Department of Civil and Environmental Engineering
Michigan State University

Tarabara research group:
Overview of recent and current projects

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Last updated: March 25, 2019

Current research interests

Currently active and recently completed projects

- **Virus removal by membranes**
  - in drinking water treatment (ceramic MF). Hybrid MF-UV.
  - In water reuse (MBRs)
  - Sample concentration for virus detection
- **Virus adhesion: to membranes, paints, PCPs**
  - Experimental (QCM-D, bench-scale membrane tests)
  - Modeling (XDLVO)
- **Separation of emulsions by membranes and hydrocyclones**
  - Experimental (DOTM, QCM-D, bench-scale membrane tests)
  - Modeling (XDLVO, contact mechanics)
- **Coagulation and flocculation**
  - As pretreatment for membranes
  - Natural coagulants: mechanisms

Research on membranes

MEMBRANE MATERIALS

polymer nano- and mesocomposites

- for improved flux and selectivity
- for flow-through reactions

membrane surface modification

- by polylectrolyte multilayer films
  - antiadhesive layers
  - sacrificial layers
- by catalytic inorganic coatings

MEMBRANE PROCESSES

water treatment

- membrane-based redox reactions
- effects of pretreatment

separation of oil-water emulsions

- by porous membranes
- by filtering hydrocyclones

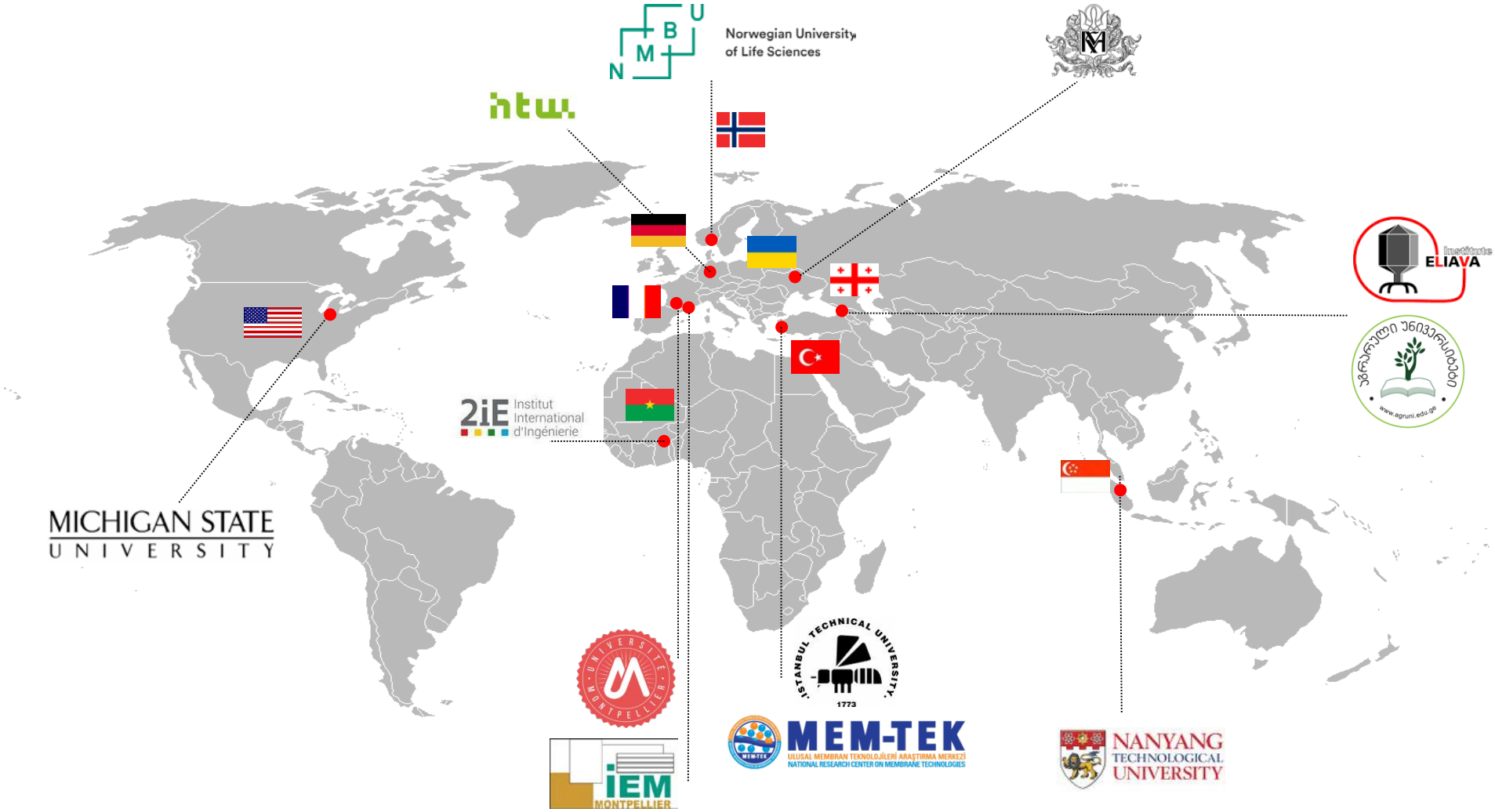
separation of viruses by membranes

- for removal in treatment systems
- for concentration and detection

crosscutting themes:

- functional membranes for reactive separations
- understanding and managing membrane fouling

