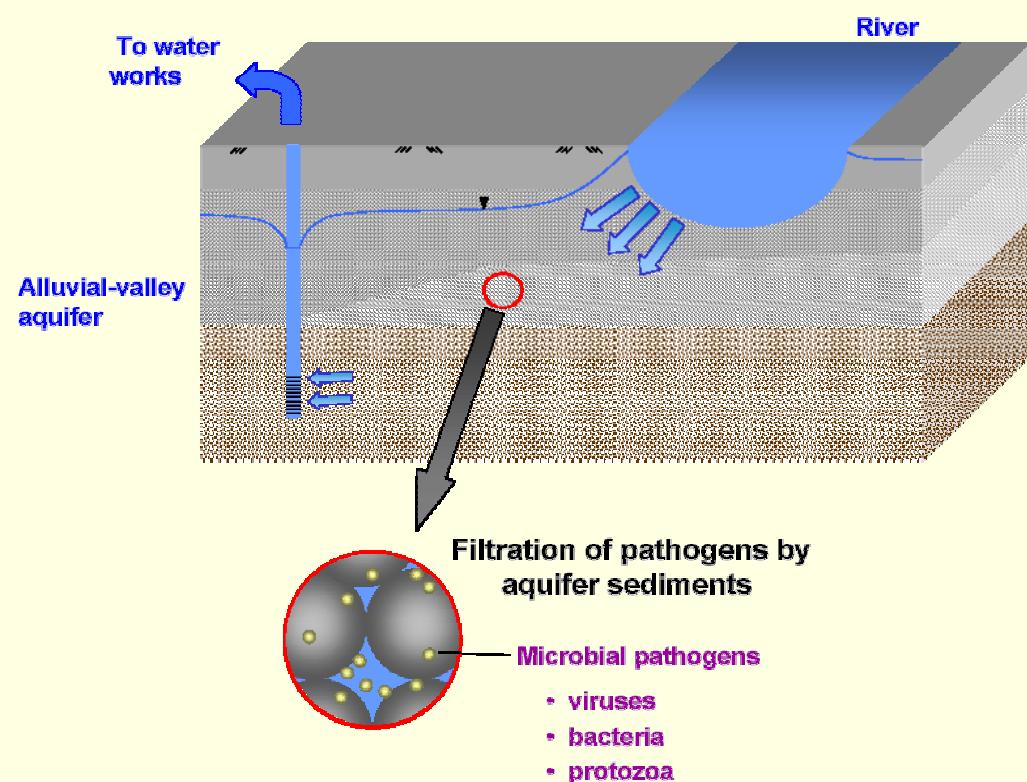
Riverbank Filtration

Motivation

alluvial sediments

- grain size variability
- surface charge variability
- solution chemistry variability

Tufenkji et al., ES&T, 2002



Cryptosporidium parvum Oocysts

- Source

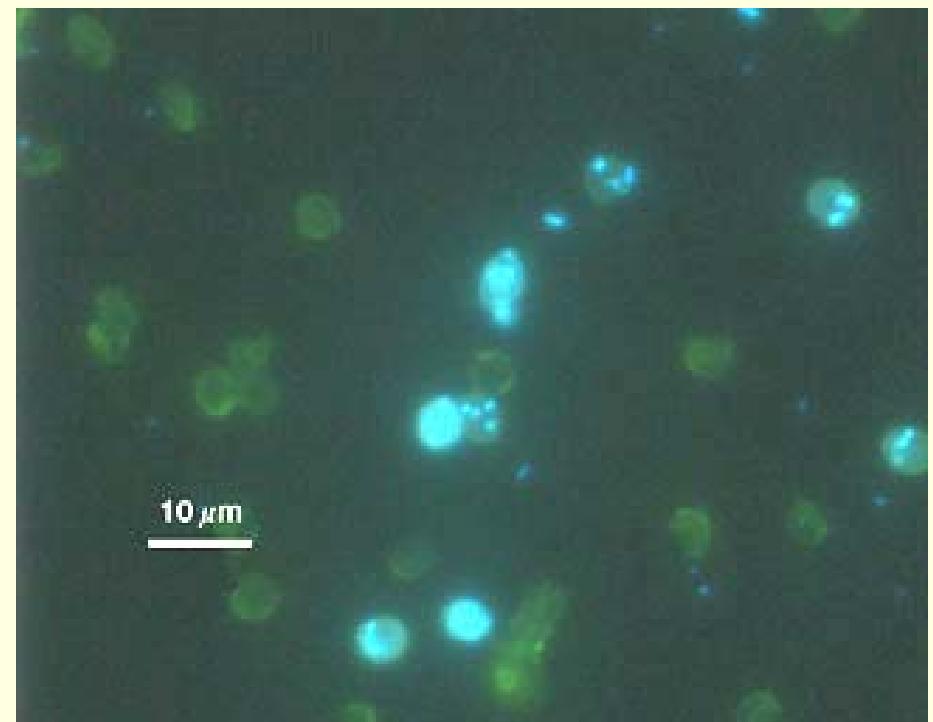
- University of Arizona,
Sterling Parasitology
Laboratory

- Preparation

- live, heat-treated, and
formalin-inactivated

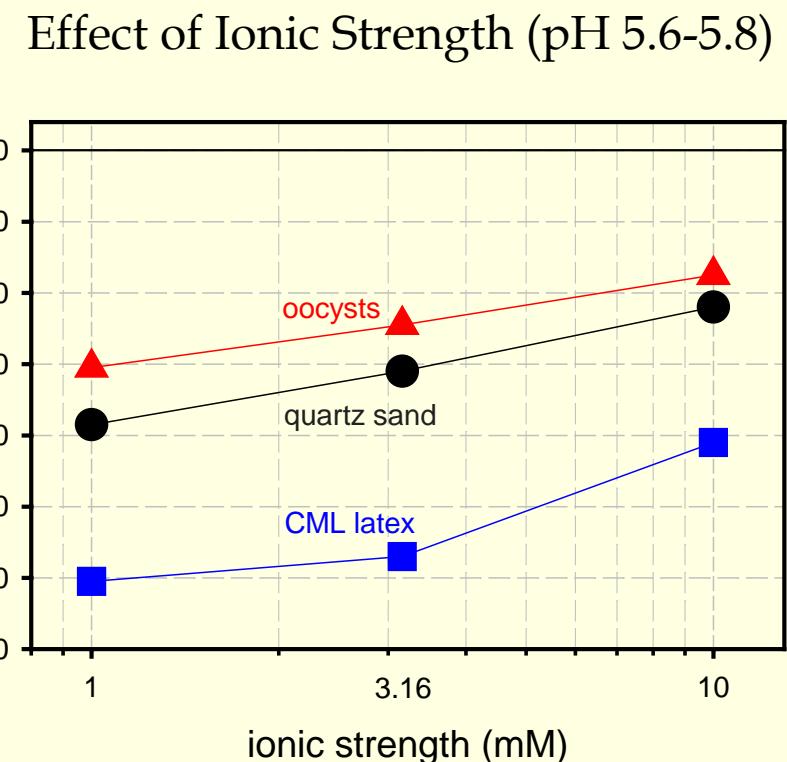
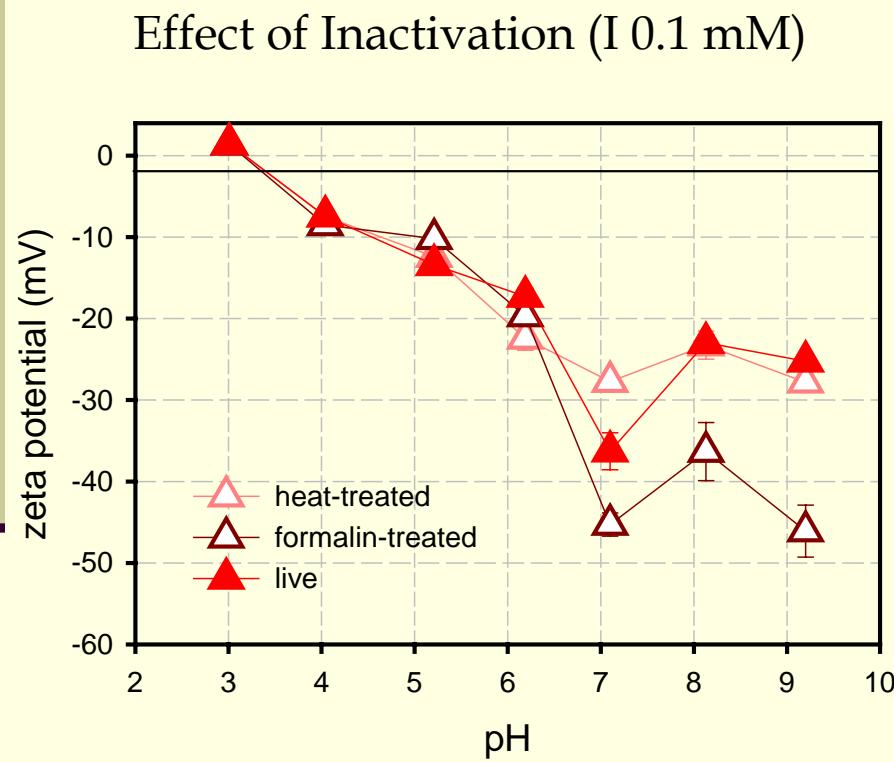
- Detection

