



Pilot-Scale Assessment of Ferrate for Wastewater Recycling

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NEWEA Annual Conference & Exhibit, Session 26

Water Reuse in Action: Technologies & Operations

Wednesday January 26, 2022



Background & Motivation

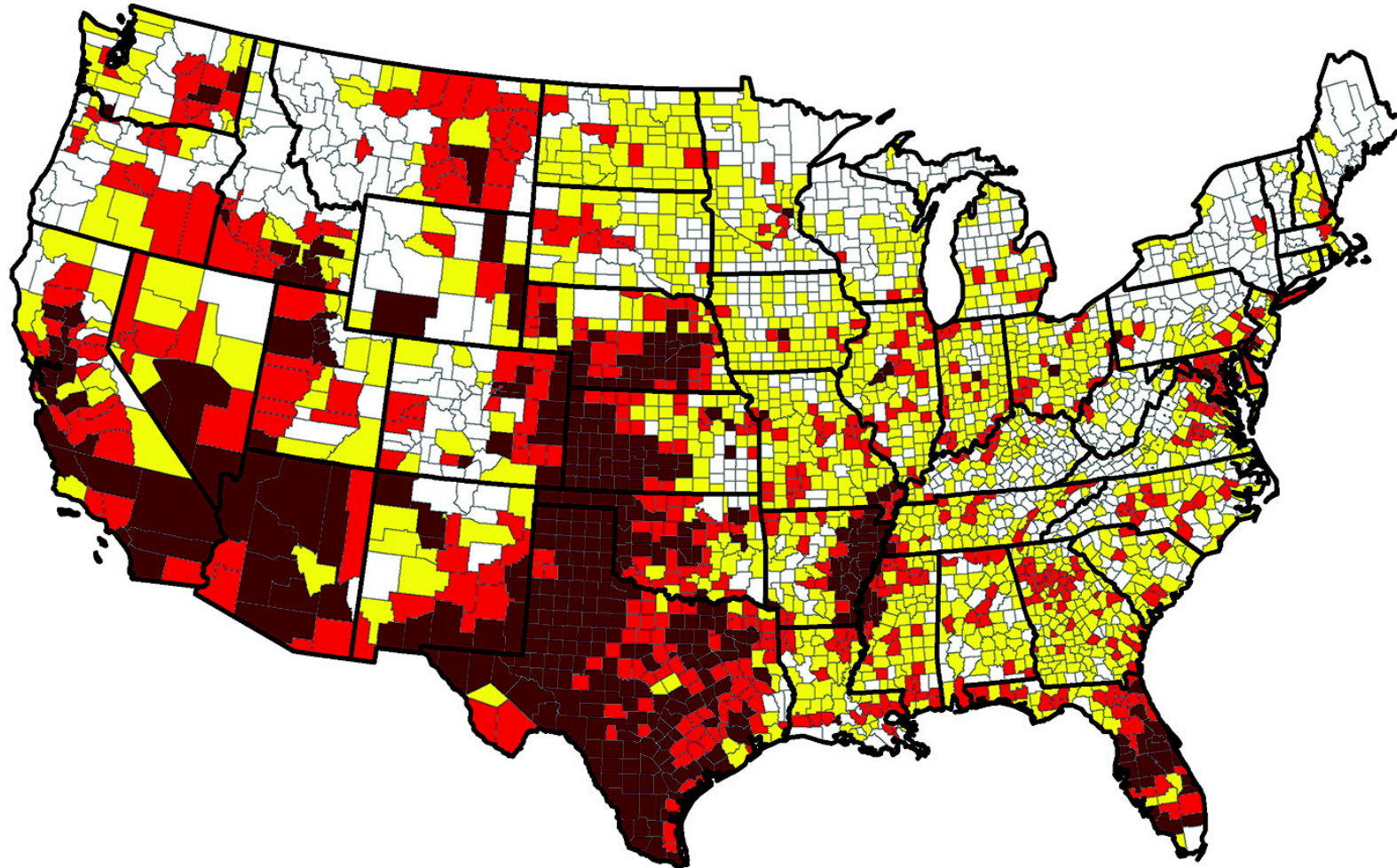
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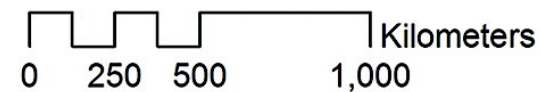