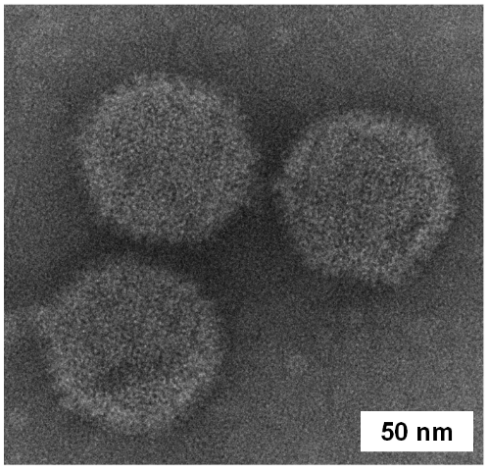
International collaborations



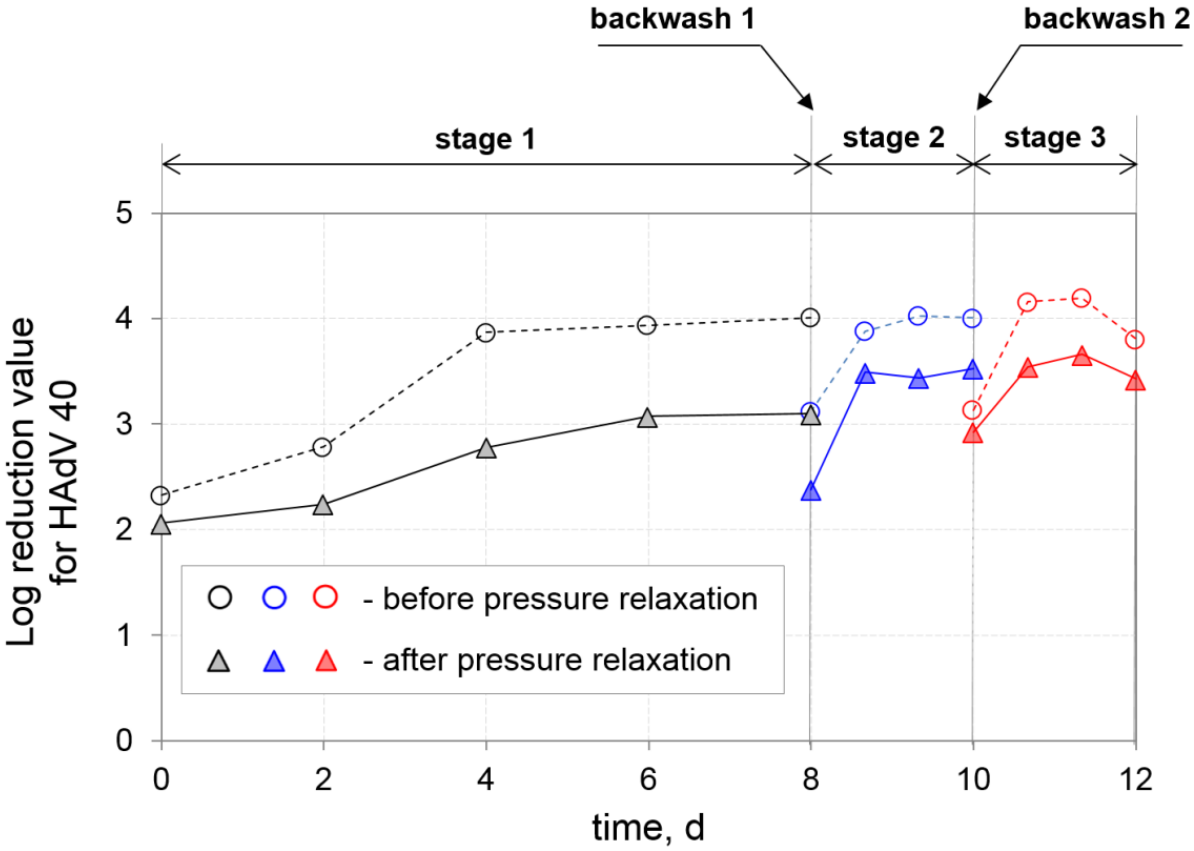
Virus removal in a bench-scale MBR

for water reuse

Human Adenovirus 40



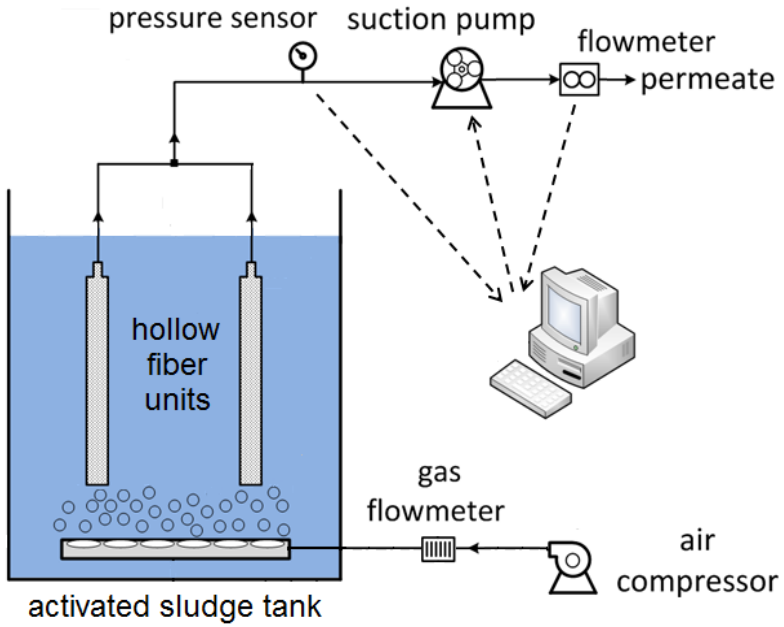
Appl. Environ. Microbiol. 82 (2016) 4982

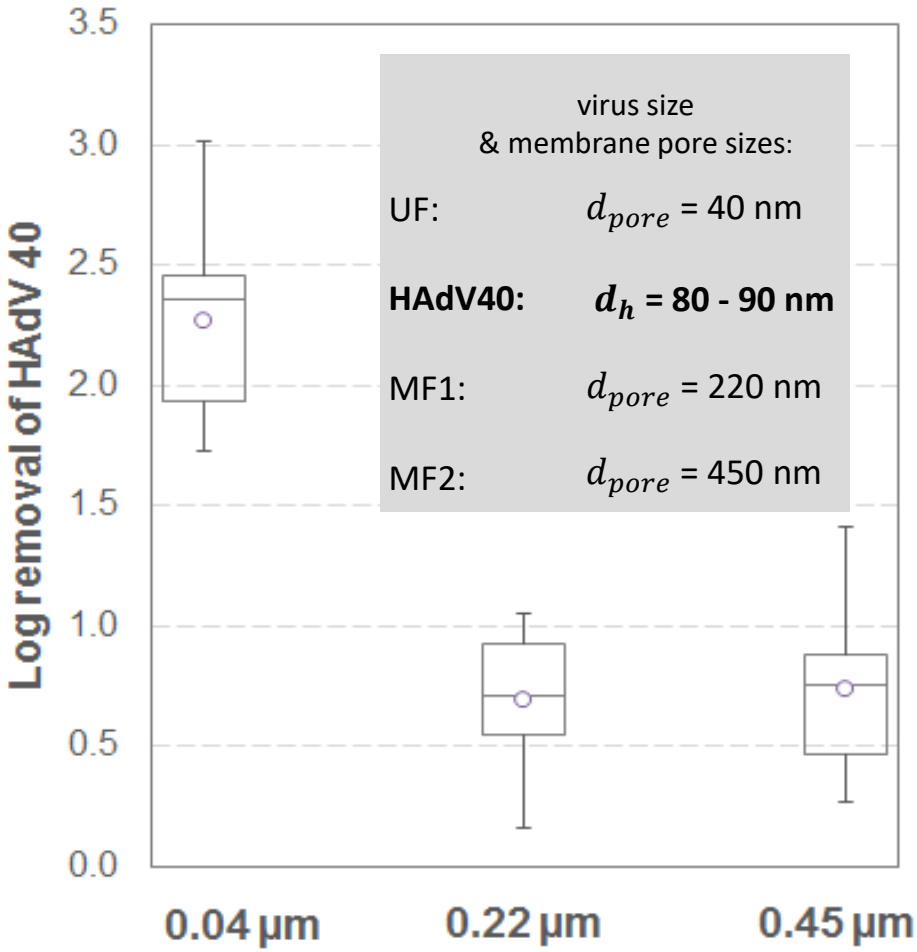


Water Res. 88 (2016) 750

Virus removal by micro- and ultrafilters

for drinking water safety

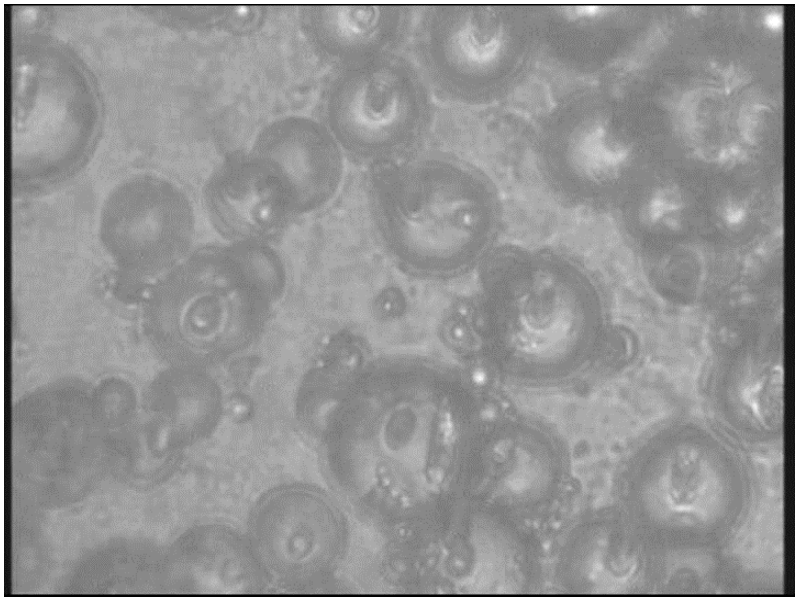


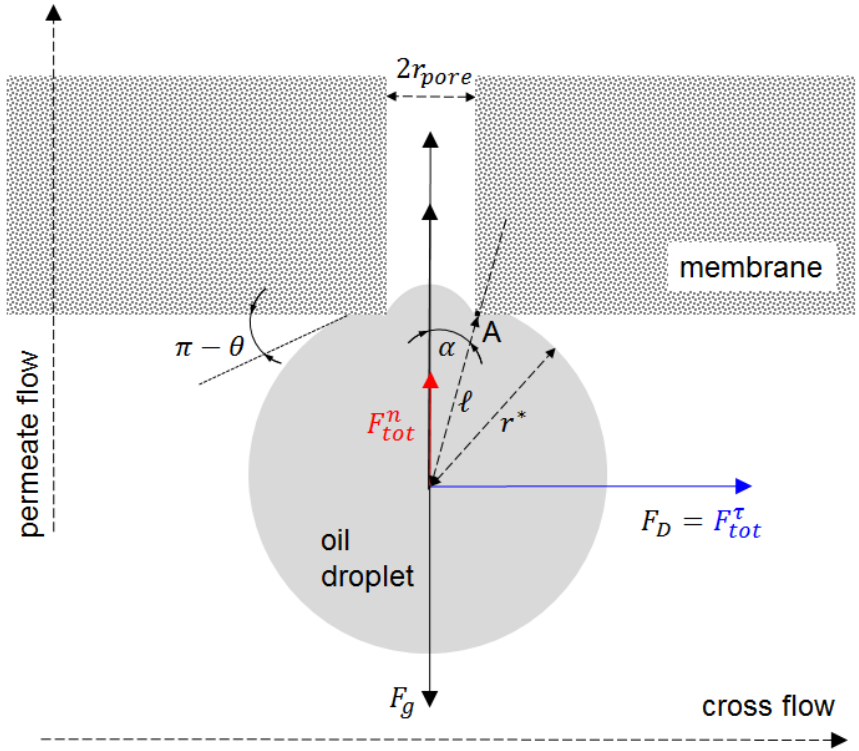


Microfiltration of emulsified oil

for produced water treatment

Direct observation through membrane (DOTM)