- DAPI stain
 - epifluorescence
microscopy
 - flow cytometry



Cryptosporidium parvum Oocysts

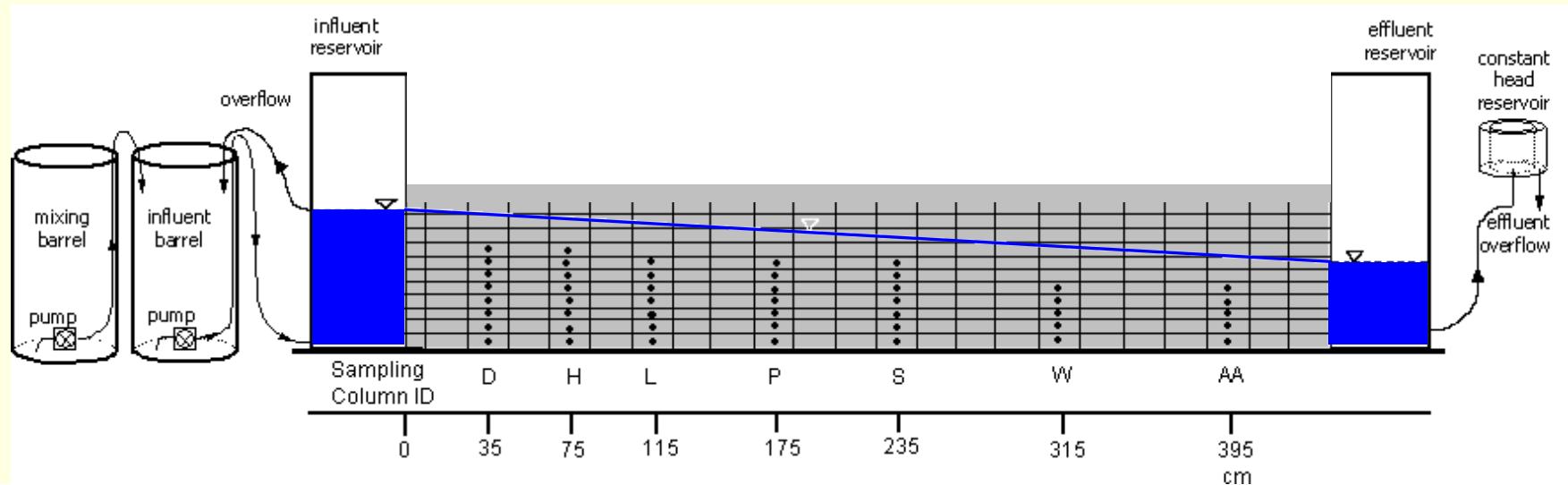
Zeta potential



Aquifer Tank Experiment

Tank Setup

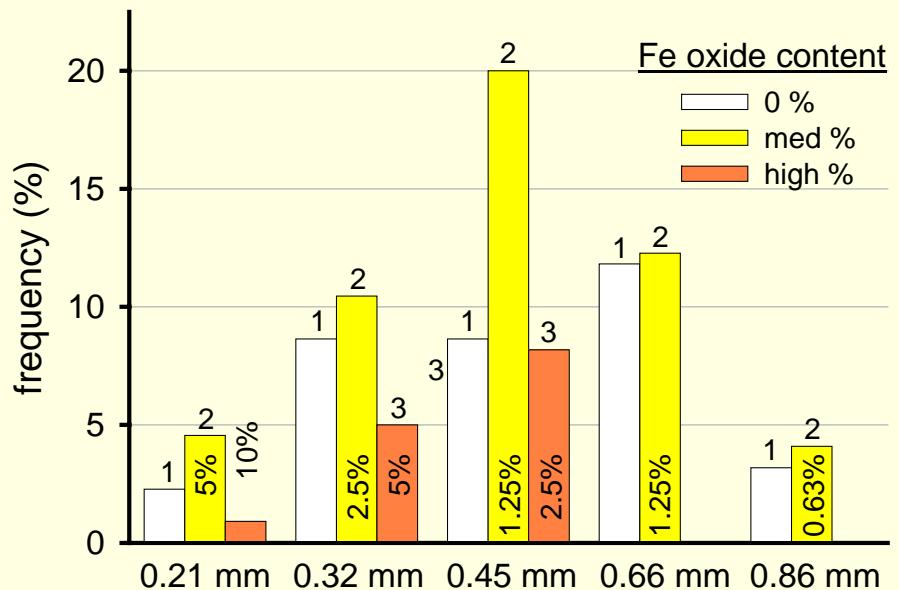
- 4.15 m length \times (50-30) cm height \times 10 cm width
- head difference 20.0 cm, velocity: 10.0 m d^{-1}
- injection
 - oocysts (formalin)
 - microspheres (4.6 μm , sulfate, fluorescent)
 - pH 5.8-6.0, 10^{-4} M NaCl
 - tracer (sodium nitrate, 10^{-4} M , UV detection)