American Water Stress



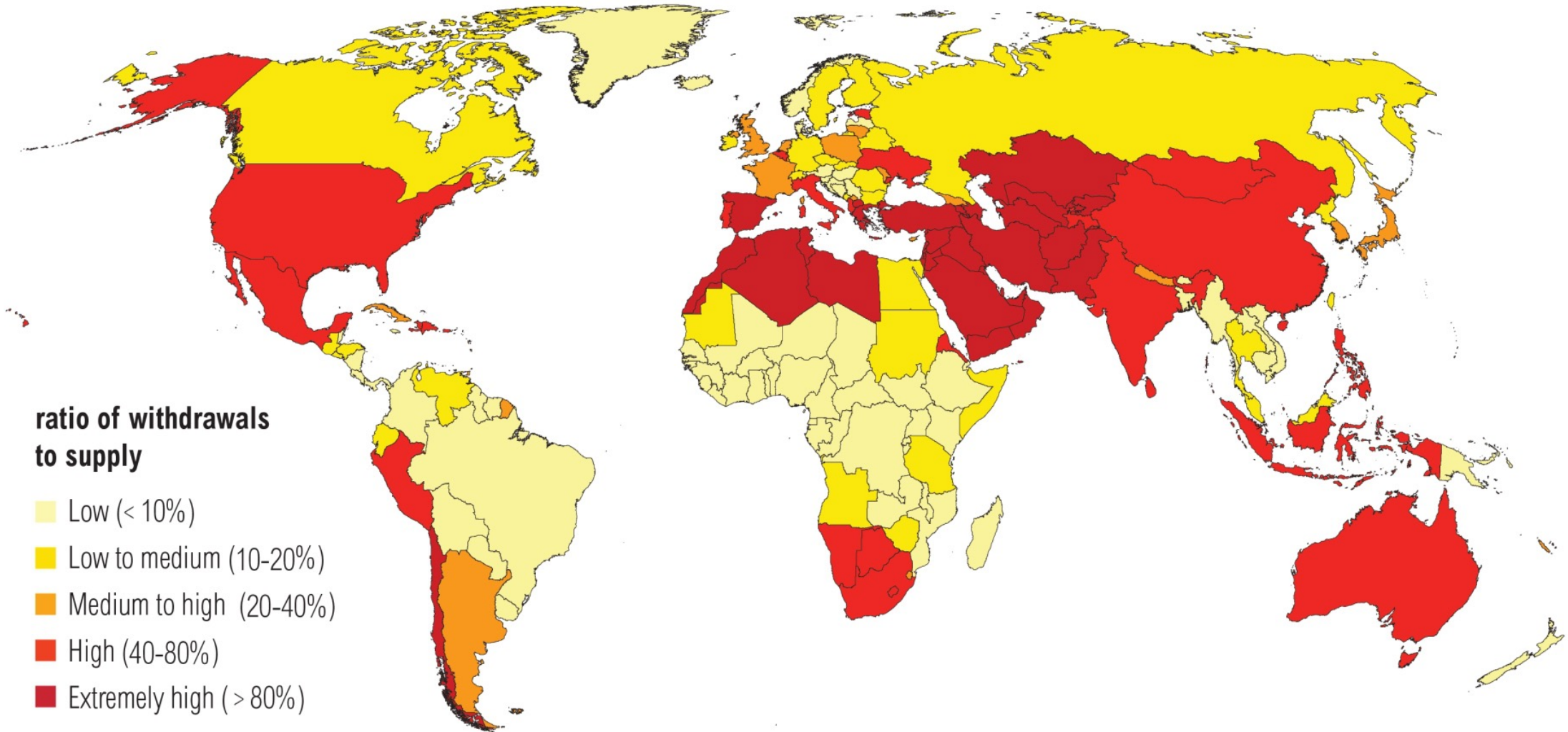
**Water Supply Sustainability Risk Index (2050)
Climate Change Effects**

- Extreme (412)
- High (608)
- Moderate (1192)
- Low (929)



Not Only an American Issue

Water Stress by Country: 2040



A Future Problem?

NATIONAL GEOGRAPHIC SCIENCE | NEWS

Why is America running out of water?

Decreasing precipitation and rising populations could bring a perfect storm of water going?

Utahns asked not to water lawns amid drought

by McKenzie Stauffer, KUTV | Monday, March 22nd 2021

Town Of Narragansett: Water Restrictions : Effective Immediately

To All Narragansett Water Users Effective IMMEDIATELY we are imposing an outdoor watering restriction

Press Release Des

Posted Wed, Jun 9, 2021 at

As climate change makes more droughts likely, state plans to issue controversial new policy that may increase water restrictions



'Red alert': Lake Mead falls to lowest water level since Hoover Dam's construction in 1930s

Ian James Arizona Republic

Published 2:38 p.m. ET Jun. 10, 2021 | Updated 4:39 p.m. ET Jun. 11, 2021



CNN Weather

Multiyear drought builds in western US with little relief in sight

By Chad Myers and Monica Garrett, CNN Meteorologists

Updated 11:24 AM ET, Mon March 8, 2021

CNBC MARKETS BUSINESS INVESTING TECH POLITICS CNBC TV WATCHLIST PRO 6

ENVIRONMENT

Nearly half the U.S. is in drought and conditions are expected to grow worse, NOAA says

PUBLISHED THU, MAR 18 2021-12:12 PM EDT

Emma Newburger @EMMA_NEWBURGER

SHARE f t in e

A Future Problem?