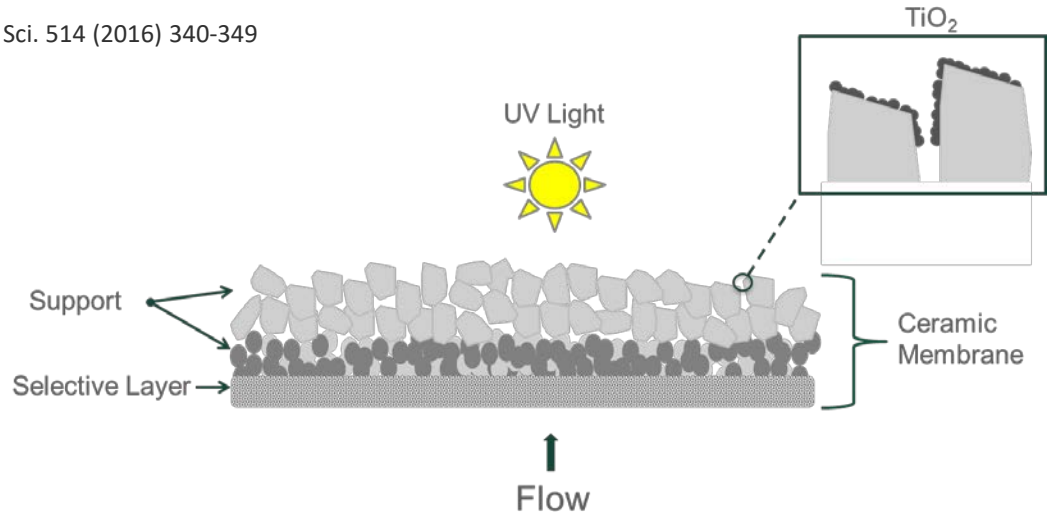


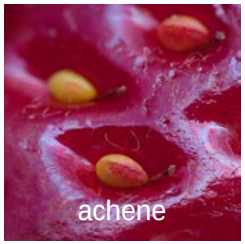
Tummons, E. N.; Tarabara, V. V. Chew, J. W.; Fane, A. G. *J. Membr. Sci. 2016, 2017*

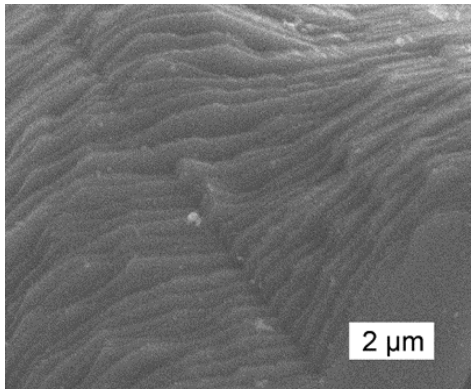
Photocatalytic membranes

for virus removal and inactivation

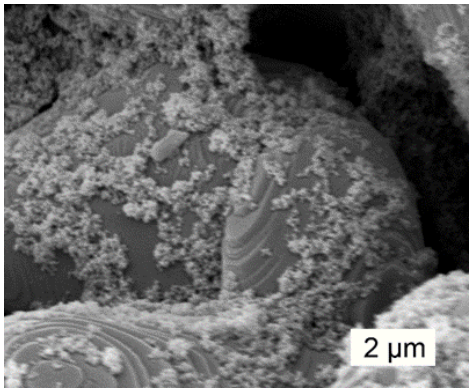
J. Membr. Sci. 514 (2016) 340-349



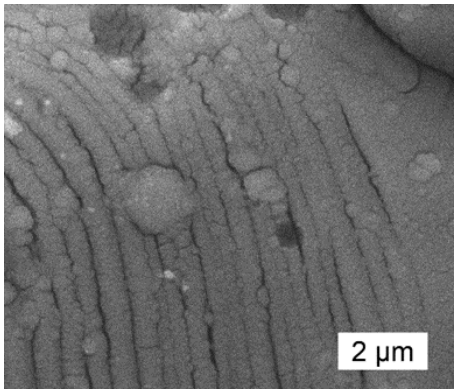




Uncoated membrane



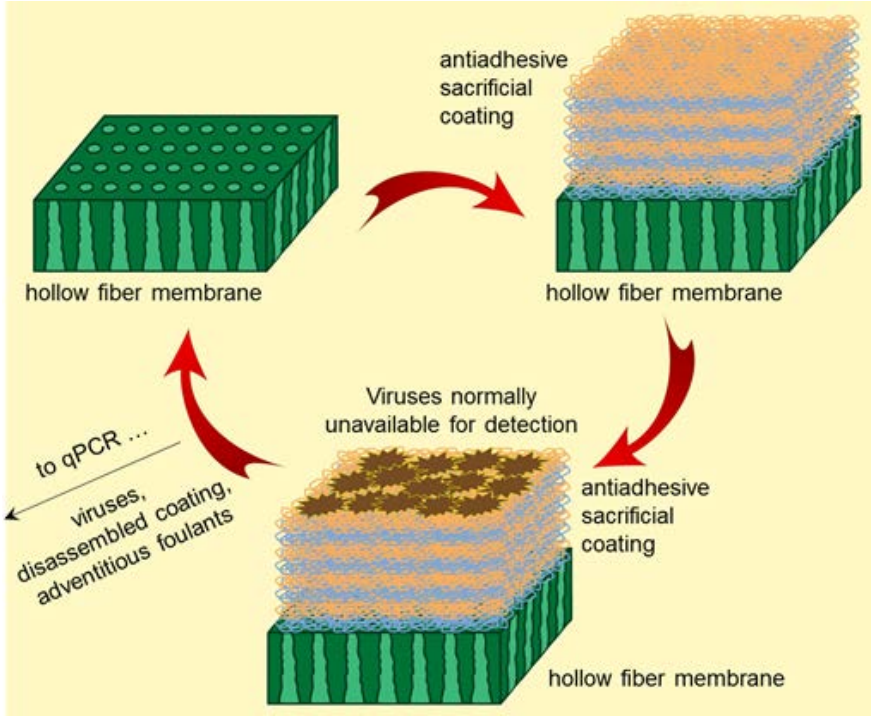
LbL-coated membrane



CVD-coated membrane

Sample concentration/processing

for virus detection



Sacrificial ("snake-skin") coatings to maximize virus recovery and enable near real time detection

The **goal** is to develop a technology that enables fast, efficient and reproducible concentration of viruses from high-volume water samples for near real time detection

1. Instrumental value for quantifying viral loads and developing accurate mass balances for viruses in treatment utilities.
2. Informing risk assessment and helping formulate design guidelines for current and future treatment plants to increase virus removal
3. Enabling acquisition of data in support of regulatory decision making.
4. Advancing fundamental understanding of virus adhesion to surfaces

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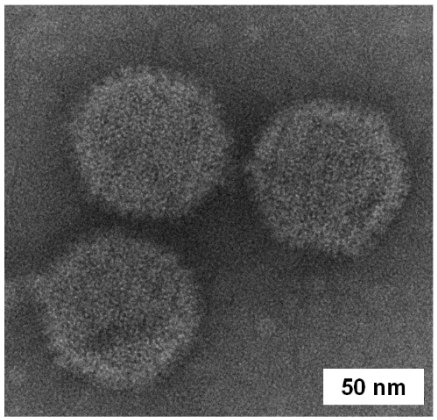
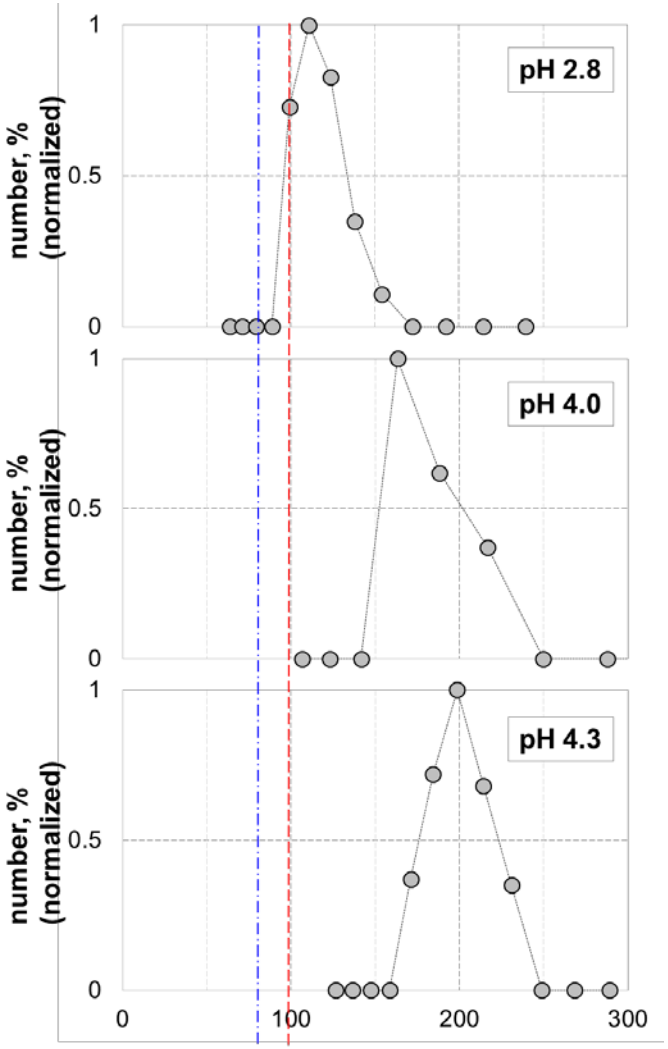
Human Adenovirus 40