Aquifer Tank Experiment

Tank Packing

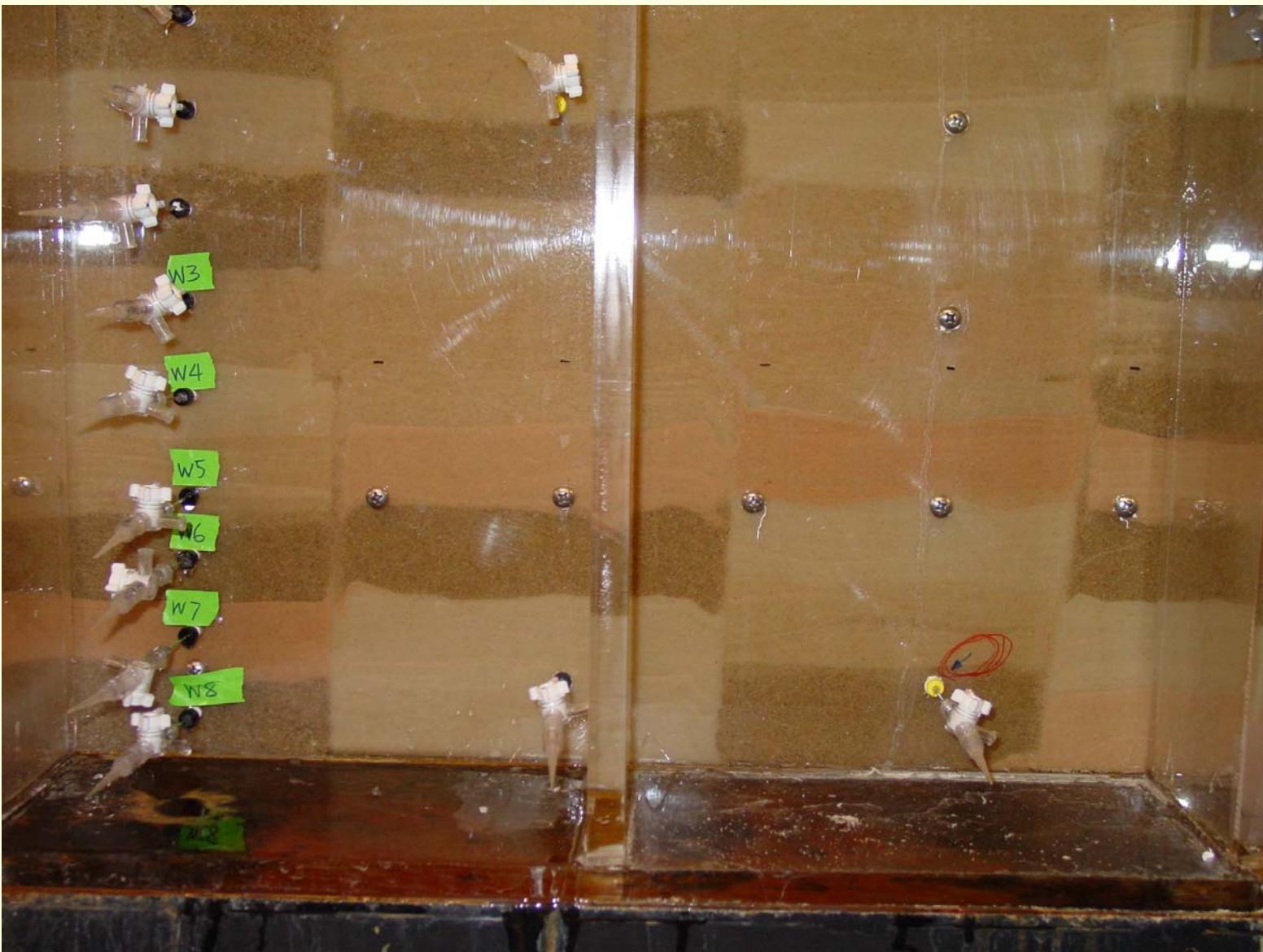
- 5×20 cm blocks
- grain size
- ferric oxyhydroxide coating



D			H			L			P			S			W			AA		
1	2	2	3	2	1	2	1	1	1	2	3	3	1	1	1	2	2	3	2	1
1	2	2	3	2	2	1	2	1	2	1	3	1	3	2	2	2	2	2	2	
1	2	2	1	2	2	2	1	1	1	1	2	1	1	1	1	2	2	1	1	
1	2	1	2	3	1	1	3	2	3	1	2	1	1	1	1	2	1	2	3	
1	2	1	2	1	3	1	1	1	1	1	2	2	1	2	2	1	1	1	2	
1	2	2	3	1	2	2	3	3	2	1	2	1	3	2	2	3	3	2	1	
1	2	2	3	1	2	2	3	3	2	1	2	1	3	2	2	3	3	2	1	
1	2	2	2	2	2	3	1	1	2	3	2	1	2	1	1	1	2	2	1	
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1	2	1	1	3	2	2	2	1	2	2	2	2	1	2	2	1	1	1	3	
1	2	3	2	3	2	3	2	2	2	1	1	2	1	3	1	2	1	2	3	
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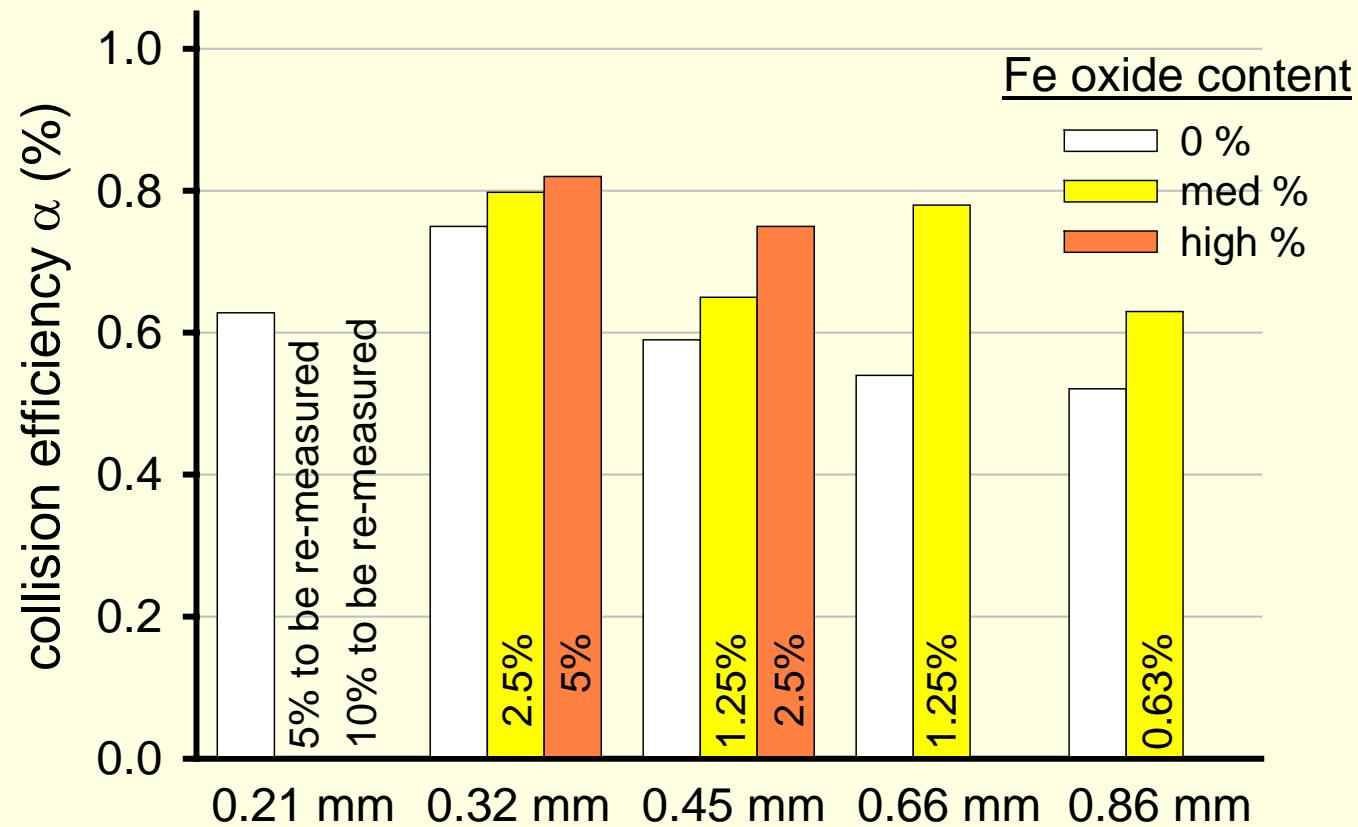
Legend: 0.86 mm grain (blue), 0.66 mm grain (green), 0.45 mm sand (orange), 0.32 mm sand (pink), 0.21 mm sand (yellow)