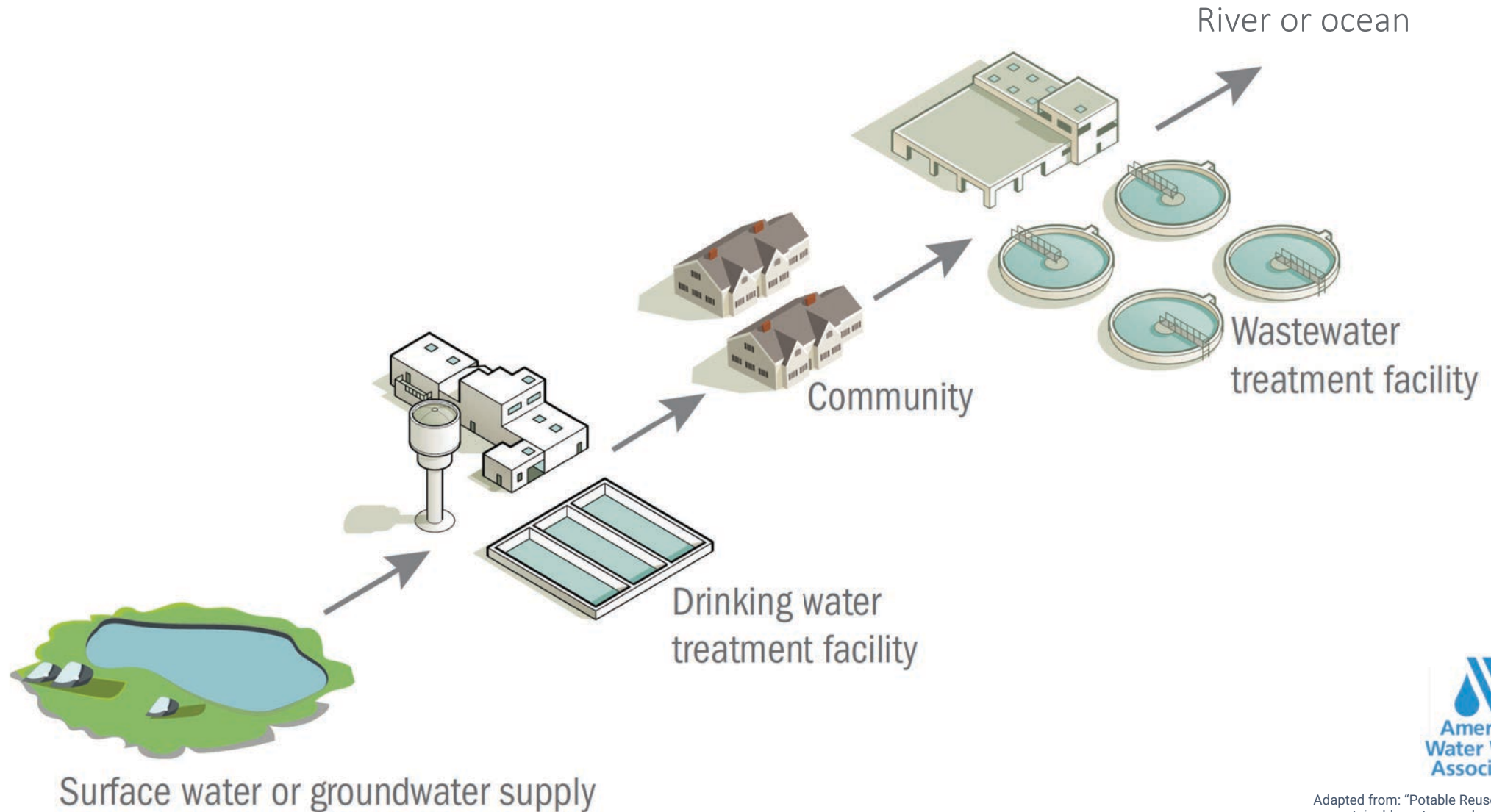


Sept. 2015

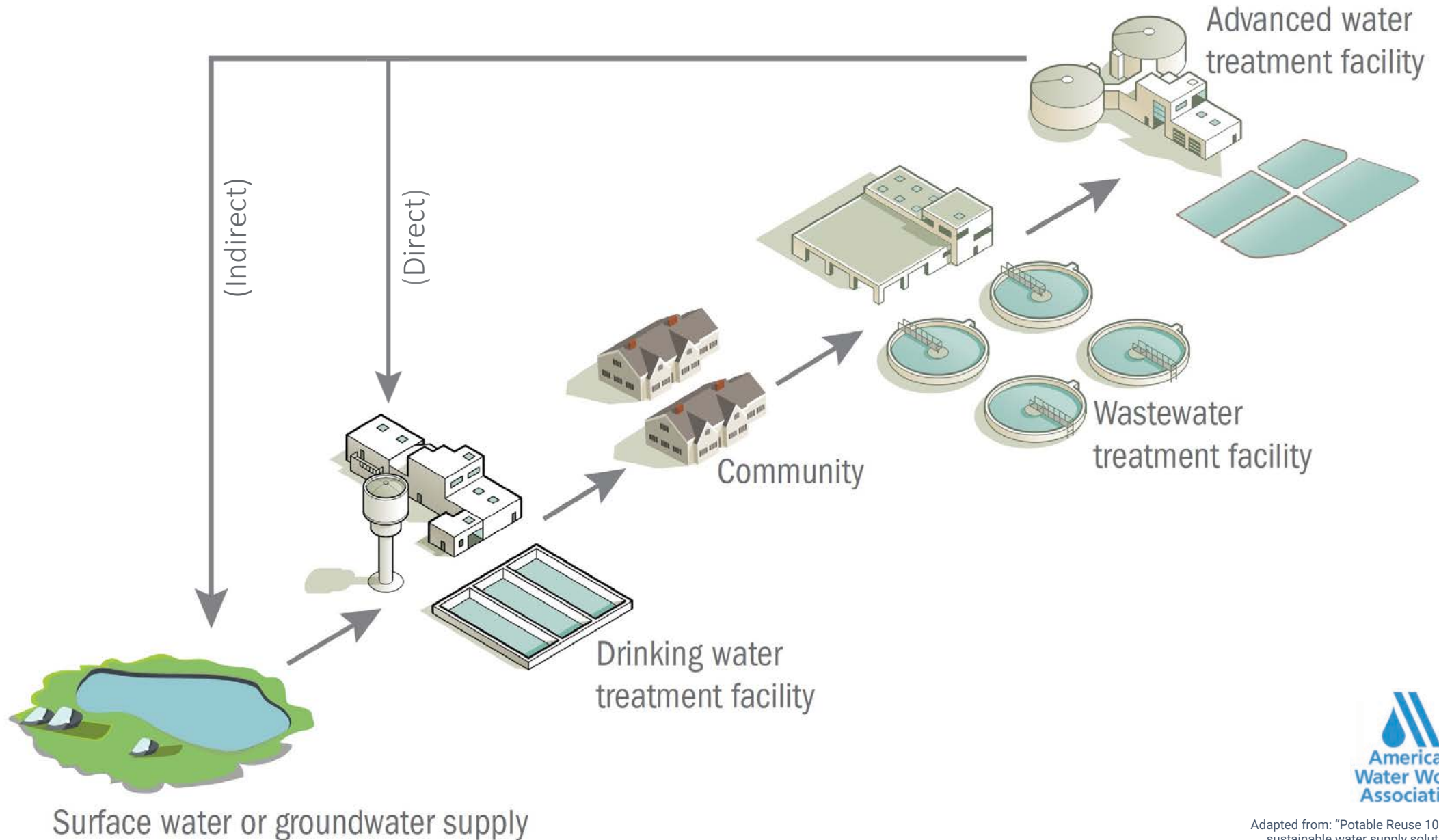
May 2016

NO
TRESPASSING
PUBLIC WATER