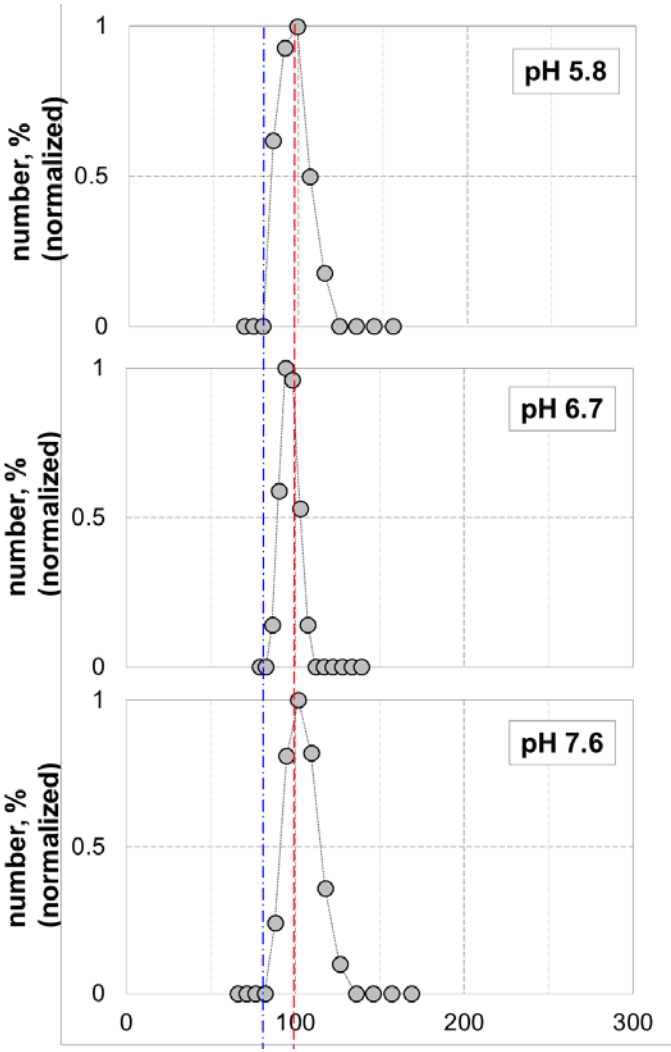
pH dependence of the aggregation state

TEM: ~ 80 nm

DLS: ~ 99 nm



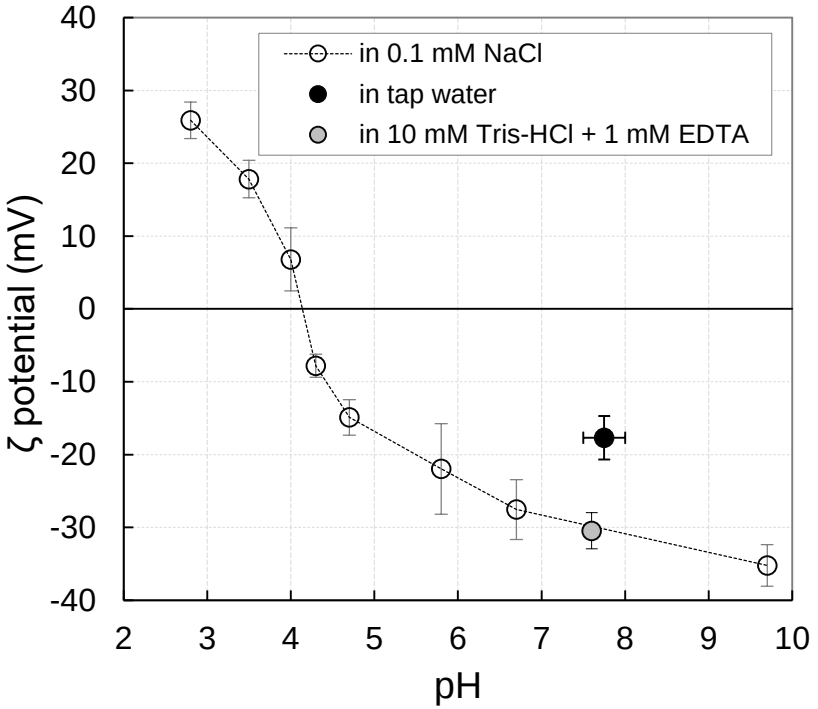




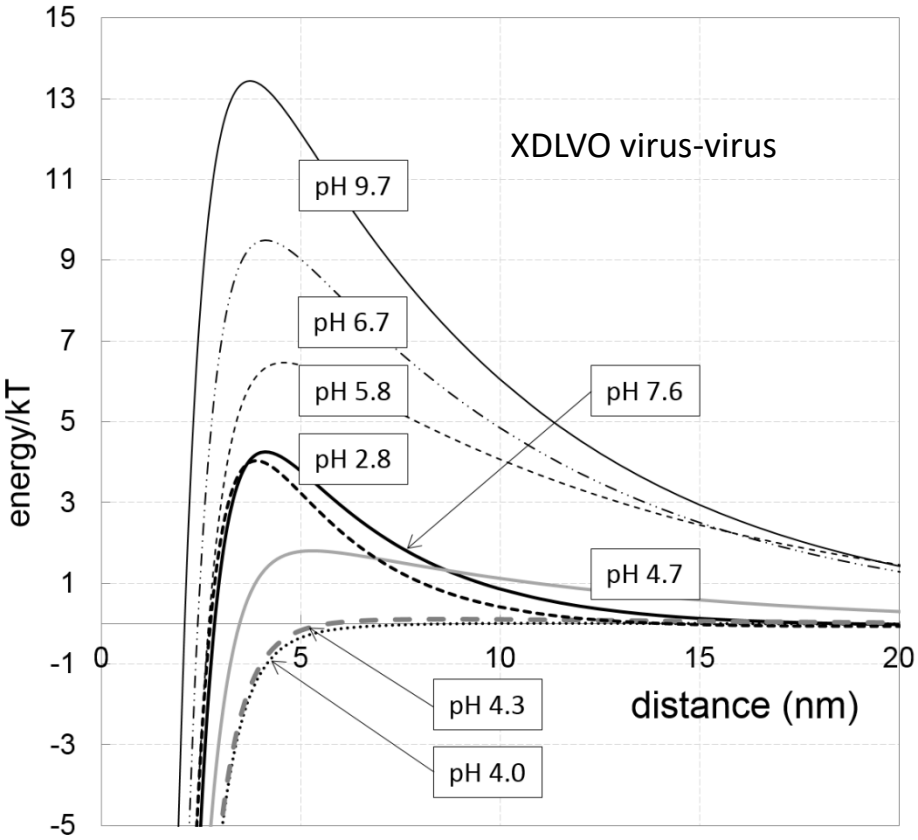
Human Adenovirus 40

Hydrophobicity, surface charge → virus-virus interactions

ζ–potential of individual (non-aggregated) HAdV virions



Shi, H. et al. Appl. Environ. Microbiol. 2016



$$\sigma = \frac{2\varepsilon_r\varepsilon_0\kappa kT}{ze}\sinh\left(\frac{ze\zeta}{2kT}\right)\sqrt{1+\frac{1}{\kappa\frac{d_p}{2}}\frac{2}{\cosh^2\left(\frac{ze\zeta}{4kT}\right)}+\frac{1}{\left(\kappa\frac{d_p}{2}\right)^2}\frac{8\,ln\left[\cosh\left(\frac{ze\zeta}{4kT}\right)\right]}{\sinh^2\left(\frac{ze\zeta}{2kT}\right)}}$$