Aquifer Tank Experiment



Aquifer Tank Experiment

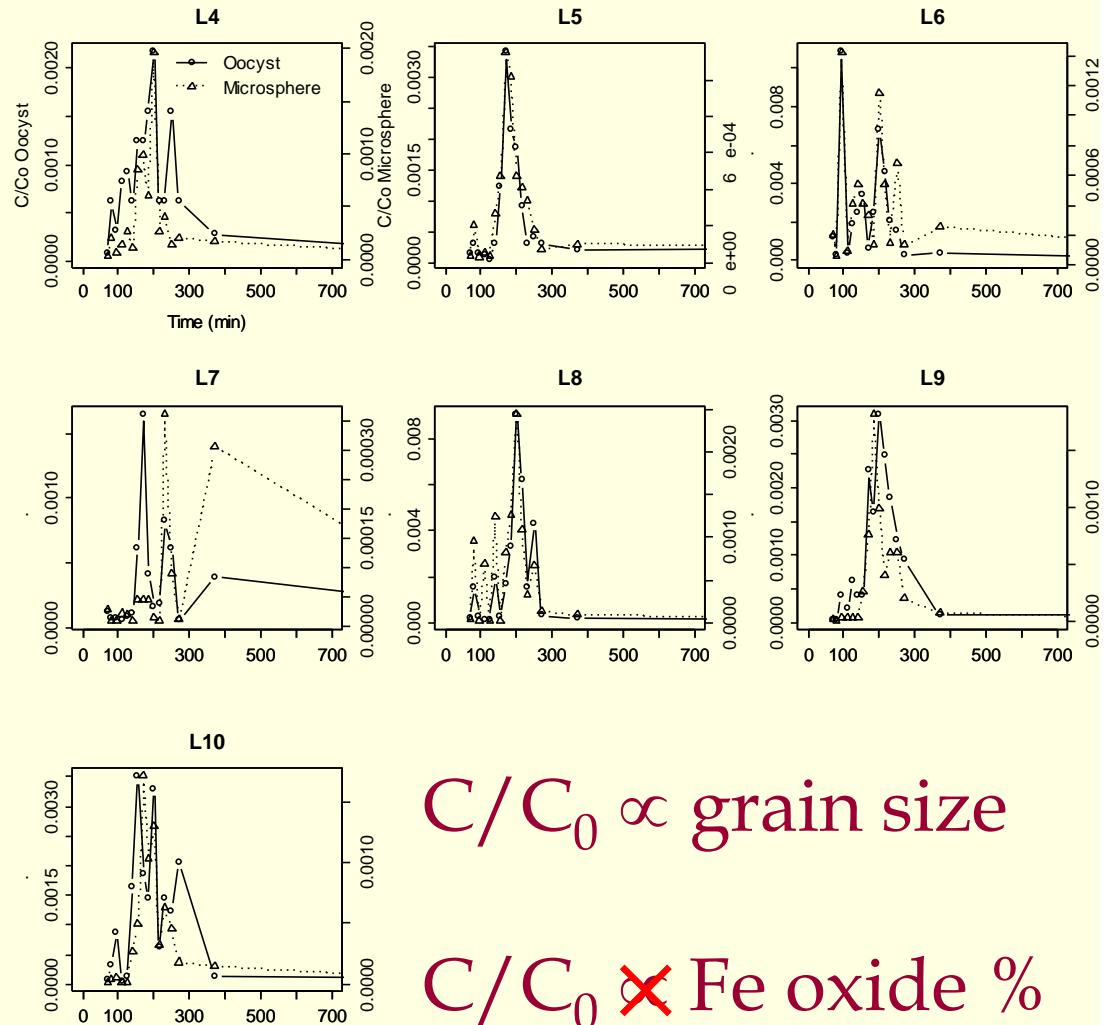
- Deposition in column experiments
 - oocysts, formalin inactivated



Aquifer Tank Experiment

■ Breakthroughs in Tank

- oocysts
 - flow cytometry
 - epifluorescence microscopy
- microspheres
 - fluorimetry

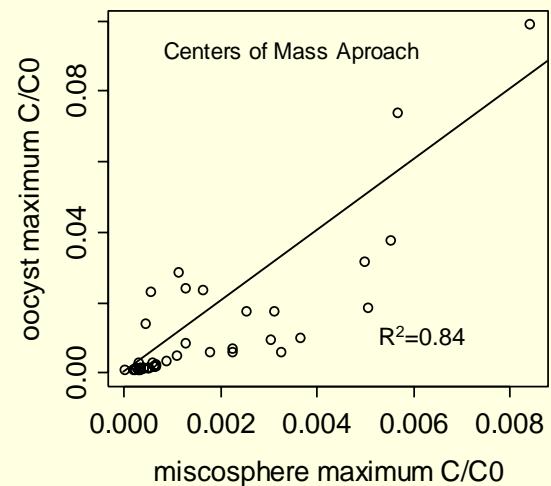
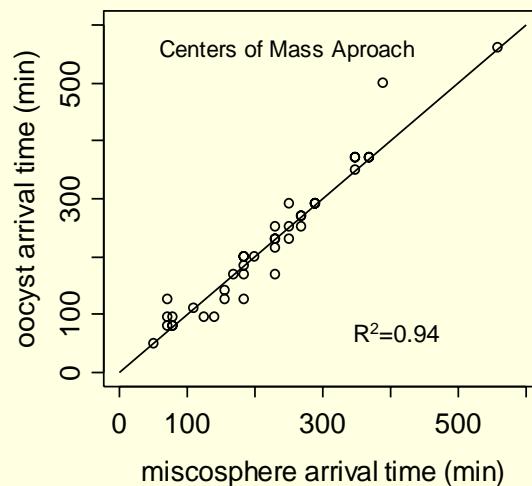
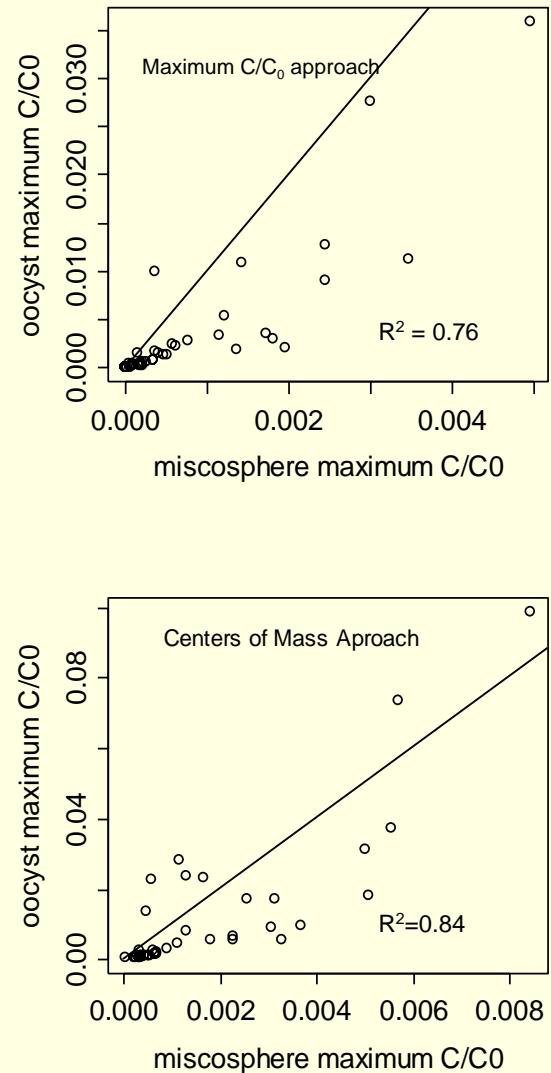
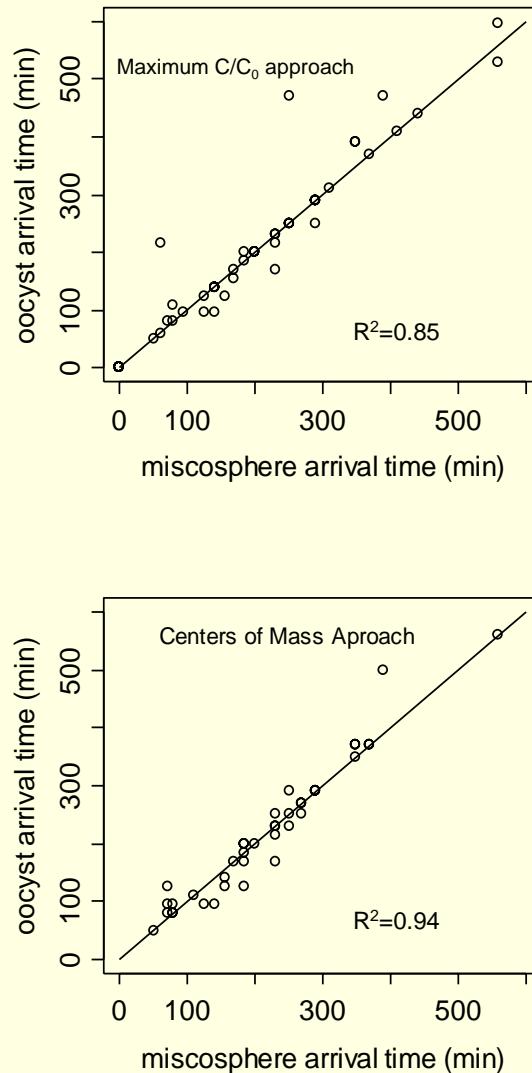