SUPPLY
CITY OF CAMBRIDGE

Current Water Paradigm



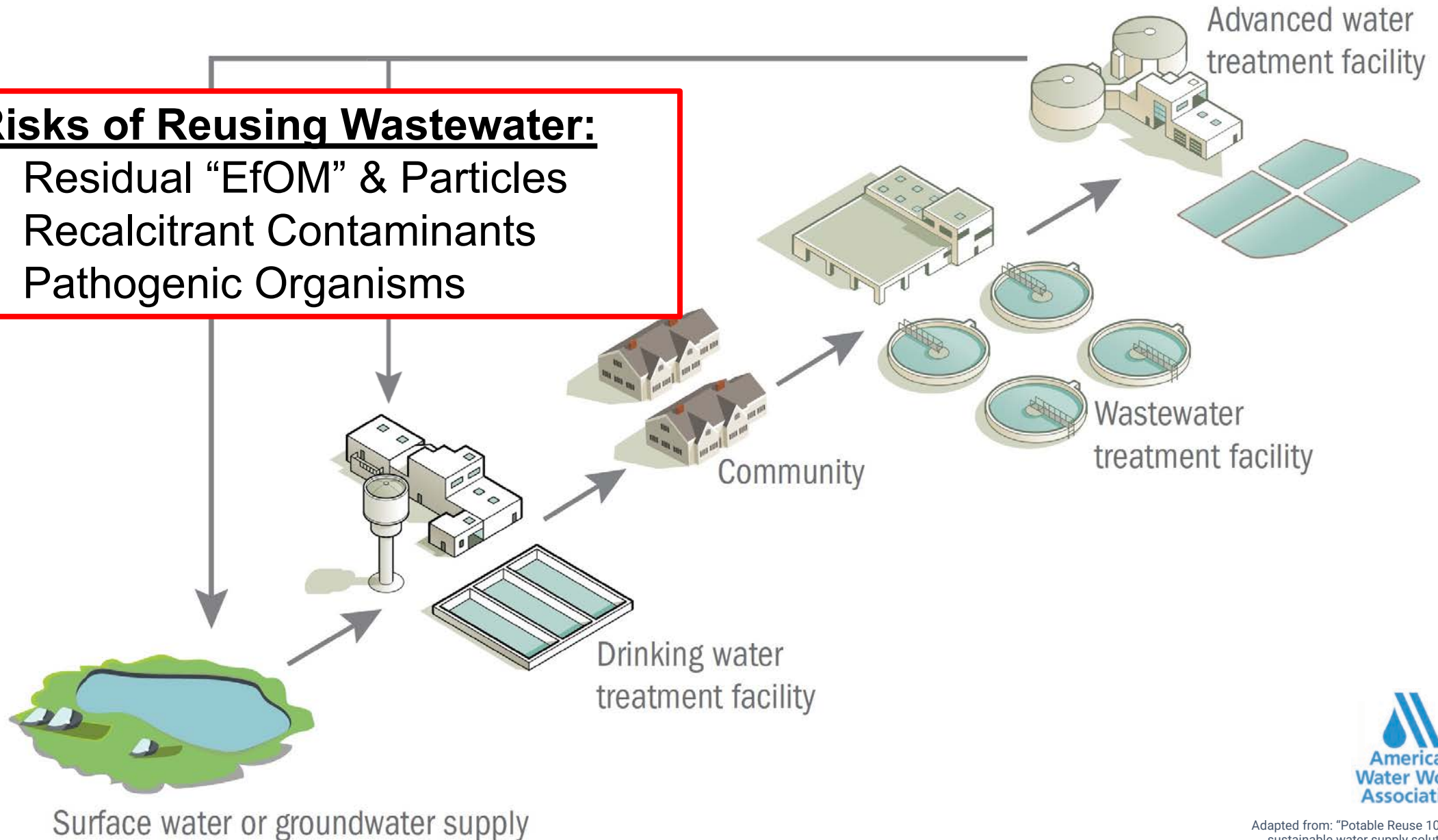
Solution: Shift Towards Recycling Wastewater



