Contaminant Removal Using Membrane Distillation for Sustainable Drinking Water Treatment

Amy E. Childress[1], Edward P. Kolodziej[2], Chanwoo Park[3], Sage R. Hiibel[2], Austin A. Krater[2], Vahid Vandadi[3], Roberto Bejarano[3], Tianlin Song[2]

[1]Department of Civil and Environmental Engineering; University of Southern California

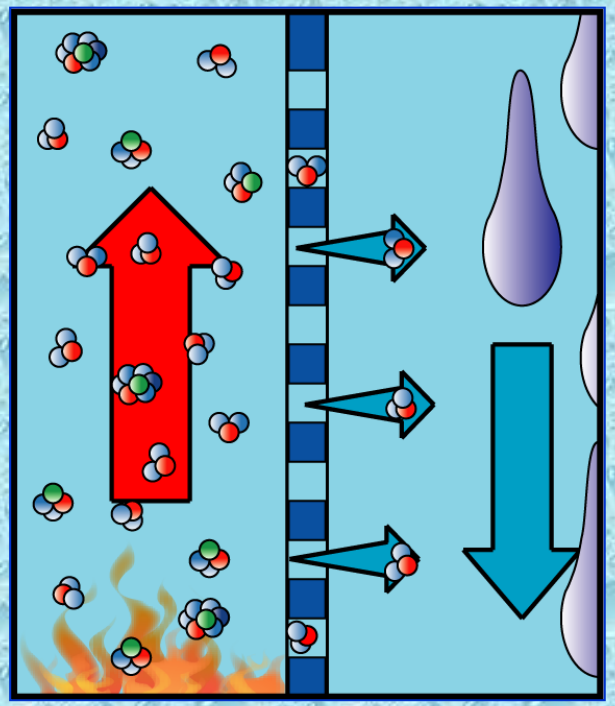
[2]Department of Civil and Environmental Engineering; University of Nevada, Reno

[3]Department of Mechanical Engineering; University of Nevada, Reno

Membrane Distillation (MD)

- Membrane separation process
- Exploits temperature gradients for in-membrane phase change
- Mass transfer induced by vapor pressure difference
- Only small temperature differences required (ΔT of 20-50 °C)

Warmer Feed Ex: 60°C



Cooler Distillate Ex: 30°C

Temperature: High → Low

Water Quality: Low → High

MD System Advantages

- Ideal technology for small systems in a complex regulatory environment
  - Simple one-step treatment train (membrane module, 2 LP pumps)
  - Broad spectrum contaminant removal (often >99+%)
  - Energy source: low-grade ("waste") heat
  - Municipalities; also industrial and commercial point-of-use applications
- Appropriate for treatment of high concentration feed waters (e.g., brines and produced waters) likely to scale/foul in conventional reverse osmosis (RO) membrane systems
- Can achieve higher quality product water by removing contaminants that can pass through RO systems
- Many "polishing" applications possible

Project Objectives

1) Evaluate contaminant removal performance

   -When to expect excellent or reduced performance?

2) Design and build a small-scale pilot MD system with an adaptable heat exchange system

   - -Innovation: Systems engineering and optimization, scale up

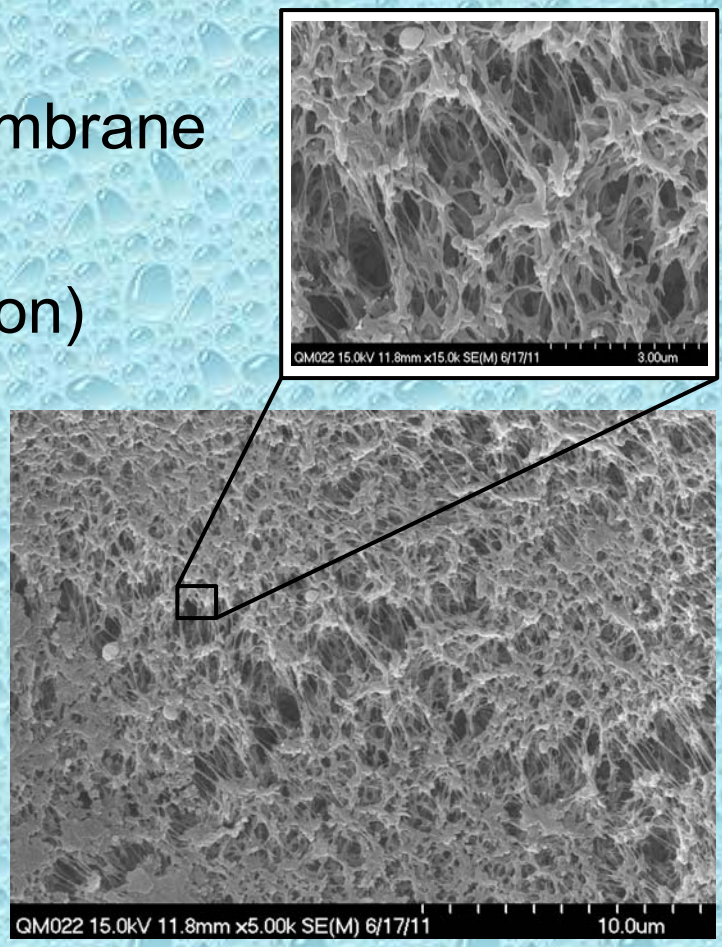
3) Operate MD system using on-site waste heat source