$C/C_0 \propto$ grain size

$C/C_0 \times$ Fe oxide %

Aquifer Tank Experiment

- Surrogate?
 - microspheres arrive at same time
 - microspheres attenuated more rapidly
 - confirming results in columns



Column Experiments

■ Injection

■ oocysts

- heat-treated

■ microspheres

- $4.1 \mu\text{m}$

- carboxyl-modified

- fluorescent

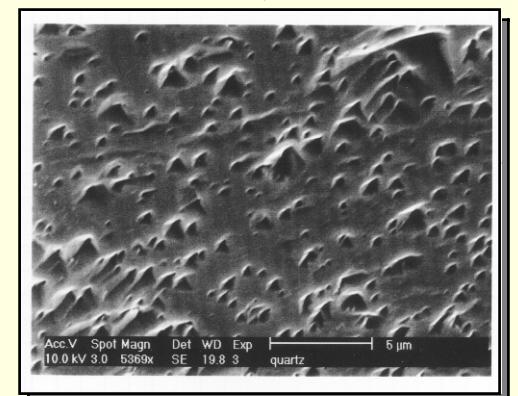
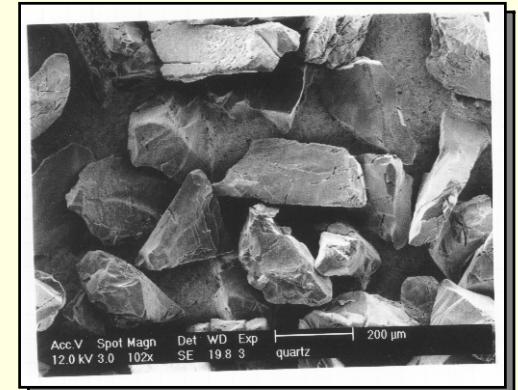
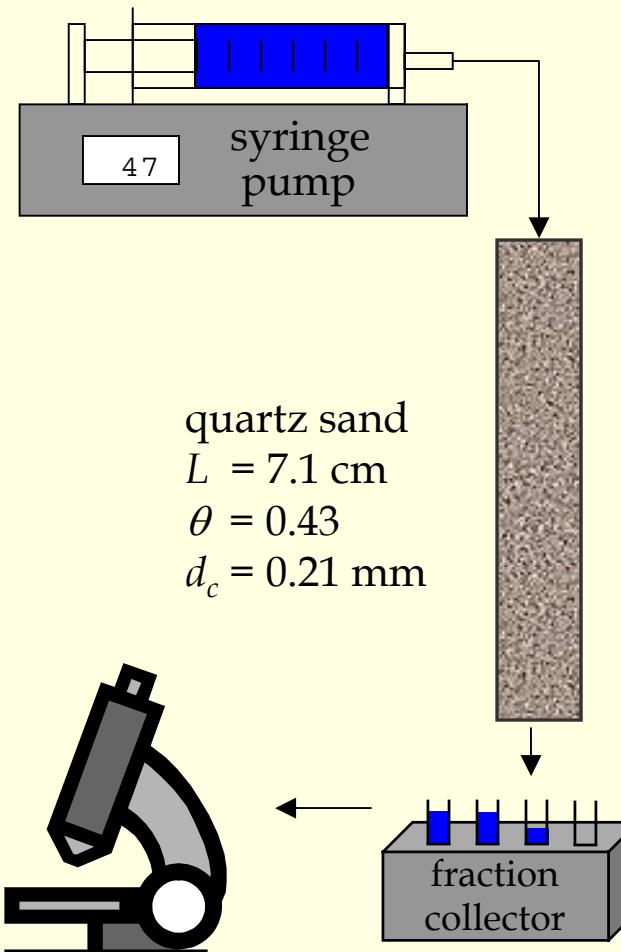
■ solution