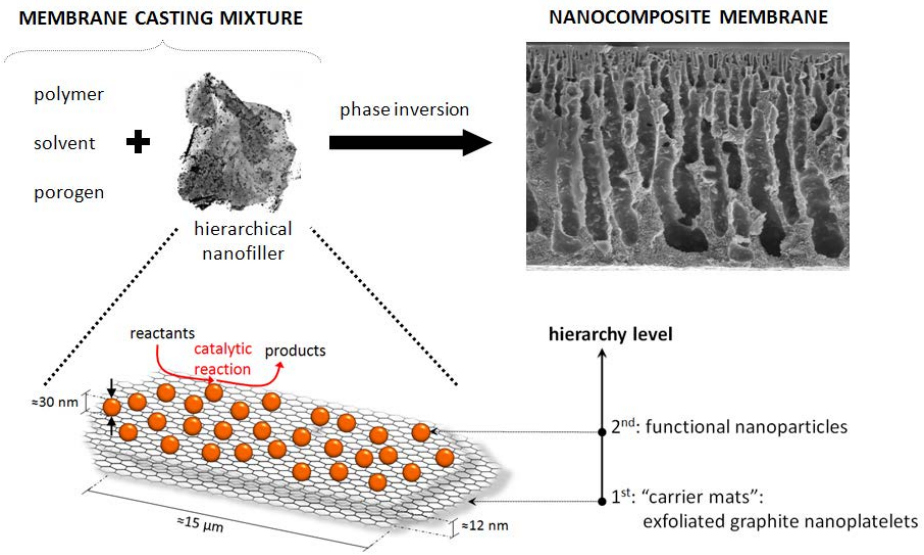
Makina and Ohshima, 2010

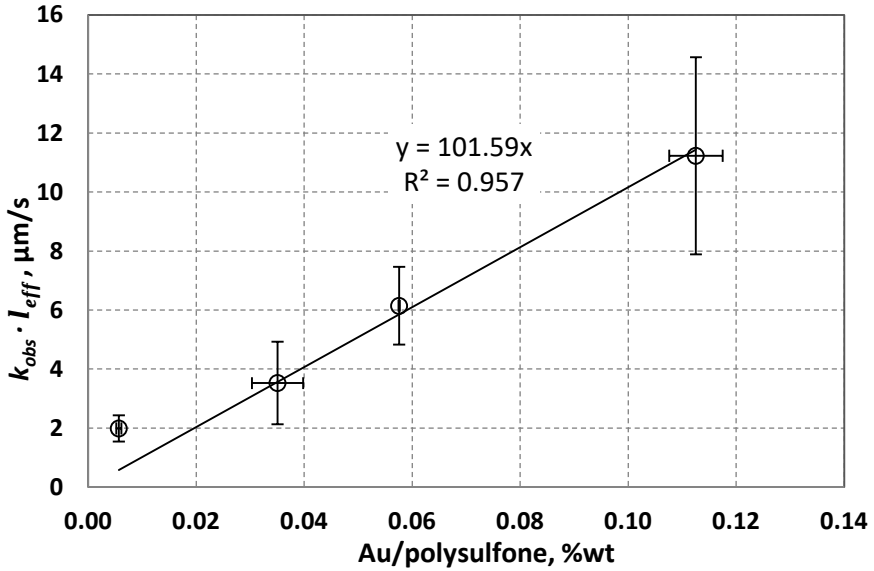
In ultrapure water (pH 5.8−6.0):

θ_w = 68 °

ΔG_{vwv} = - 30.4 mJ/ m^2

Title
Subtitle





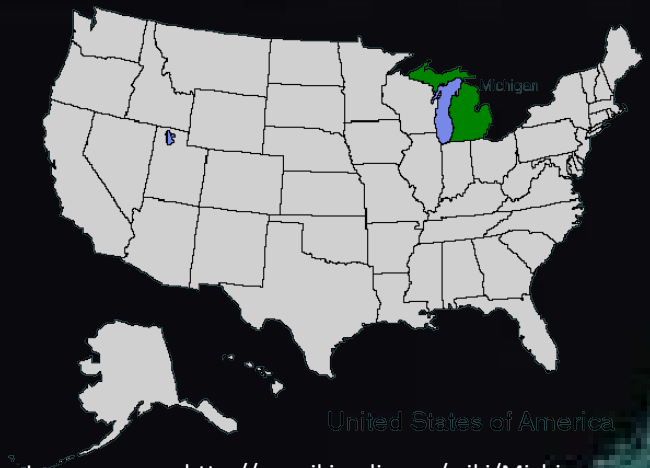
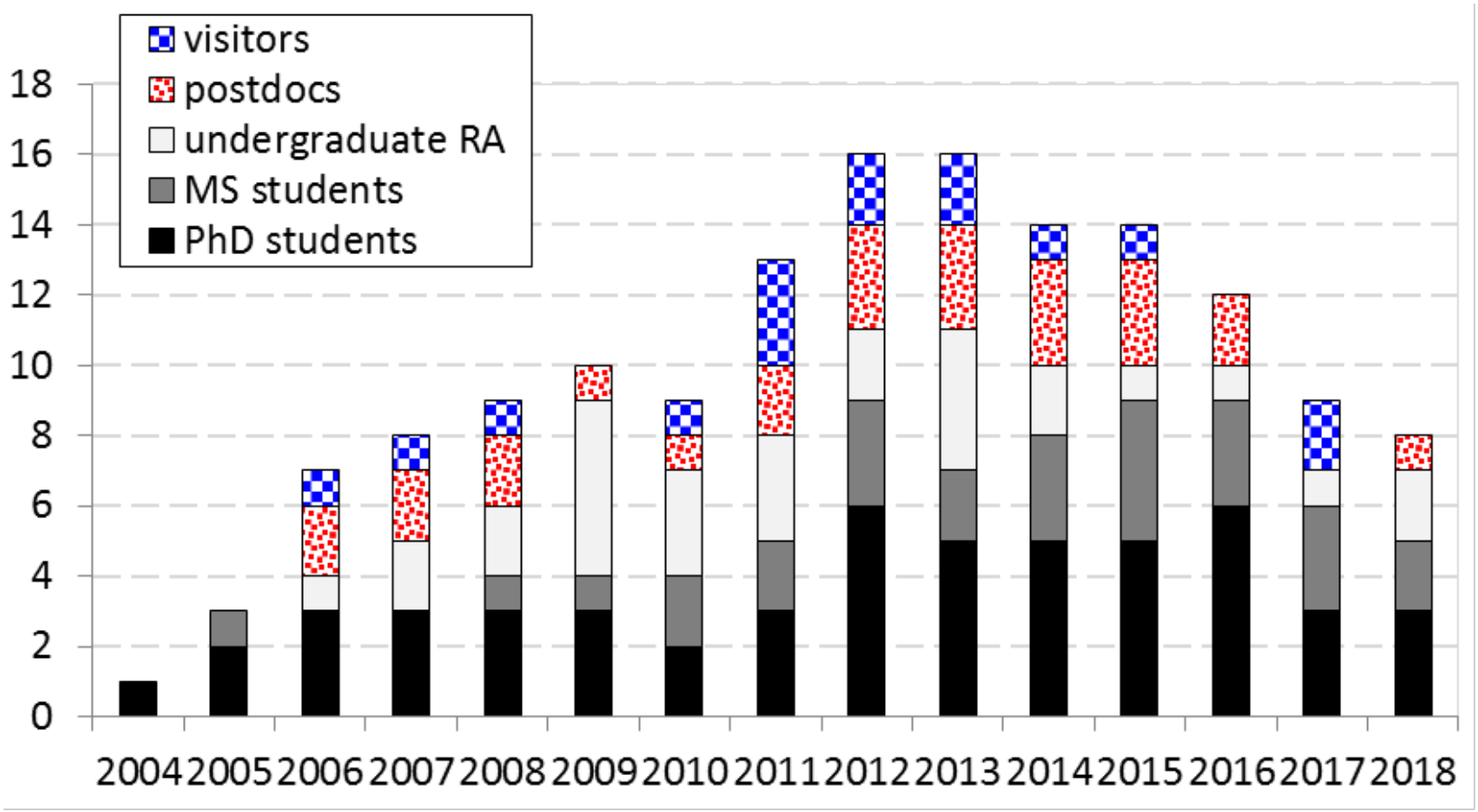