   - NV Division of Environmental Protection collaboration
   - Co-locate water, contaminants and waste energy sources for drinking water treatment
   - Optimize system performance in a field deployment

1) Membrane Characterization

Single layer hydrophobic PTFE membrane

- Liquid entry pressure: 385 kPa
- Pore size: 0.18 µm (gas permeation)
- Contact angle: 131°(goniometer)
- Thickness: 67 µm (SEM)
- Porosity: 80%
- Tortuosity: 1.79

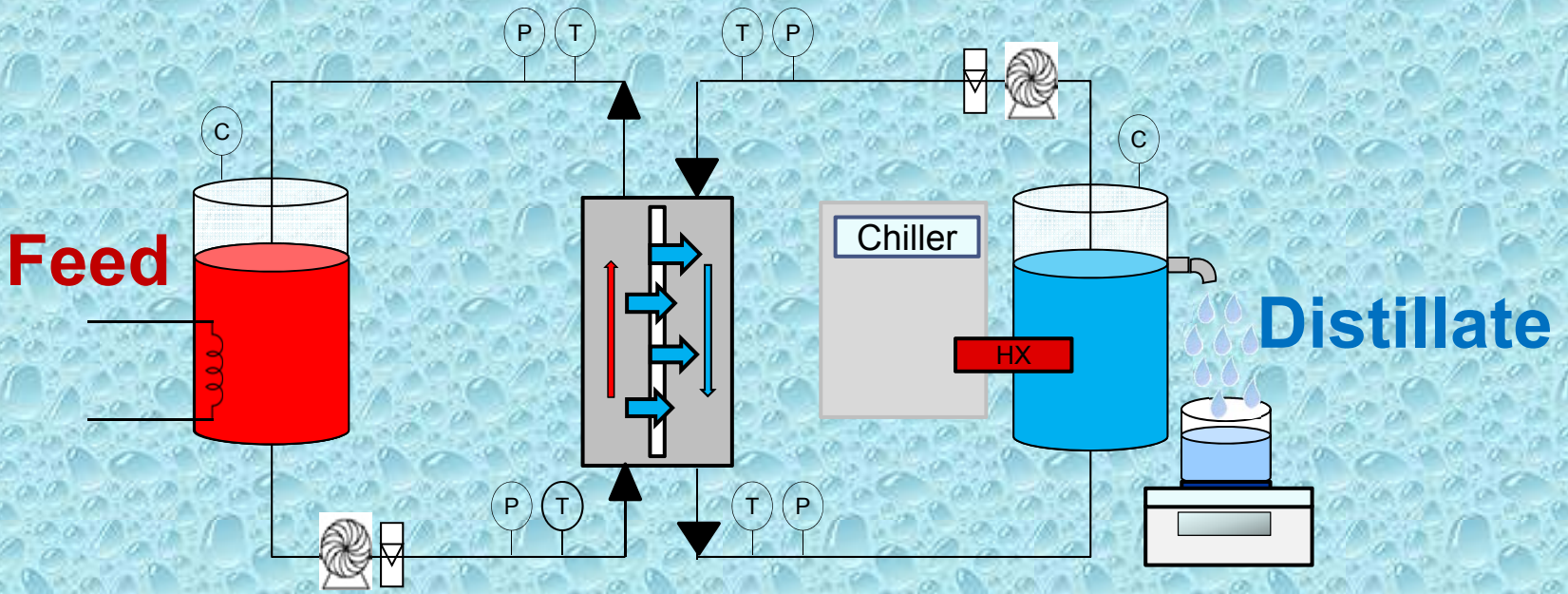


MD: Separation based on phase change:

Liquid → Gas → **Liquid**

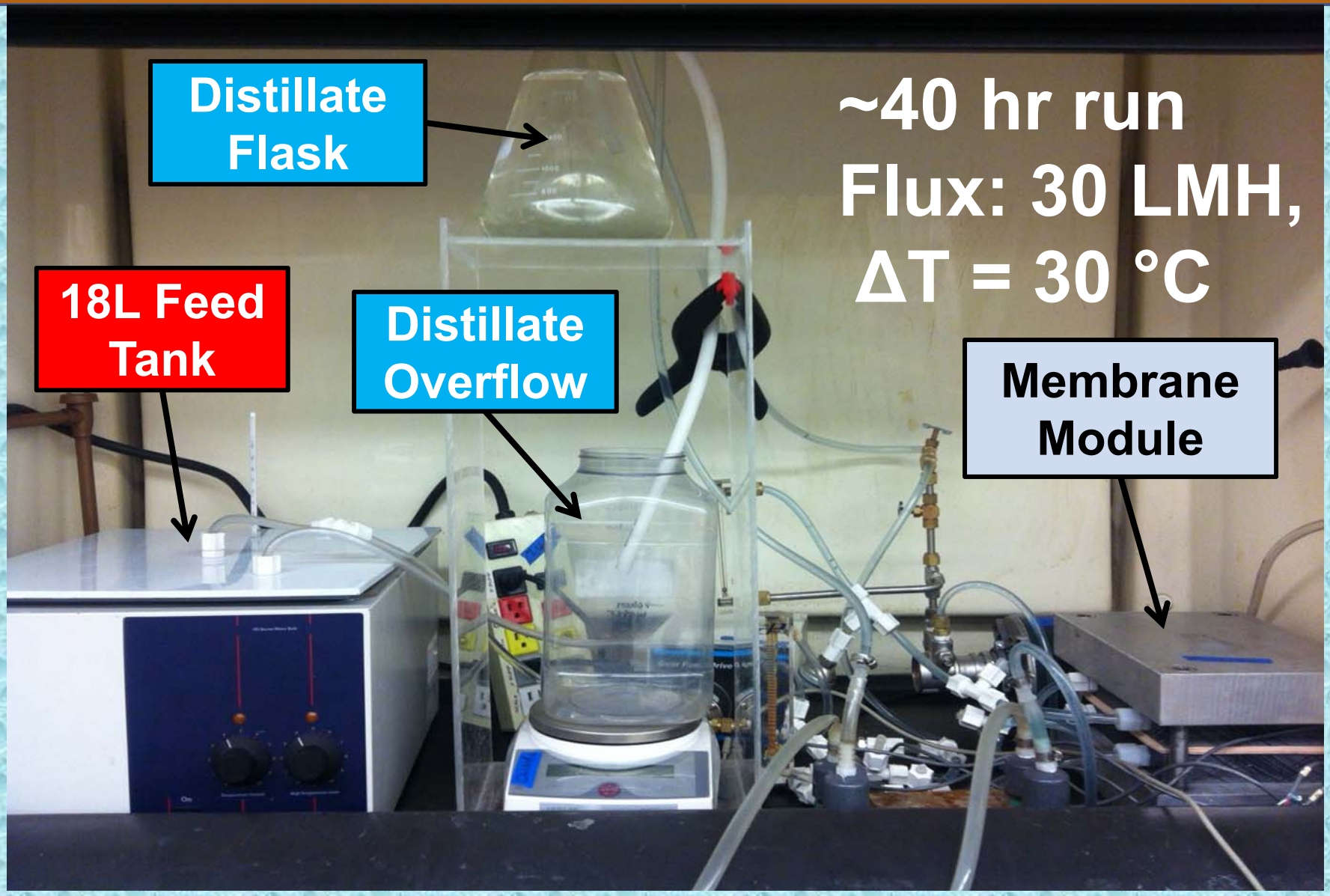
1) Bench-Scale System

- Heated feed solution; distillate cooled with circulating chiller
- Membrane surface area: 139 cm^2