- pH 5.6-5.8

- I varied

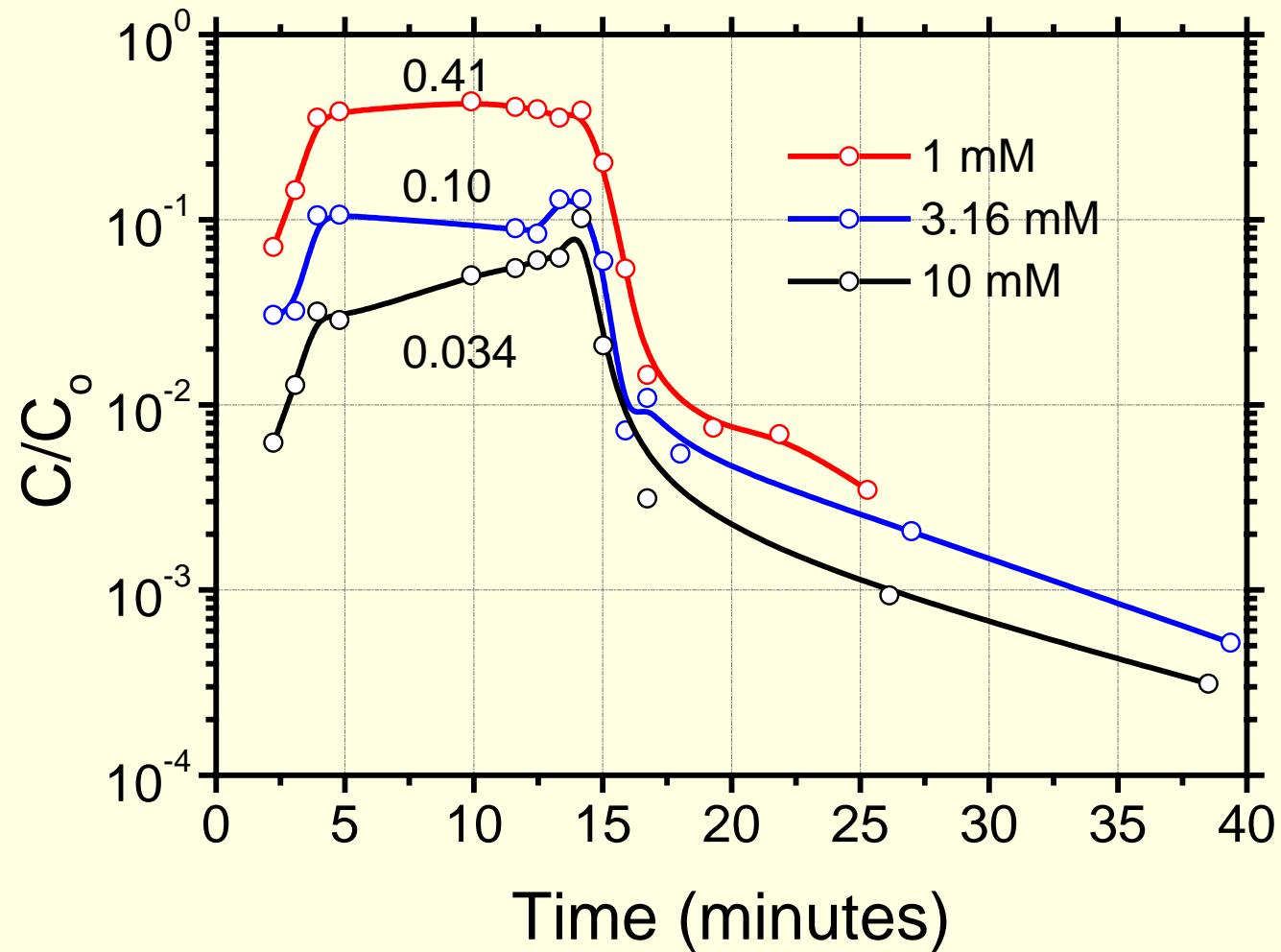
■ flow rate

- 2 mL min^{-1}



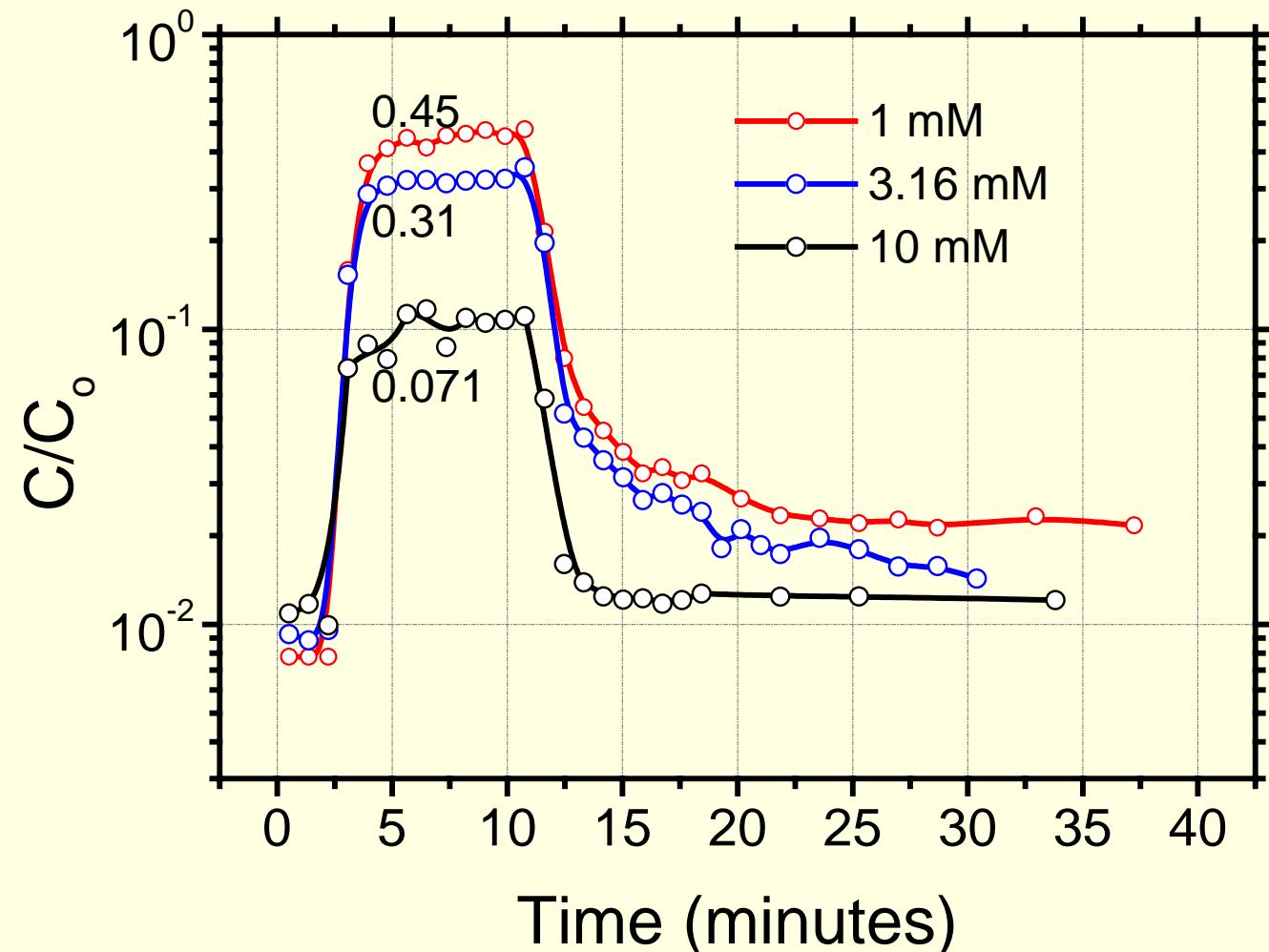
Column Experiments

Oocysts



Column Experiments

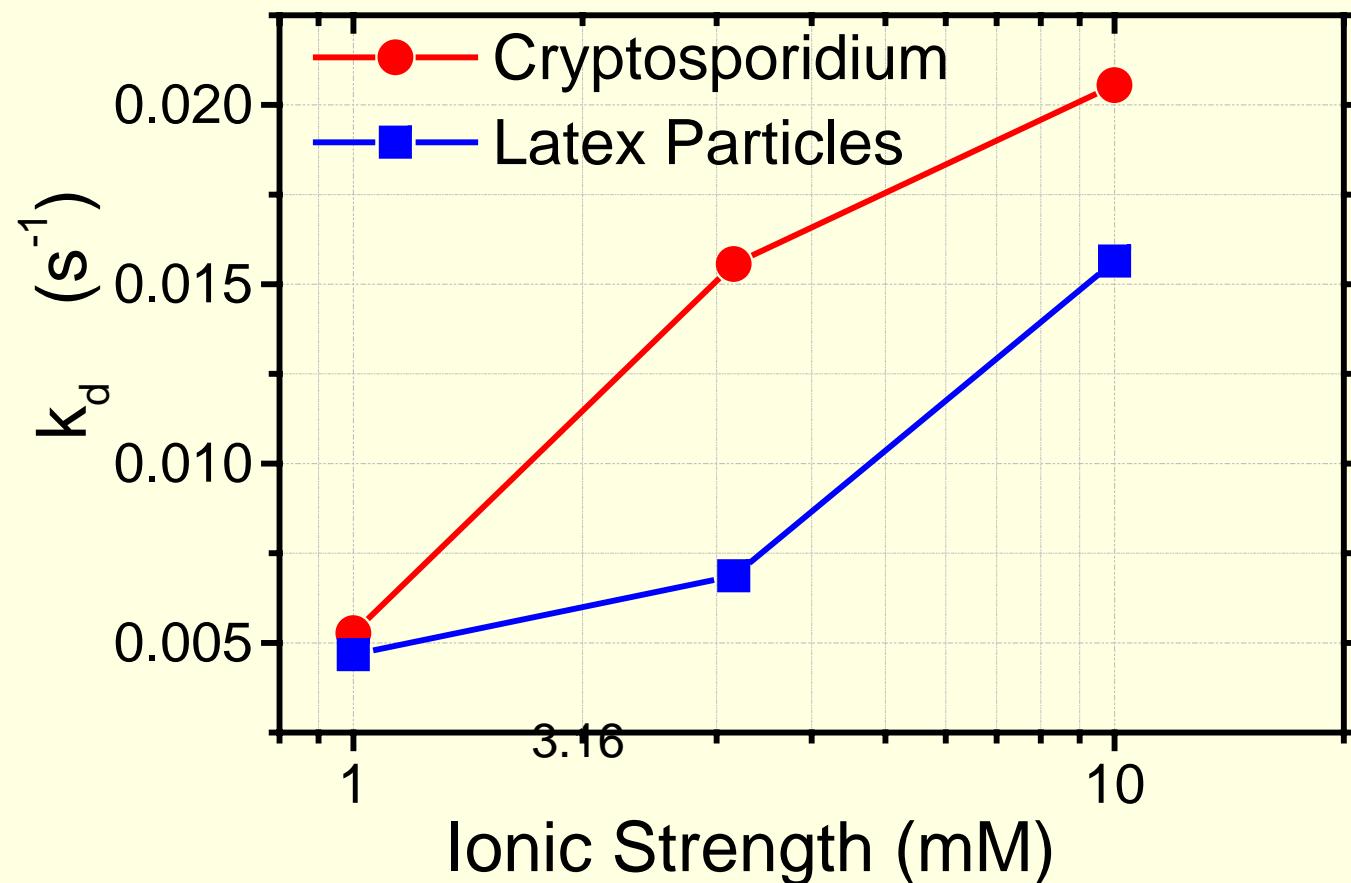
■ Microspheres



Column Experiments

- Deposition rate coefficients

$$k_d = \ln\left(\frac{C}{C_0}\right) \frac{v}{\theta L}$$

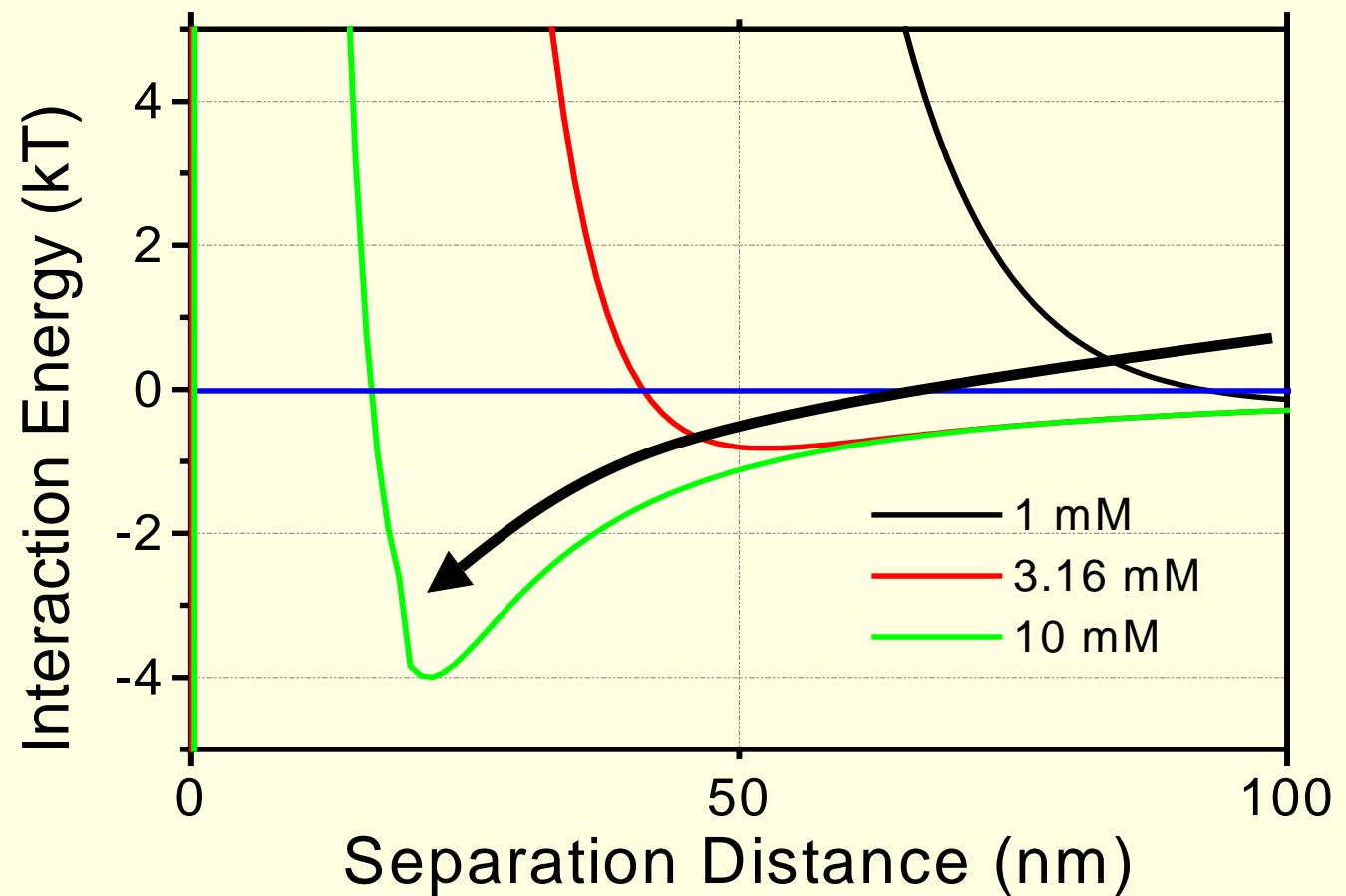


Column Experiments

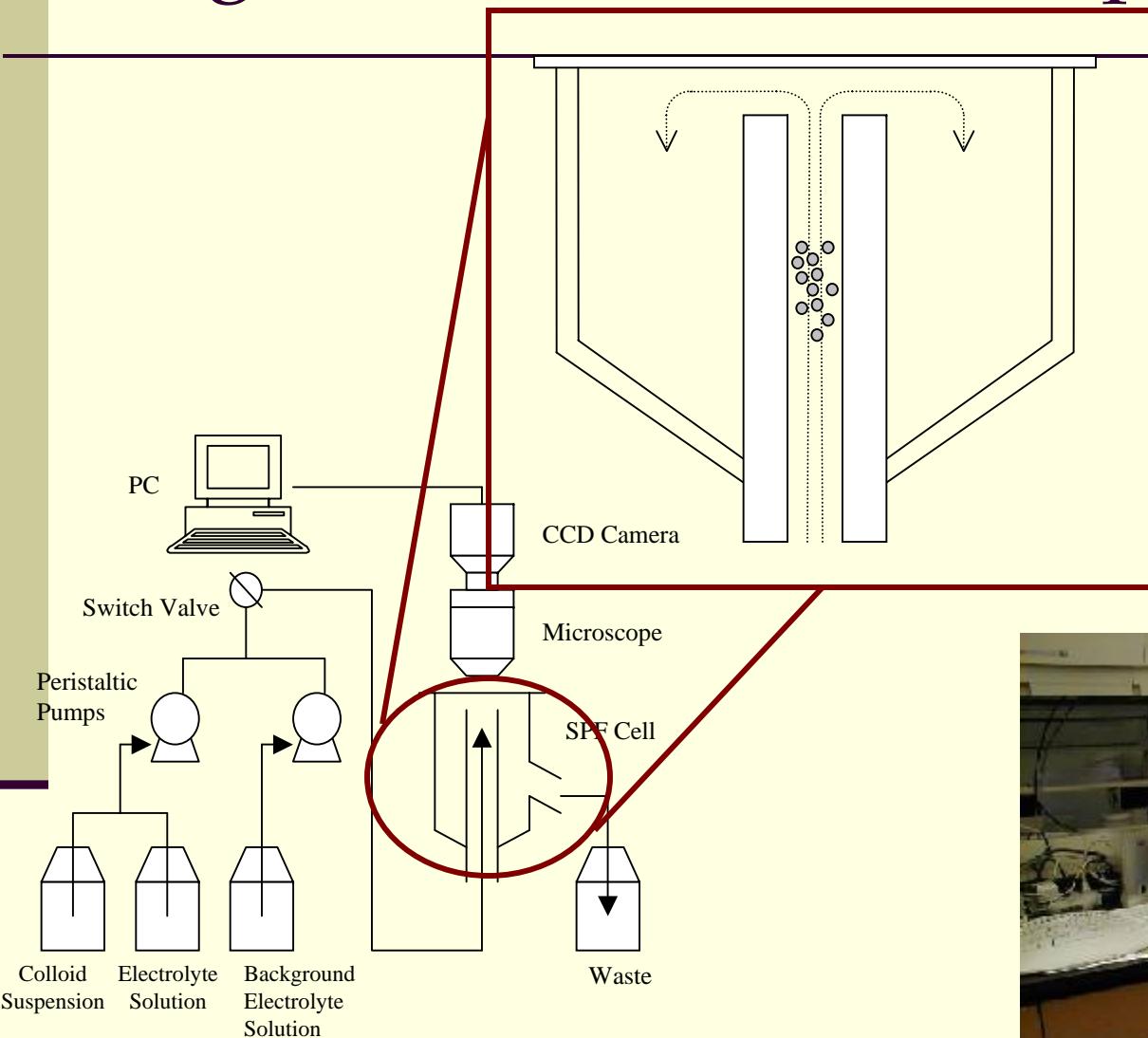
