PACl Coagulation-Ceramic Filtration as an Advanced Water Treatment Process for Virus Removal

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INTRODUCTION

Direct Potable Reuse (DPR) - a Growing Reality for Arid Lands

- Tucson, Arizona: historically a groundwater-reliant city (population ~950K and growing)
- Sonoran Desert climate (297 mm rainfall/yr)
- Increased demands on limited water supplies inevitable

Study Site: Water & Energy Sustainable Technology (WEST) Center

- Located in Tucson, AZ USA
- Partnership between Pima County, The University of Arizona, and Industry Members
- Mission: promote development/demonstration of new technologies, provide local to global outreach and educational/ research opportunities in water & energy sustainability

Study Purpose

- Determine the efficacy of PACl coagulation-ceramic microfiltration as an advanced treatment process for virus removal via collaborative research
- Amass log_{10} reduction data for process credits → potential DPR application and implementation in Arizona

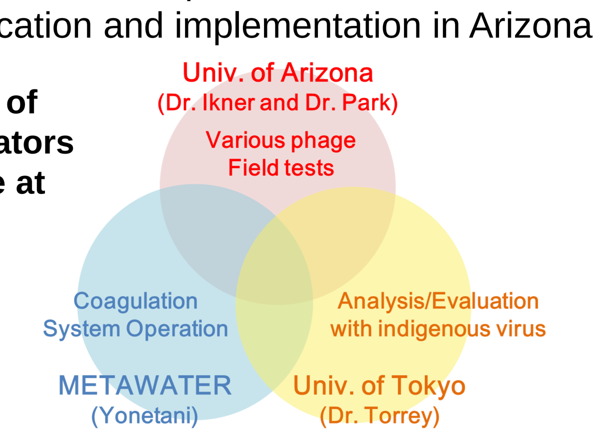
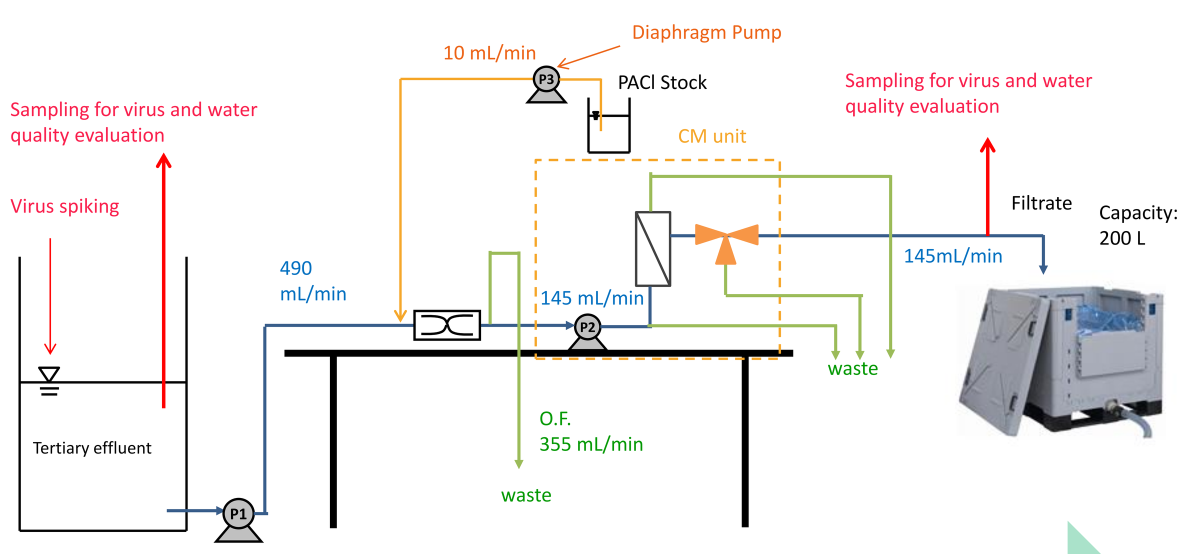