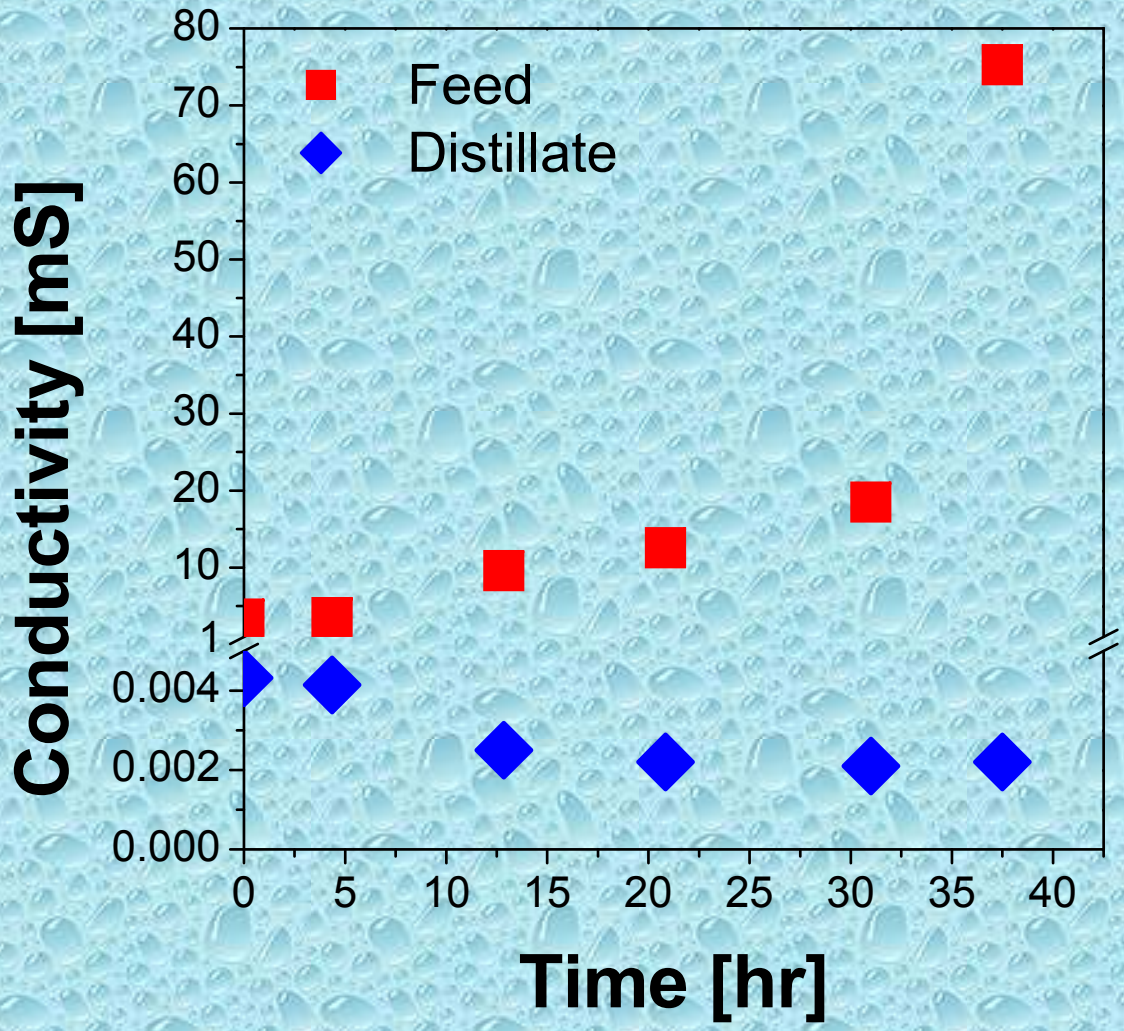


- Feed solutions spiked with contaminant classes
  - Ions, metals, pharmaceuticals and personal care products (PPCPs), volatile organic components, organic carbon nitrogenous and chlorinated disinfection by-products (DBPs)
  - Wide variety of analytical methods needed