- Effect of DLVO secondary minimum



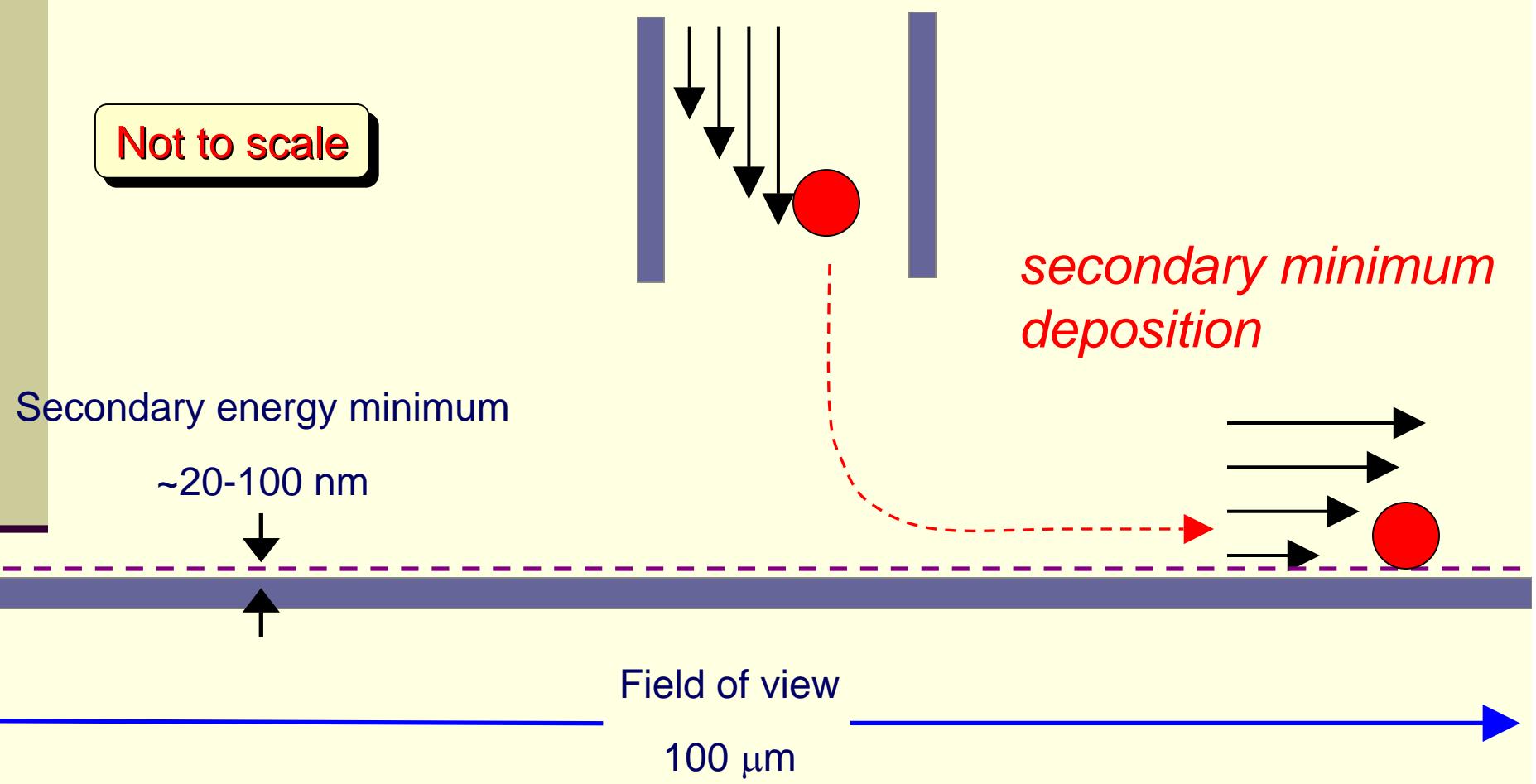
V



Stagnation Point Flow Experiments



Stagnation Point Flow Experiments



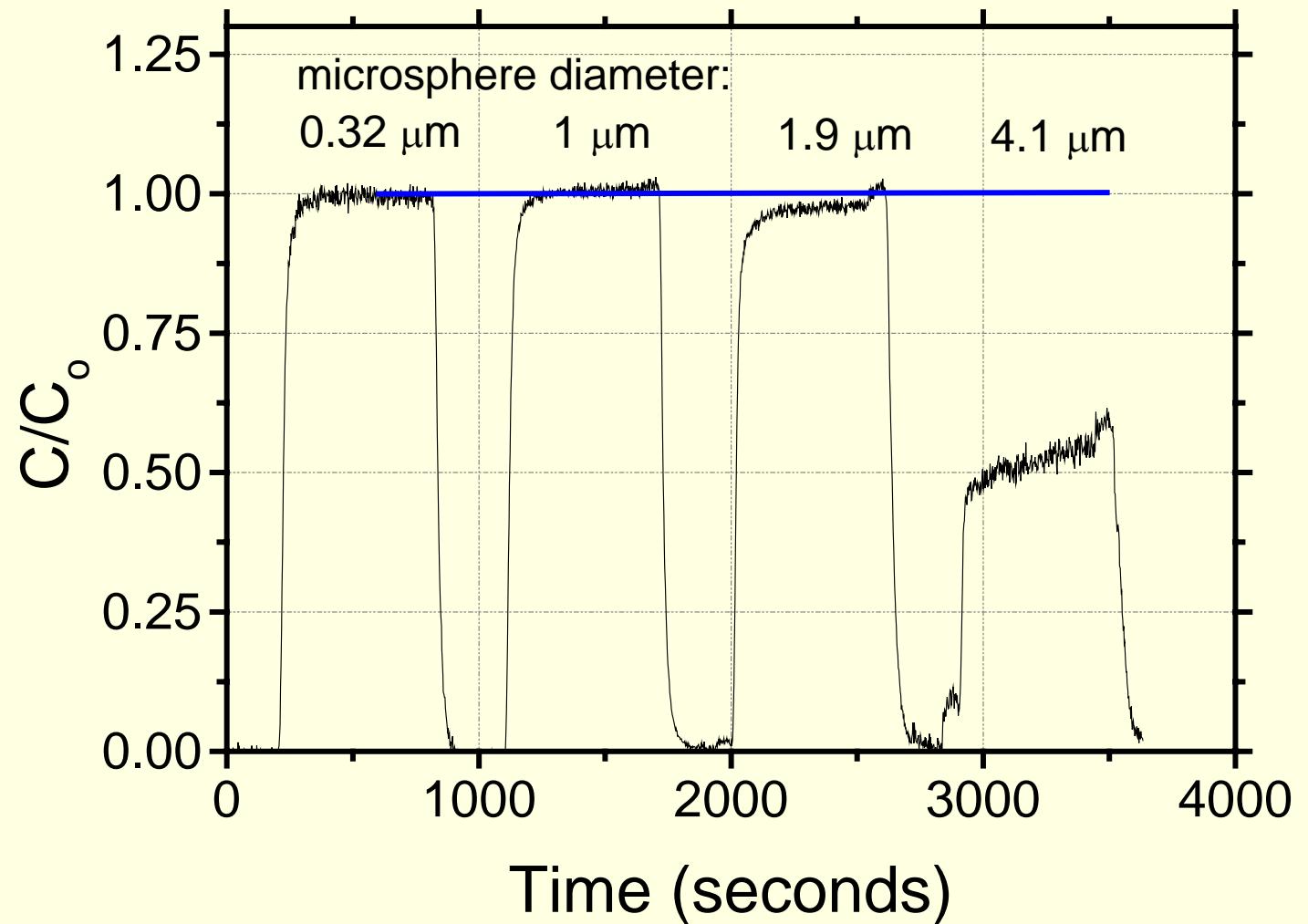
Stagnation Point Flow Experiments

■ Oocyst deposition

ionic strength (mM)	measured deposition
1	0
3.16	0
10	0
100	0

Column Experiments

■ Straining



Conclusions

- Heterogeneity
 - physical > geochemical
(grain size) (surface charge)
- Ionic strength
 - oocyst deposition depends on ionic strength
- Secondary minimum
 - oocyst deposition occurring in secondary minimum
- Surrogate
 - microsphere transport similar to oocyst
- Straining
 - significant process for ~4 μm particles in 210 μm sand

Acknowledgements

- U.S. Environmental Protection Agency



- U.S. Department of Agriculture

- Jeremy Redman (Yale University)
- Nicole DeNovio, Christina Osborn, Amanda Peirce, Sara Reinsel, Alice Wood (University of Colorado)