Image source: http://en.wikipedia.org/wiki/Michigan

Image source: michigan.gov

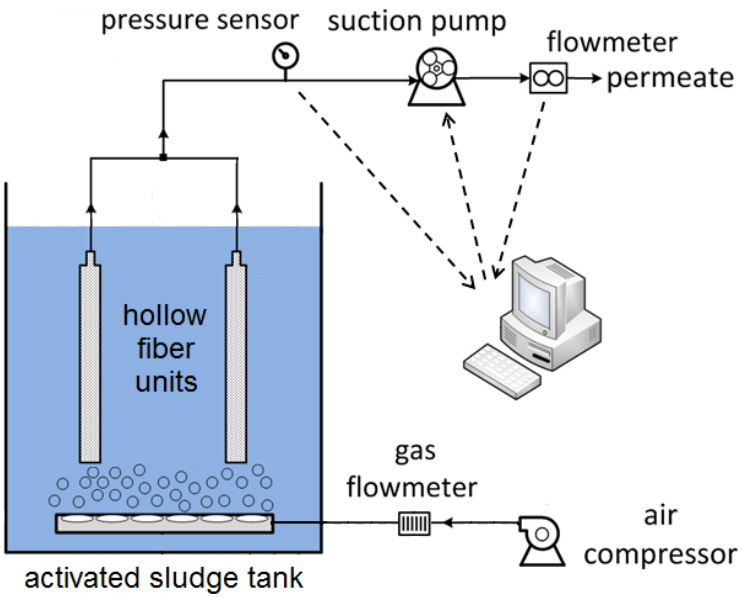
Group members in numbers

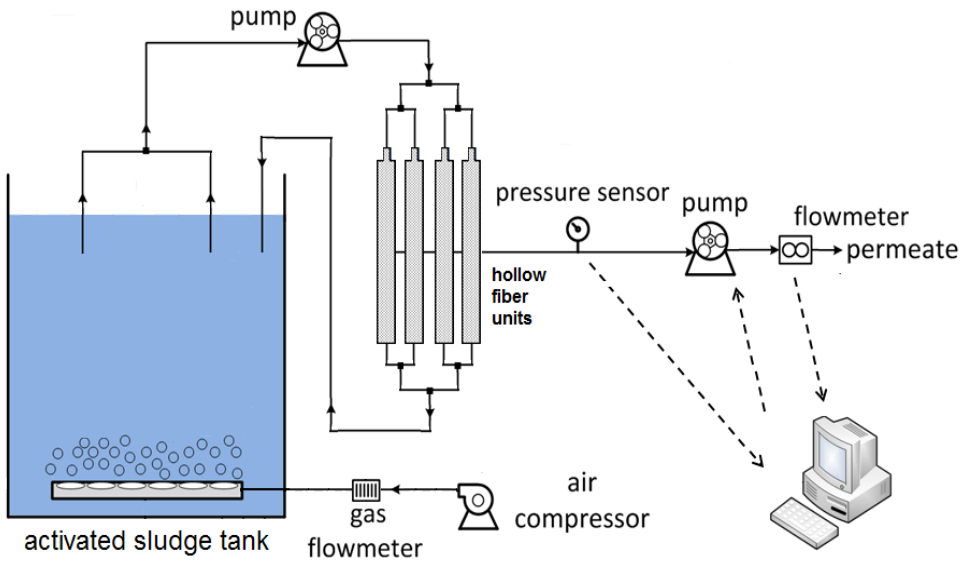
2014 - present



Virus removal in a bench-scale MBR

Effects of cleaning (pressure relaxation and backflush)



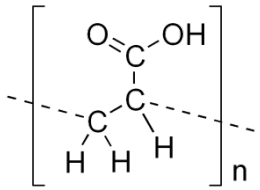


Virus removal in a bench-scale MBR

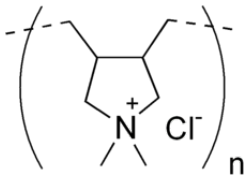
Effects of cleaning (pressure relaxation and backflush)

Step 1: Four bilayer PAA/PDADMAC coating

Poly(acrylic acid)



Polydiallyldimethylammonium chloride



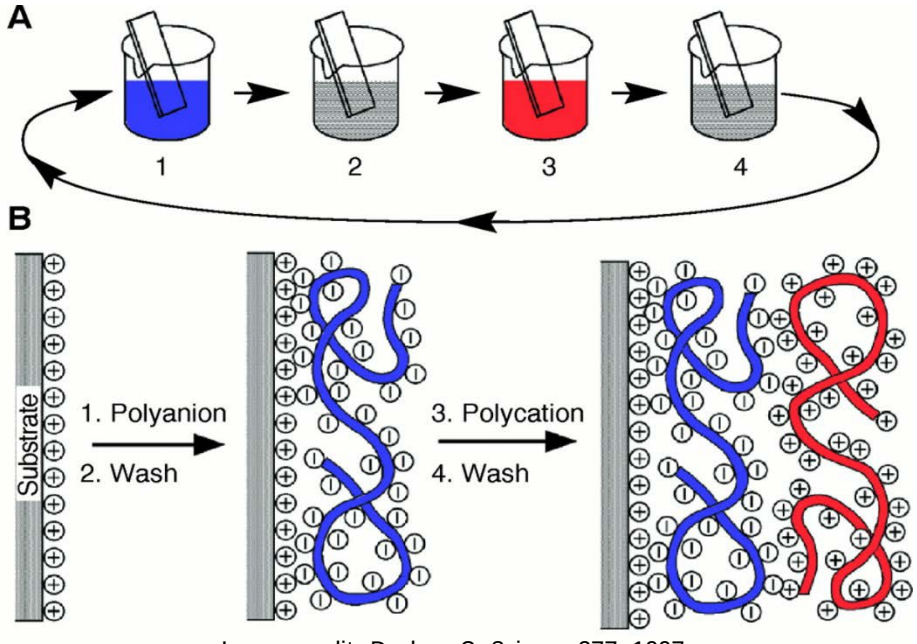


Image credit: Decher, G. Science 277, 1997

Step 2: TiO_2 deposition

300 mg(TiO_2)/L

Degussa P25 photocatalyst

Deposition time: 30 min.