1) Bench-Scale System



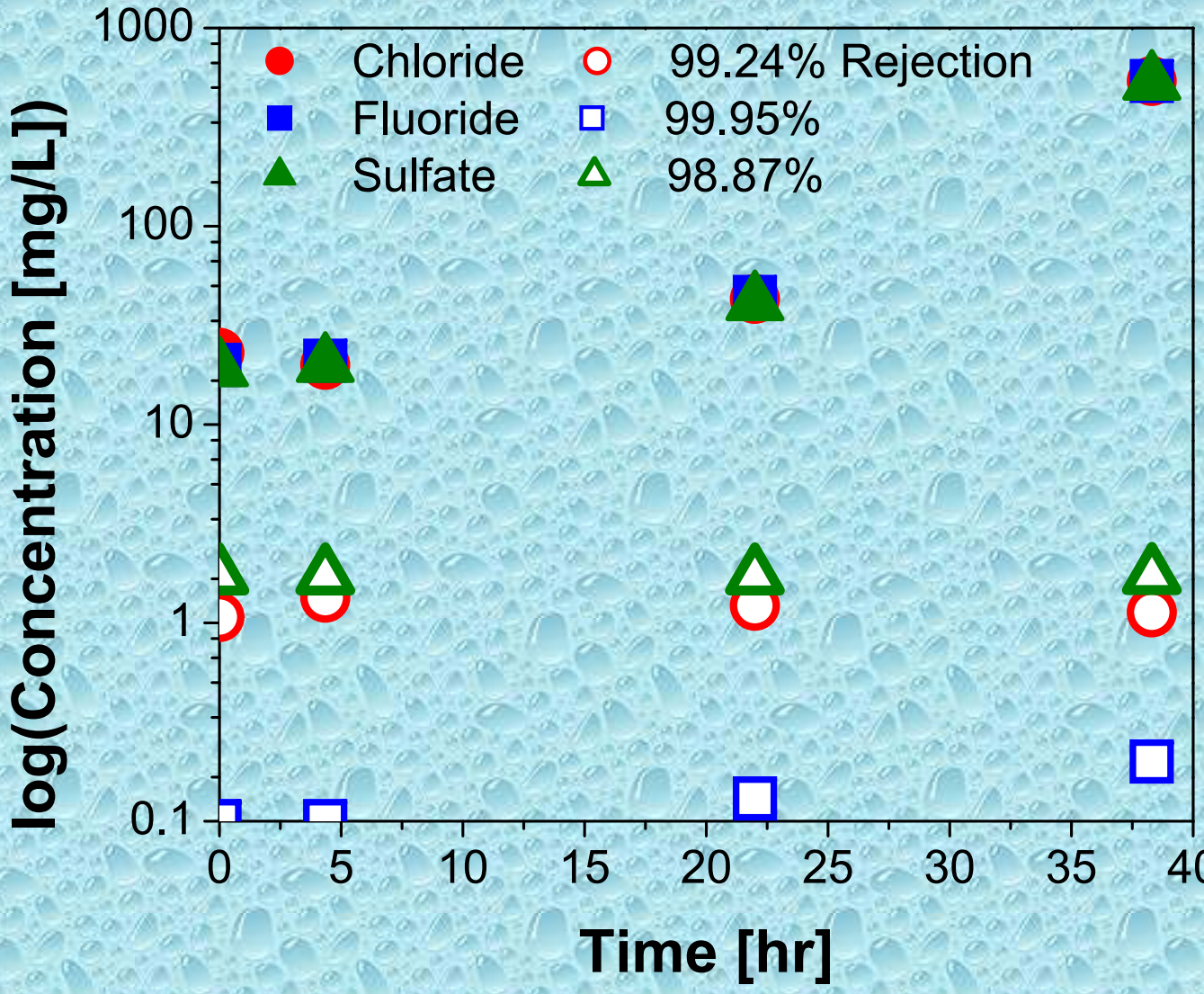
1) Bench-Scale Results



Control system: monitor distillate conductivity

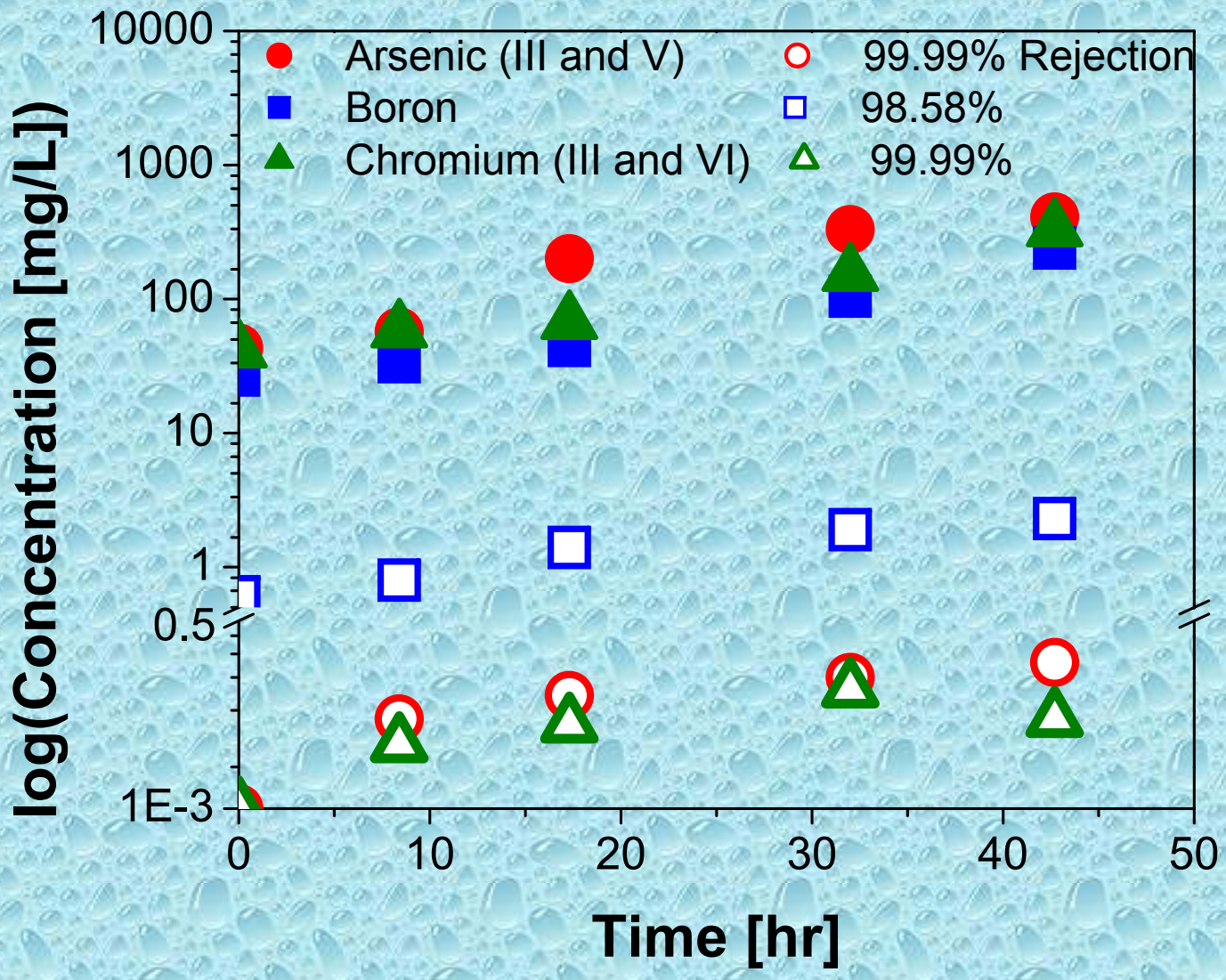
Total ionic rejection at 99.86% (based on conductivity)

1) Bench-Scale Results



System mass balances close

1) Bench-Scale Results



2) Pilot-Scale System

- Feed solution warmed with waste heat source (flue gas)
- Distillate cooled with cooler or via ambient cooling
- Fabrication site: UNR Main Heat Plant
- Feed spiked with representative contaminants
- Adaptable heat exchanger will be installed either (a) before or (b) after the economizer

3) Ongoing and Future Work

-Bench Scale: Evaluate removal performance for DBPs, PPCPs, perchlorate, volatiles and semi-volatiles

- Gas-tight system for volatiles analysis
- Potential concentration enhancement if $P_{contam} > P_{H2O}$
- Can Henry's Law predict removal performance?

-Pilot Scale: Systems Engineering

- Heat exchanger design, sizing, and installation for the initial fabrication site UNR Main Heat Plant underway
- Interchangeable gas-to-liquid heat exchanger

-Small-Scale Field Deployment: NV Division of Environmental Protection collaboration

- Future test sites, co-locate waste heat and water
- Contaminants and contaminant classes of interest

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Project Contact

Edward P. Kolodziej
koloj@unr.edu