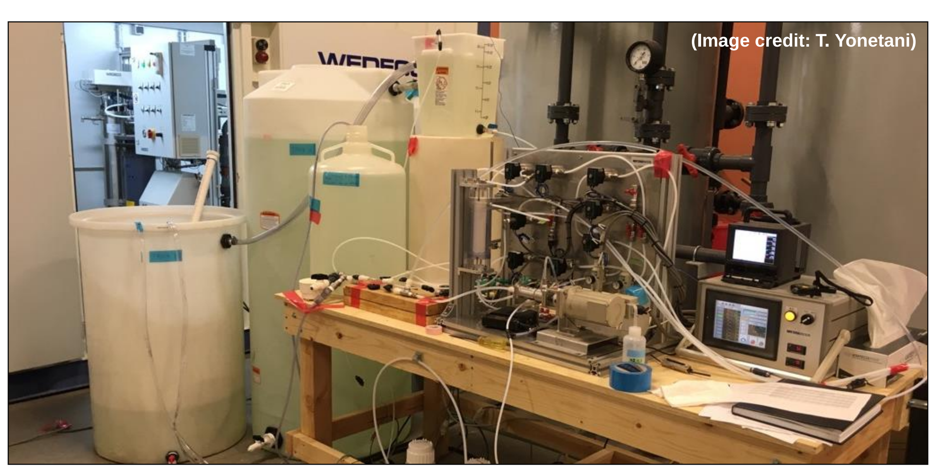
Figure 1. Diagram of research collaborators also in attendance at IWA 2018.

(Image credit: T. Yonetani)

METHODS

Figure 2. Experimental Set-Up at the WEST Center





Spike Experiments: MS2 Bacteriophage 15597-B1

Purpose: determine log_{10} removal values of infectious viruses from 3° Effluent (i.e. recycled wastewater)

Test Organism

- MS2: surrogate for non-enveloped, human enteric viruses
- Isoelectric point (pI) = 3.9
- Host: *Escherichia coli* 15597
- Target spike density = 2.50E+06 PFU/mL

Figure 3. Process Outline for Spike Experiments

Spiking of MS2

- 3° Effluent feed water container filled (150 L), held open at RT overnight
- Free Cl- levels verified as below detection (≤ 0.01 ppm)
- MS2 spiked, mixed for 30 mins, feed samples collected (2x)

Coagulation-Microfiltration

- Advanced treatment initiated by engineering team
- Several coagulant formulations/concentrations tested
- Filtrate samples collected for MS2 PFU enumeration (2L) per experimental condition

Continuous Flow Experiments: *Pepper Mild Mottle Virus* (PMMoV)

Purpose: determine log_{10} removal values of PMMoV (infectious + non-viable) from 3° Effluent Feed

Test Organism

- PMMoV: a potential indicator for non-enveloped, human enteric viruses
- Isolated from wastewater-associated matrices[1,2]
- Isoelectric point (pI) = 3.7 - 3.8