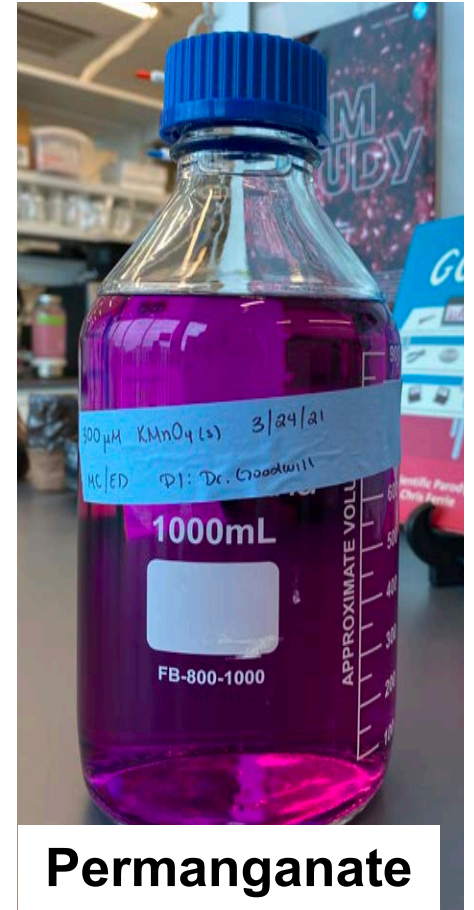
Solution: Shift Towards Recycling Wastewater

Risks of Reusing Wastewater:

- Residual “EfOM” & Particles
- Recalcitrant Contaminants
- Pathogenic Organisms

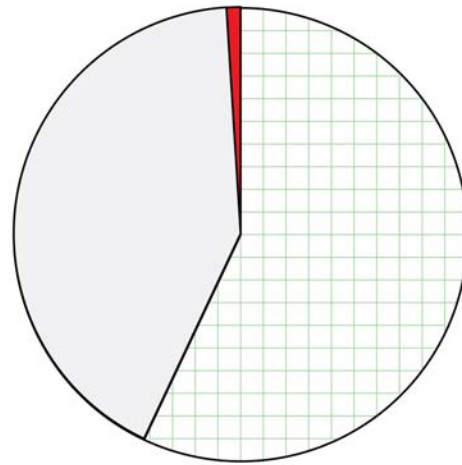


Existing Risk-Mitigation Technologies

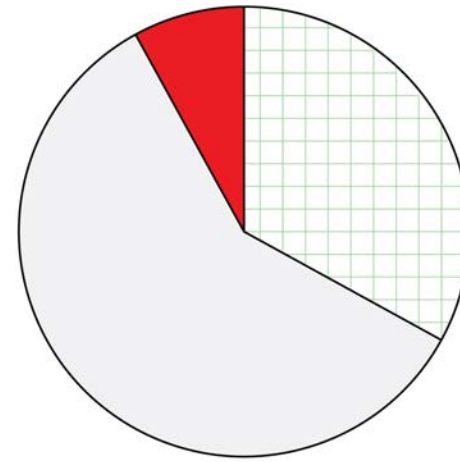


Question:

Are existing oxidation technologies appropriate for small water reuse systems?



Ozone Adaptation



UV Adaptation



Percent of rural, suburban, and urban water systems in the US that utilize existing approaches to advanced oxidation (ozone and UV) indicating a large disparity in rural adaptation. Data from AWWA with assumed setting and size equivalence.

Ferrate as an Alternative

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What is Ferrate?



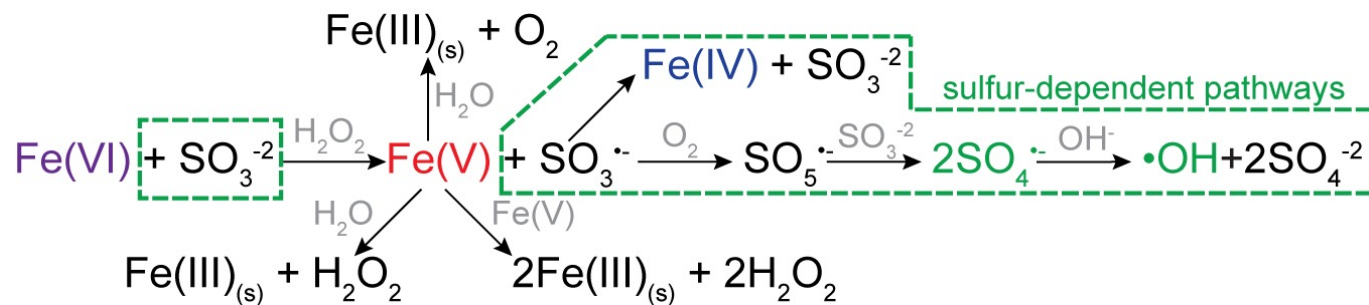
What is Ferrate?