Step 3: Sintering

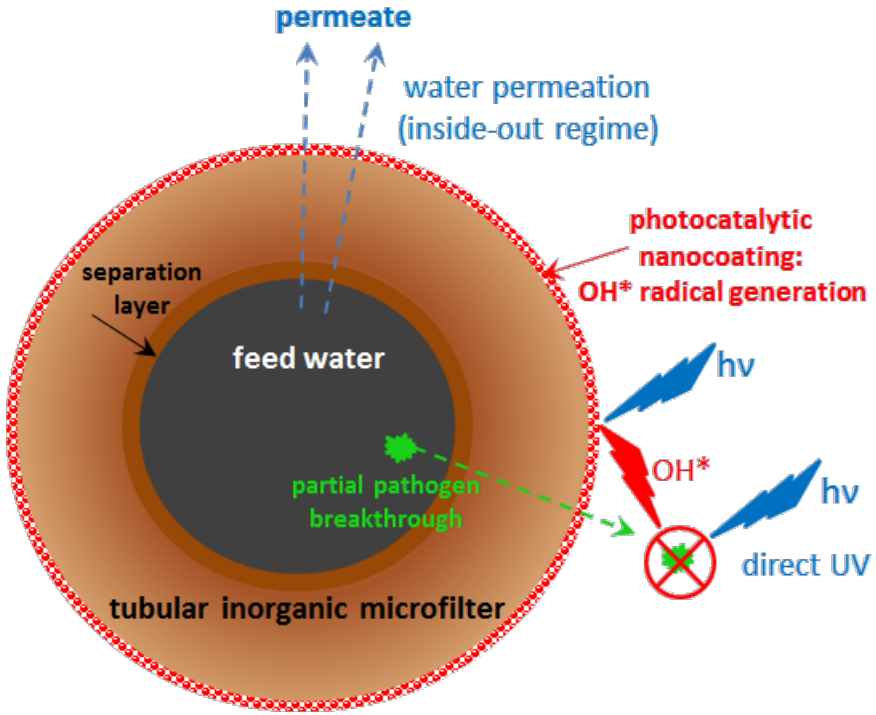
ramp rate of 4.0 ^oC/min up to 500 ^oC

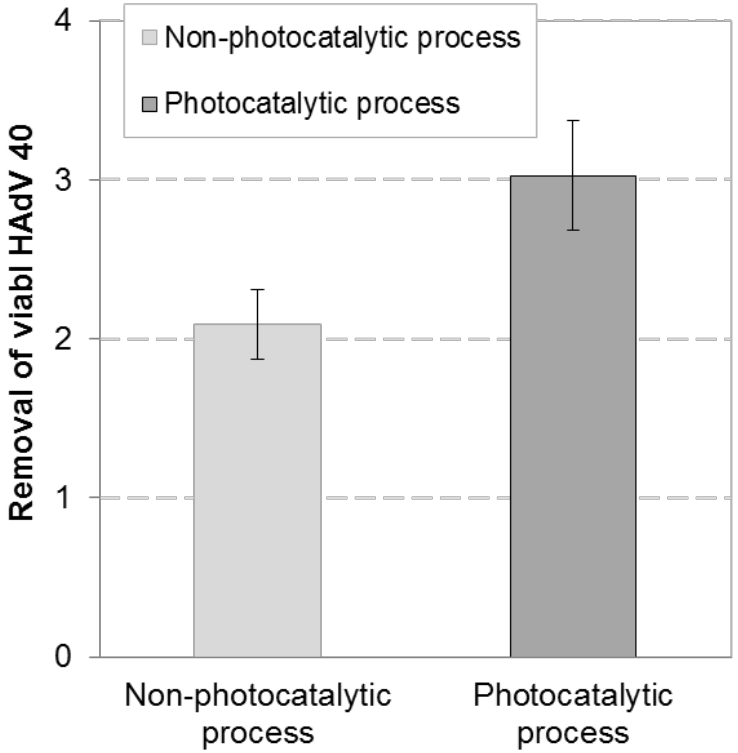
stay at 500 ^oC for 45 min

lower to 20^oC at 4.0 ^oC/min

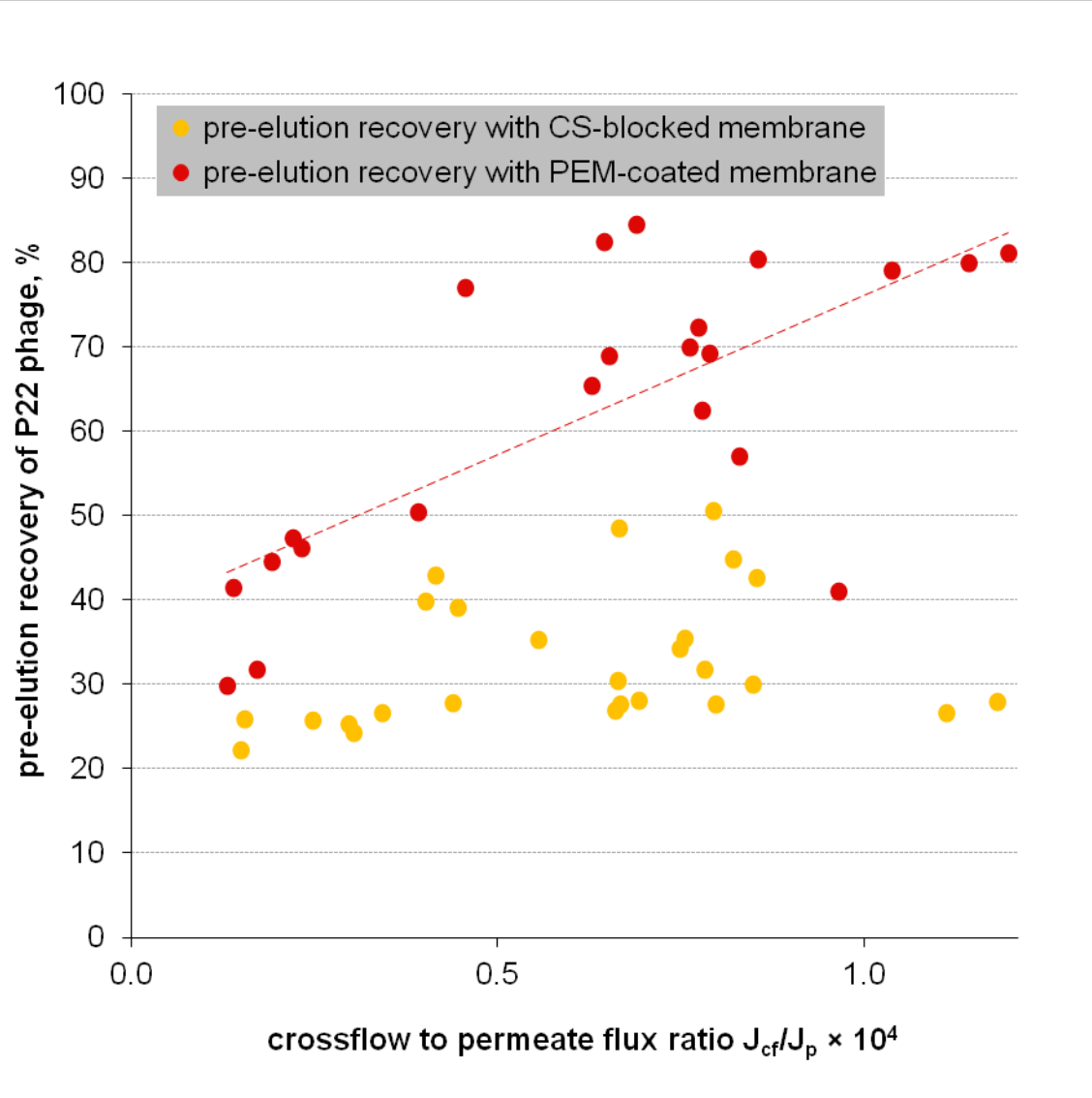
Virus removal in a bench-scale MBR

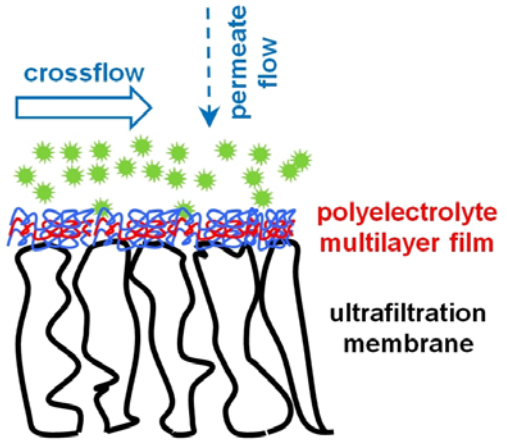
Effects of cleaning (pressure relaxation and backflush)