Figure 4. Continuous Flow Tests: Feed Sample Processing

HA Filtration (2L→10mL) → Centriprep 10mL→ ~1mL → PMMoV RT-qPCR

Figure 5. Continuous Flow Tests: Filtrate Sample Processing

OptiCap XL Filtration (>100L→200mL) → Centricon 200mL→ ~1mL → PMMoV RT-qPCR

RESULTS and DISCUSSION

Figure 6. Removal of MS2 from 3° Effluent using high-basicity PACl

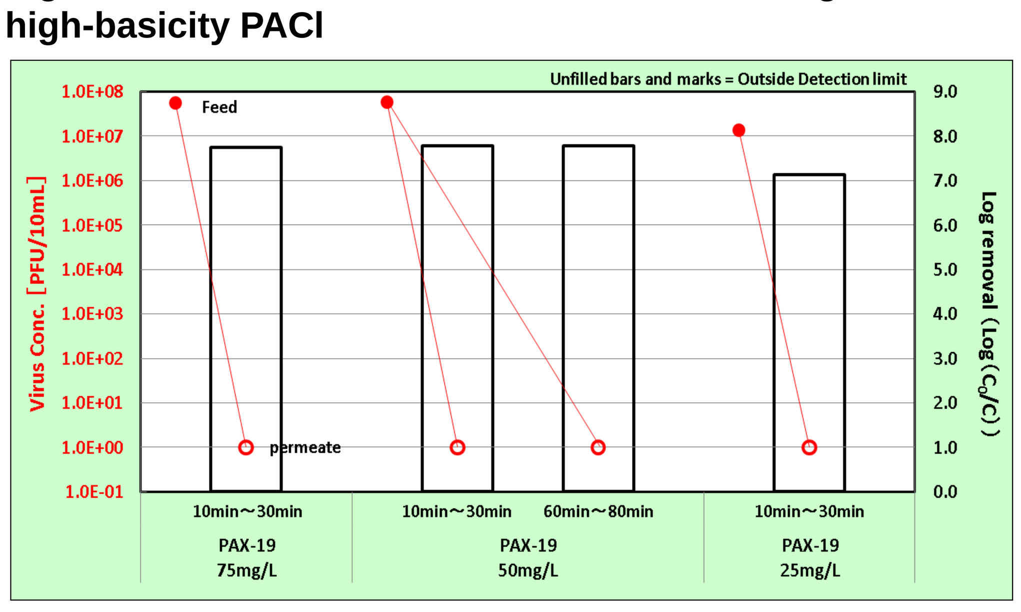