- **Fe⁶⁺, Fe(VI)**
- Strong oxidant (pH dependent)
 - *Similar to Ozone*
- Disinfectant
- Potential Coagulant
- Minimal concern of halogenated disinfection byproducts
- Rapid decay in water to “natural” Fe³⁺
 - Can only be used as a pre-oxidant (before filtration)



“Activated Ferrate”

- **Fe(VI) + Reducing Agent in solution**
 - *Examples: Sulfite, Thiosulfate, HCl*
- Produces a mixture of high-strength radicals (similar to UV/Peroxide) & Fe⁵⁺/Fe⁴⁺
- Leads to significantly improved removal of certain organic pollutants
- **Sulfite-Activated Fe(VI) = “FeSAOP”**



“Pilot-Scale” Integrated-Assessment of Fe(VI) for Wastewater Recycling

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Piloting Motivation:

Laboratory bench-scale experiments (i.e., in a beaker) are insufficient for full-scale adaptation. Ignores the effect of Fe(VI) and FeSAOP on downstream treatment process operation and other water quality parameters.

Piloting Treatment Apparatus

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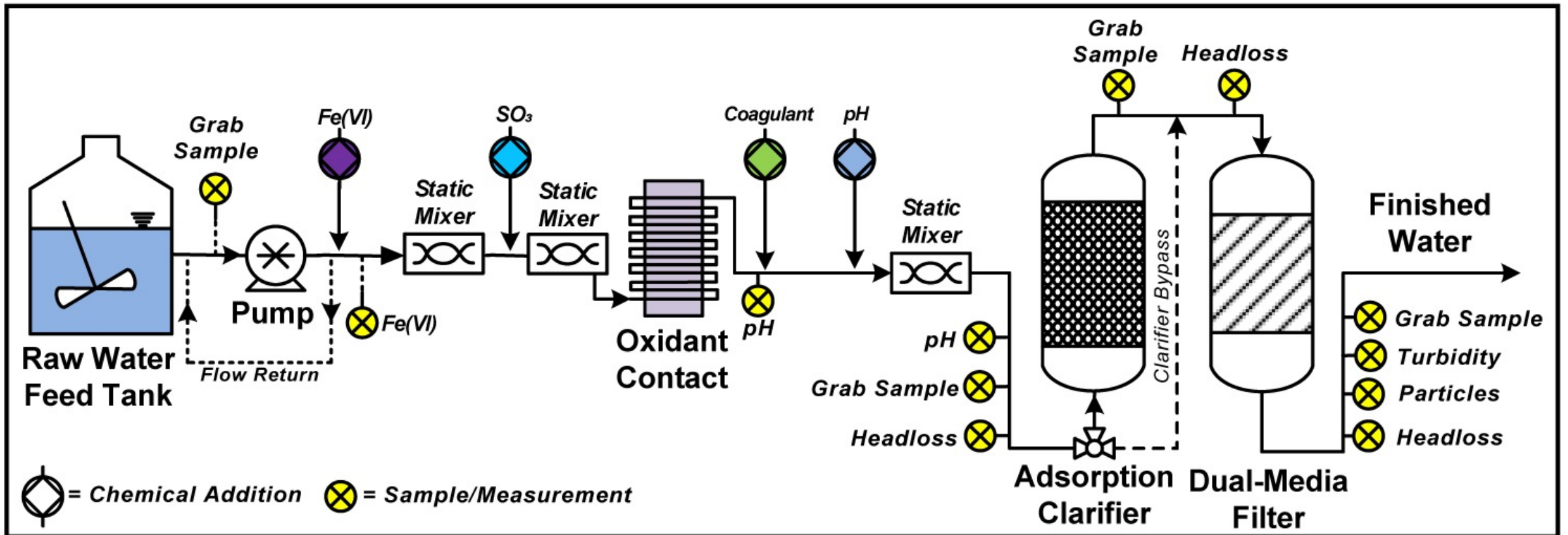
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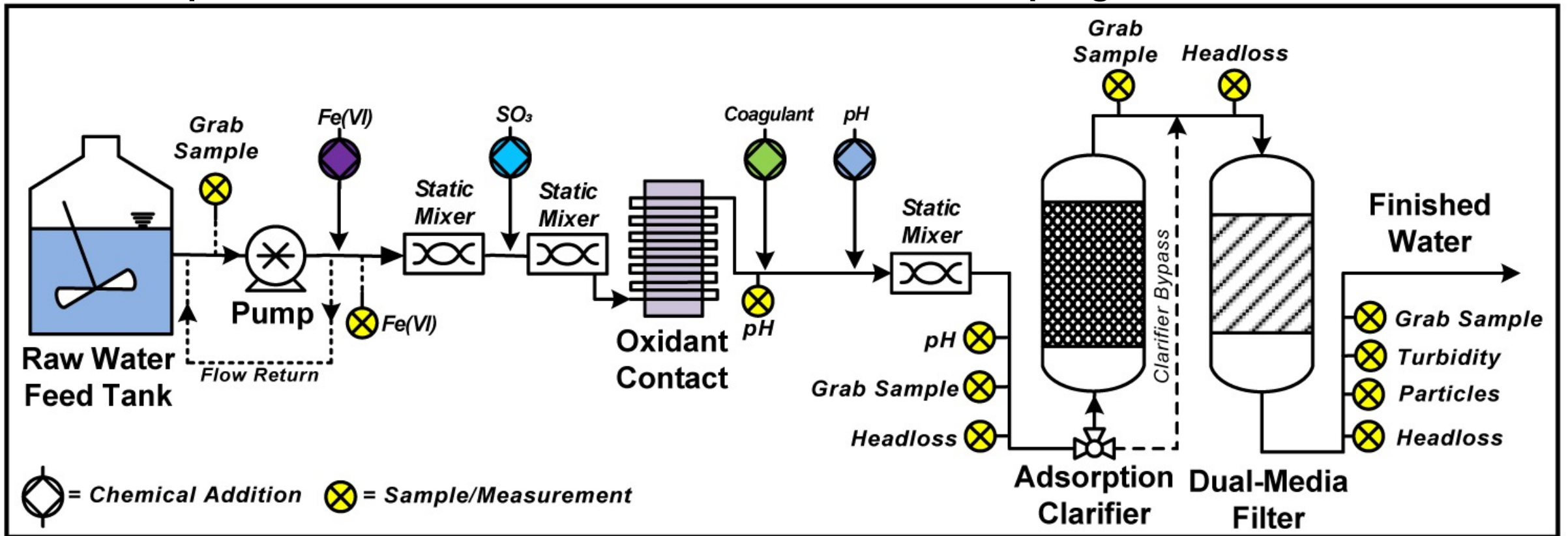
Specific Objective:

Design and Construct an integrated pilot-scale treatment system to treat wastewater effluent by FeSAOP



System Processes

- 250gal raw water tank
- System diaphragm pump
- Ferrate & Sulfite feed pumps (*FeSAOP*)
- 30min pre-oxidation contact tank
- Coagulant feed pump
- Up-flow plastic media clarifier (3' dia)
- Anthracite over sand media filter (4' dia)
- Effluent sampling module



Design & Construction



Completed Pilot Treatment System



Typical Operating Conditions

- **System Flow Rate:** 1 L/min (*~360 gal/day*)
- **Run Time:** 8.0 hours
- **Filter Loading Rate:** 3 gpm/ft²
- **K₂FeO₄ Dose:** 10 mg/L (*3 mg/L as iron*)
- **Sulfite Dose (“Activation”):** 2 mg/L
- **Coagulant:** Cationic Polymer or Ferric Chloride
- **Contaminant Spike:** Caffeine (C₈H₁₀N₄O₂)
- **pH Adjustment:** *None*

Measured Water Quality Parameters

- pH
- Turbidity
- Particle Counts
- Total Nitrogen (“TN”)
- Nitrate (NO_3)
- Phosphate (PO_4)
- Total Organic Carbon (“TOC”)
- UV-Absorbing Organics (“UV254”)
- Caffeine Concentration
- Total Iron (Fe)