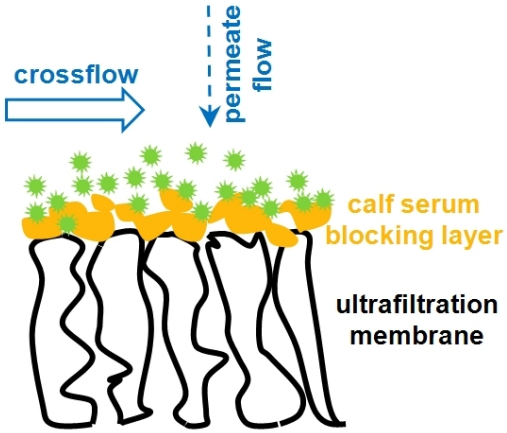




Recovery of P22 bacteriophage
using polyelectrolyte-coated membranes



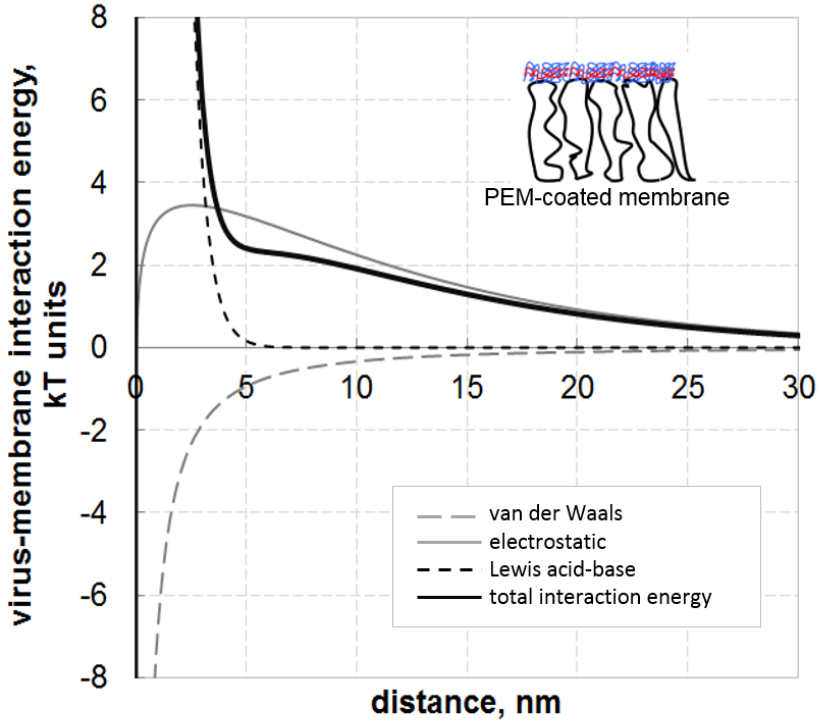


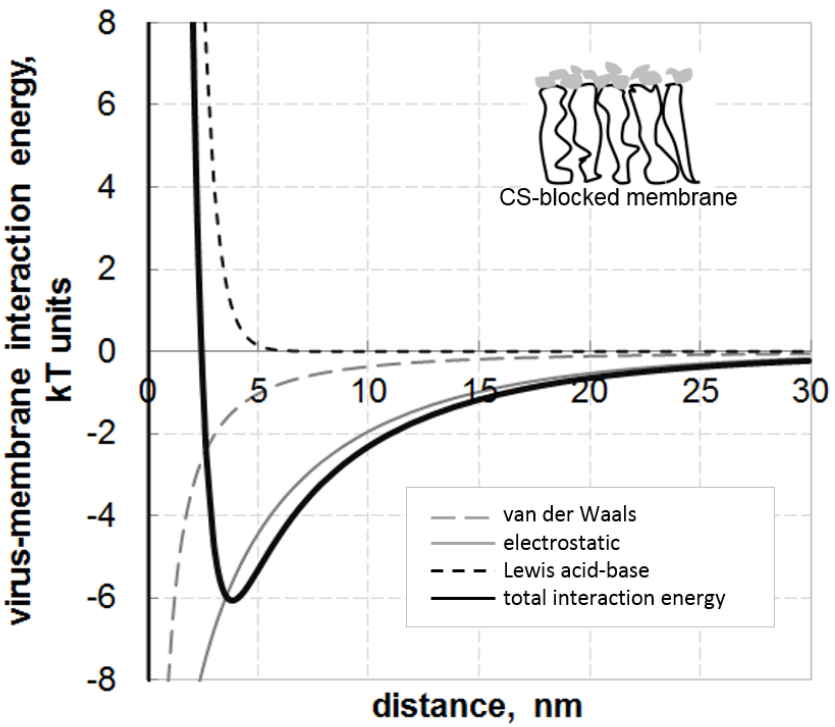


Membrane-virus interactions

assessed by XDLVO modeling

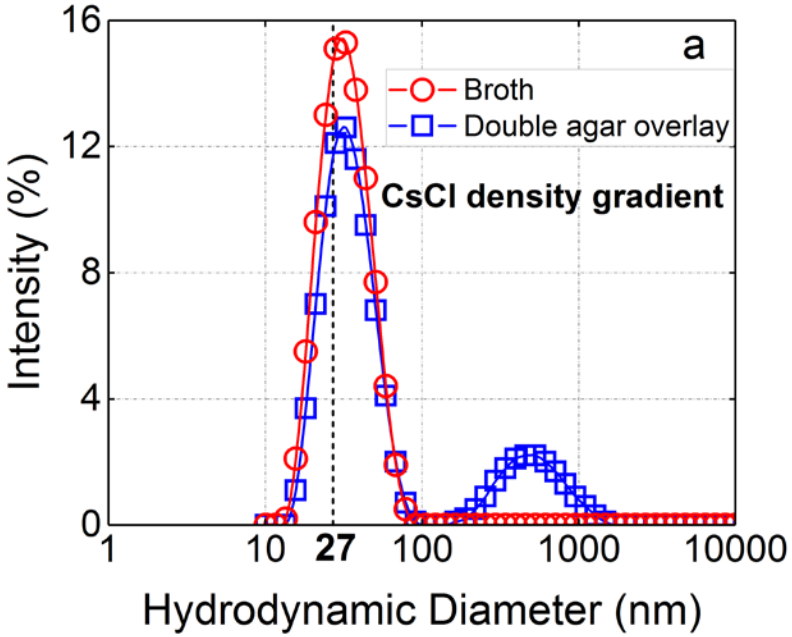
	ζ potential at pH = 6	Water contact angle
Calf serum-blocked membrane	+ 3 ± 2 mV	66 ± 13°
PEM-coated membrane	- 7 ± 3 mV	36 ± 3°
P22 phage	-17 ± 5 mV	49 ± 8°

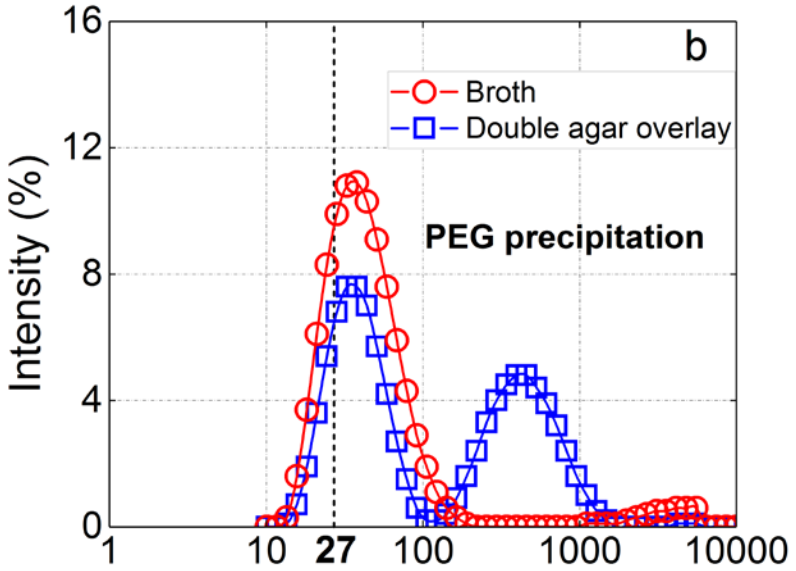


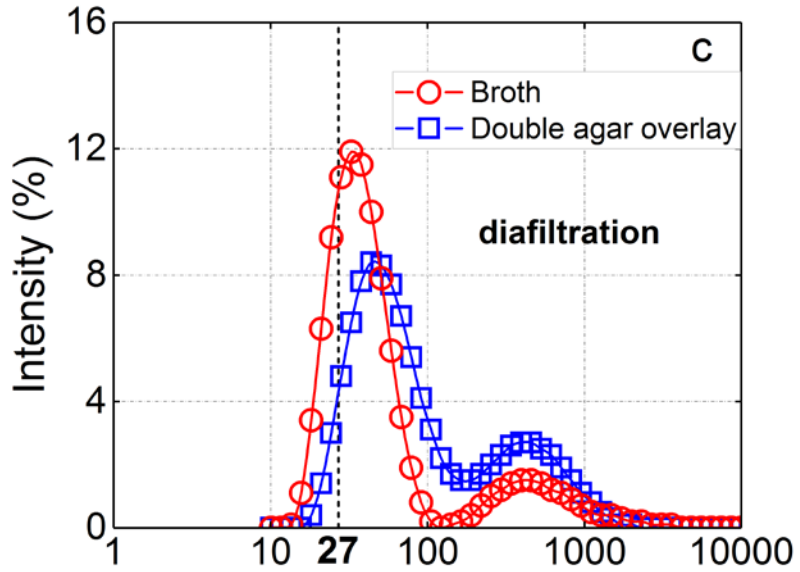


Effect of the propagation method

on MS2 size determination

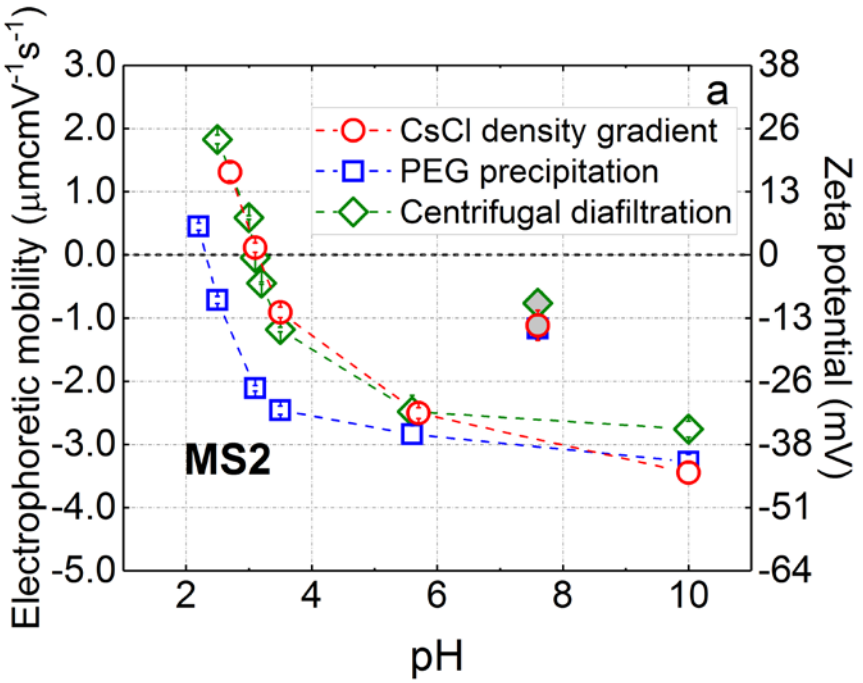


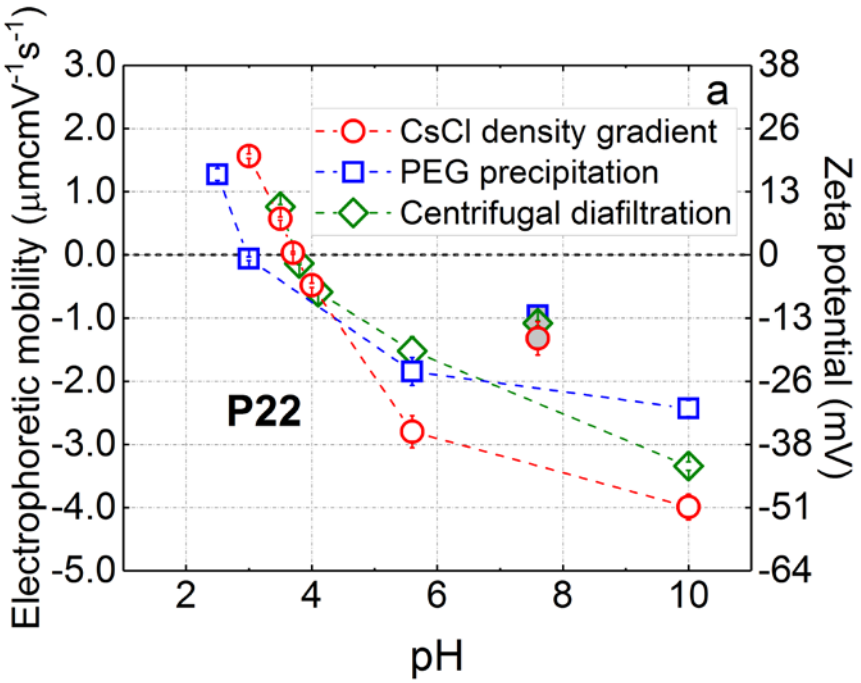




Effect of the purification method

on virus size and charge determination





Recovery of HAdV 40 from lake water

with protein-blocked and PEM-coated membranes