Figure 7. Influence of coagulant formulation and concentration on MS2 removal

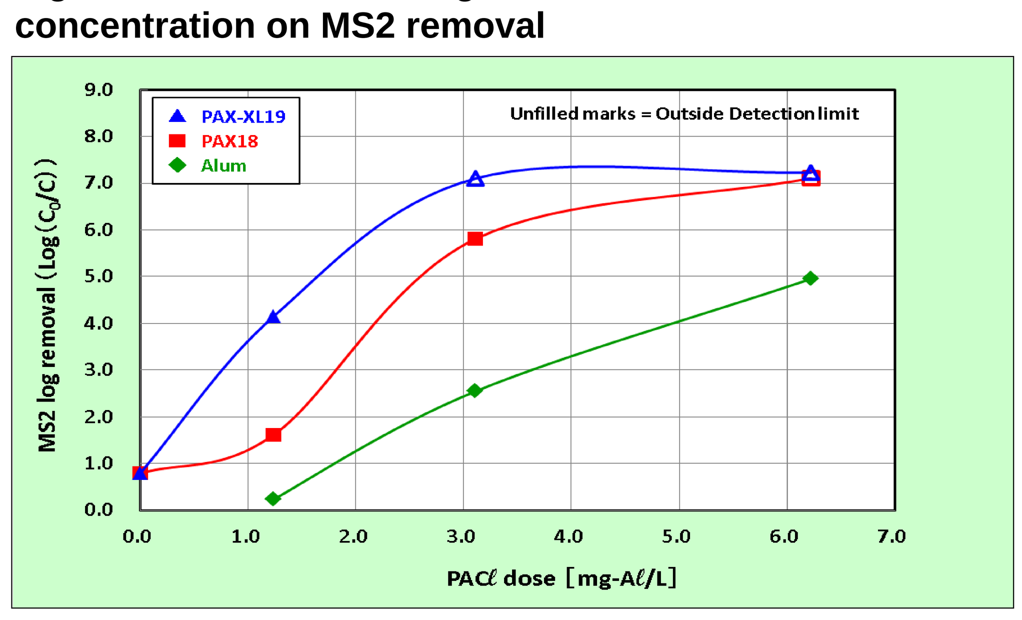


Figure 8. Removal of MS2 from 2° Effluent using high-basicity PACl

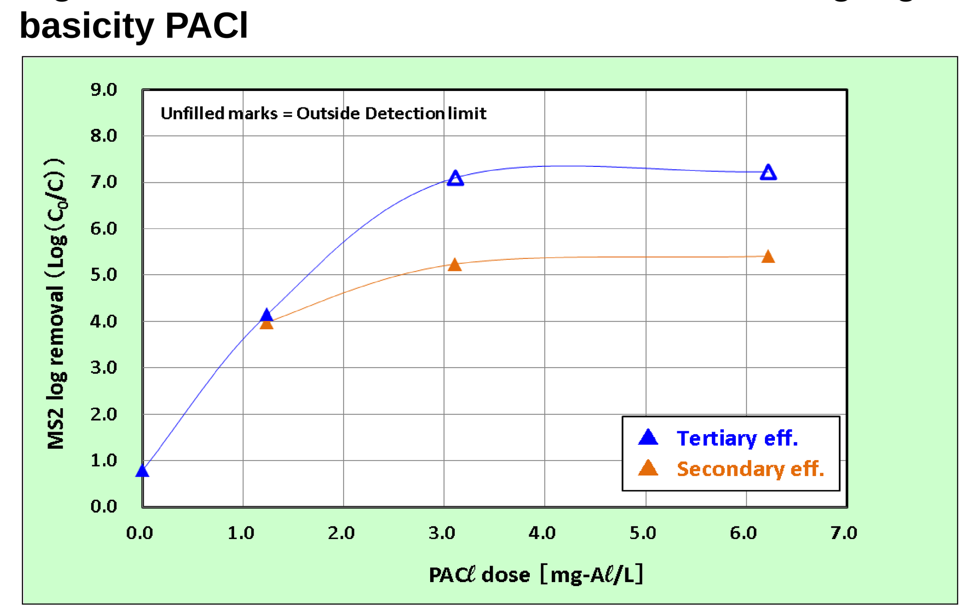


Figure 9. Removal of PMMoV from 3° Effluent using high-basicity PACl (PAX-XL19)

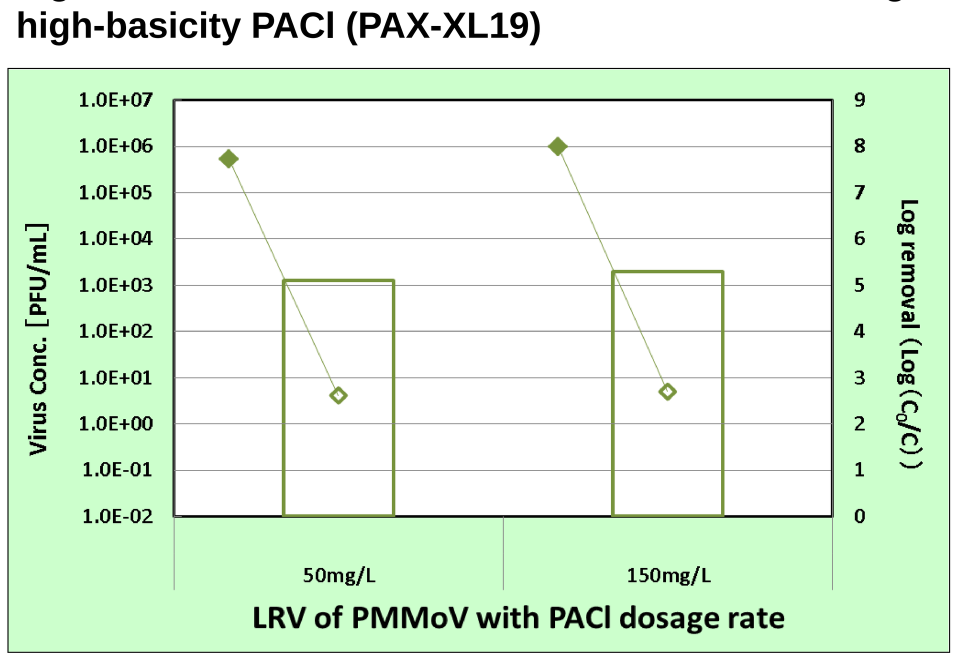
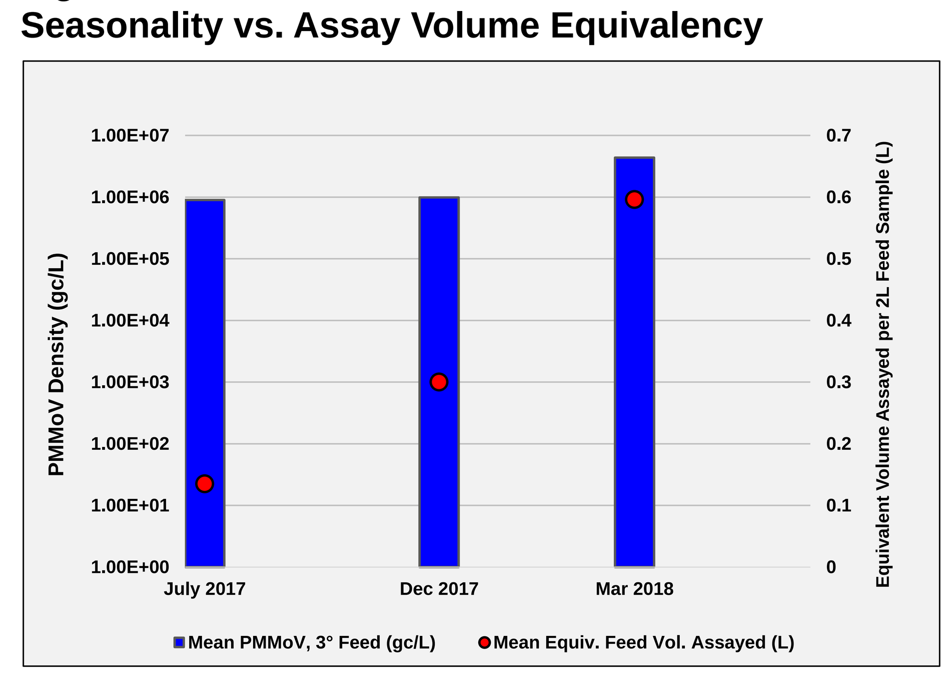


Table 1. Removal of PMMoV from 3° Effluent using high-basicity PACl (PAX-XL19) at 50 mg/L

Continuous Run Dates (*n*)	PACl Dosage (mg/L)	PMMoV in 3° Feed (gc/L)	PMMoV in Filtrate (gc/L)	Log_{10} Reduction
7/18/17, 7/25/17, 7/27/17 (n=3)	50	4.83E+05 to 2.78E+06	<1.05E+01 to 8.57E+01	4.51 to >4.68
11/30/2017 to 12/19/2017 (n=5)	50	3.90E+05 to 4.06E+06	<3.83E+00 to 3.06E+01	4.58 to 5.88
3/6/2018 (n=1)	50	4.69E+06	3.59E+01	5.12

- **Figures 6 & 7: High-basicity PACl demonstrates consistent removal (>7-log10) of MS2 to levels below LOD (<1 PFU/10mL) compared to other coagulants**
- **Figure 8: Log_{10} removal >5-log10 achieved by 50 mg/L PACl from 2° Effluent**
- **Figure 9 & Table 1: Lower PACl concentrations (50 mg/L) demonstrate similar coagulation capacity as higher PACL doses (150 mg/L) for removal of PMMoV**
- **Figure 10: PMMoV levels in 3° Effluent demonstrate upward trend over course of study, contributing factors under investigation**

Figure 10. PMMoV Detected in 3° Effluent Feed Water: Seasonality vs. Assay Volume Equivalency



CONCLUSIONS

- Coagulation-microfiltration is a promising advanced water treatment technology for consistent virus removal from 3° Effluent wastewater that may be employed for DPR purposes in the near future.
- Although high-basicity PACl (PAX-XL19) is more expensive than other Al-based coagulants, its higher Al content imparts greater removal efficacy as demonstrated by MS2 and PMMoV data.
- More research is needed to determine sources of variability for PMMoV in 3° Effluent, including inherent seasonality effects and sample processing/concentration methods to enhance equivalent volumes.

References:
1. Haramoto, E., *et al*. Occurrence of *Pepper Mild Mottle Virus* in drinking water sources in Japan. Applied and environmental microbiology, 79(23), 7413-7418.
2. Rosario,K., et al. *Pepper mild mottle virus* as an indicator of fecal pollution. Applied and environmental microbiology, 75(22), 7261-7267.

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