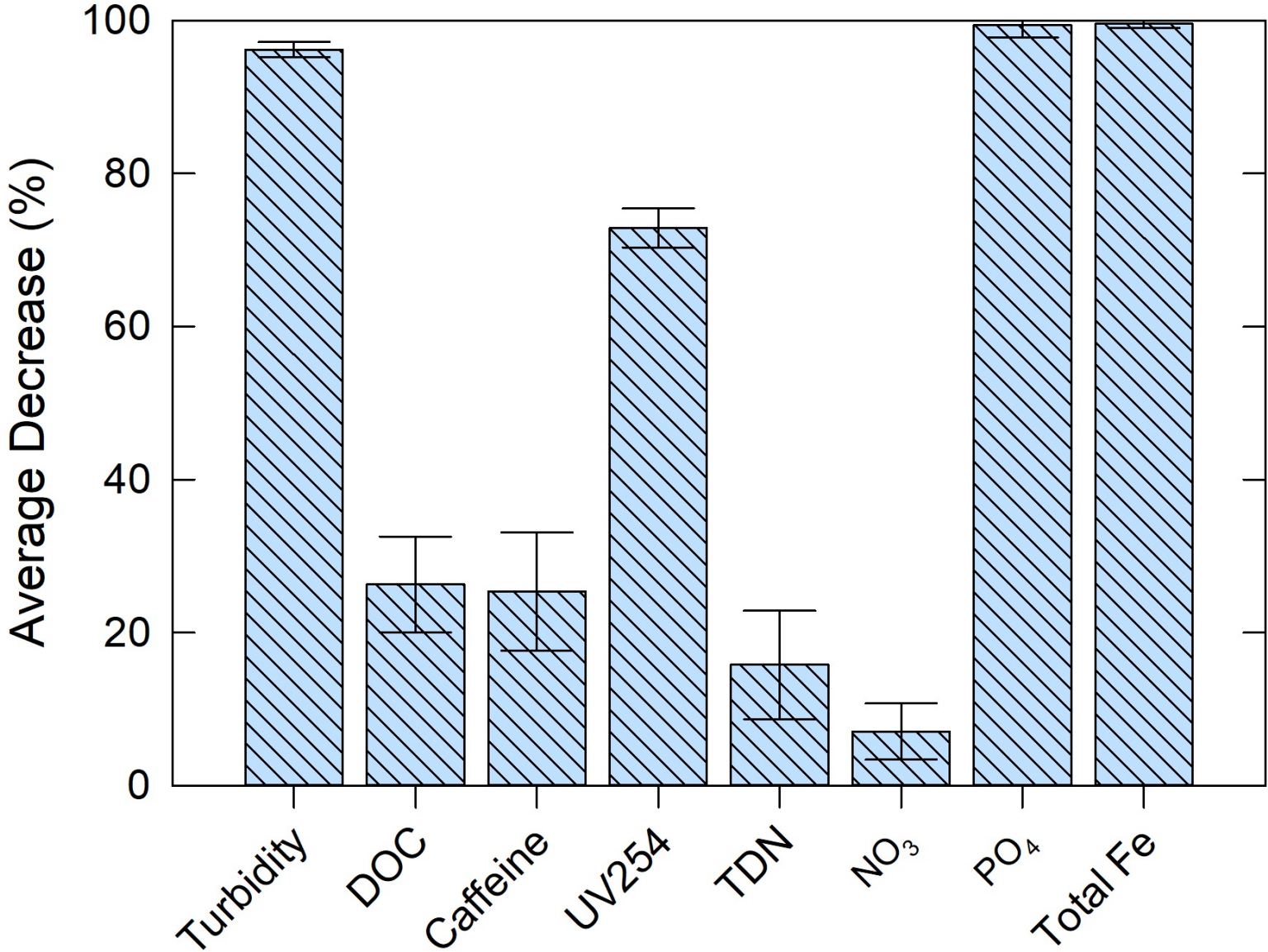


Pilot Run 1: Activated Fe(VI) w/ Synthetic Wastewater

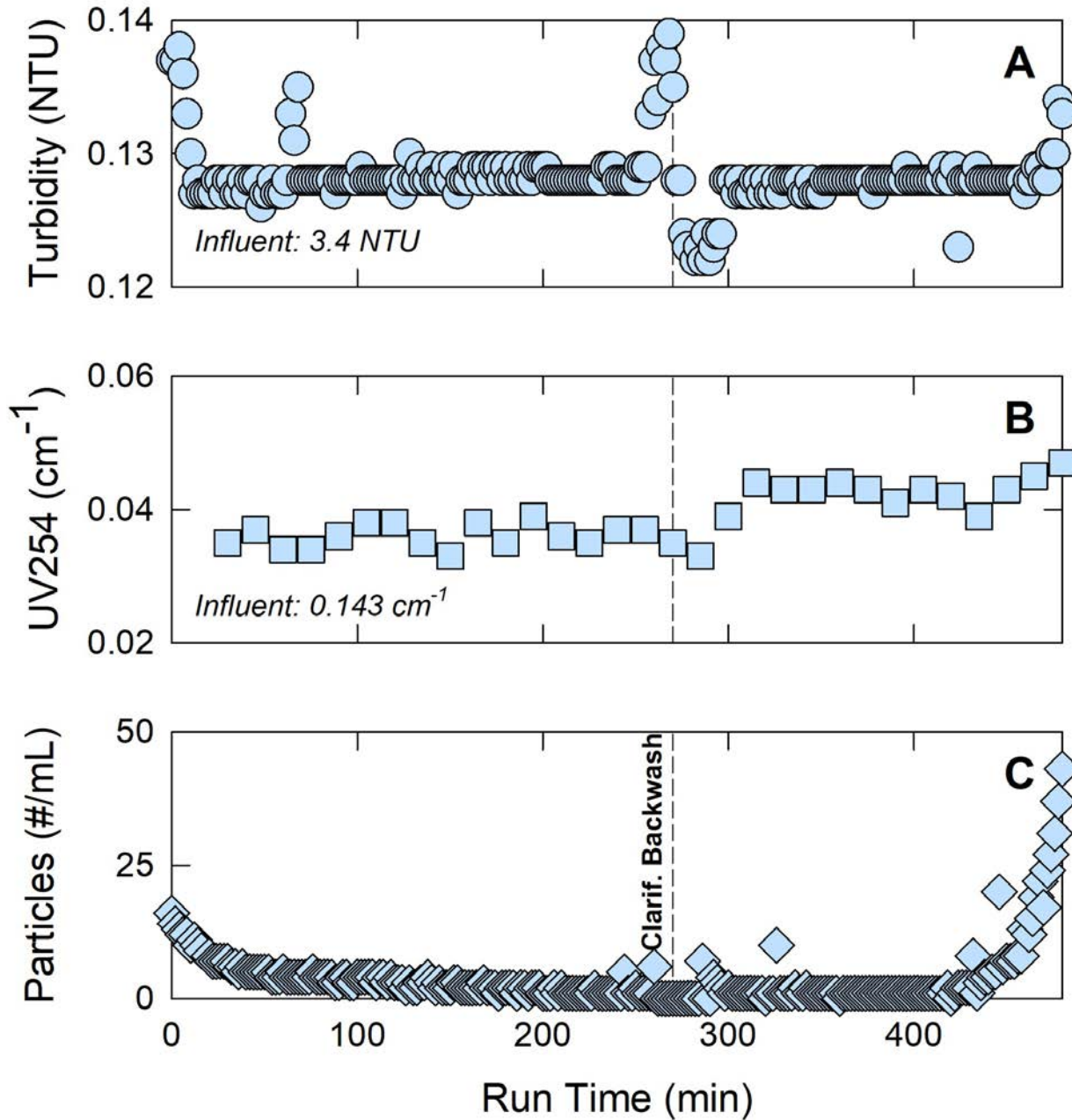
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Removals Across System w/ FeSAOP

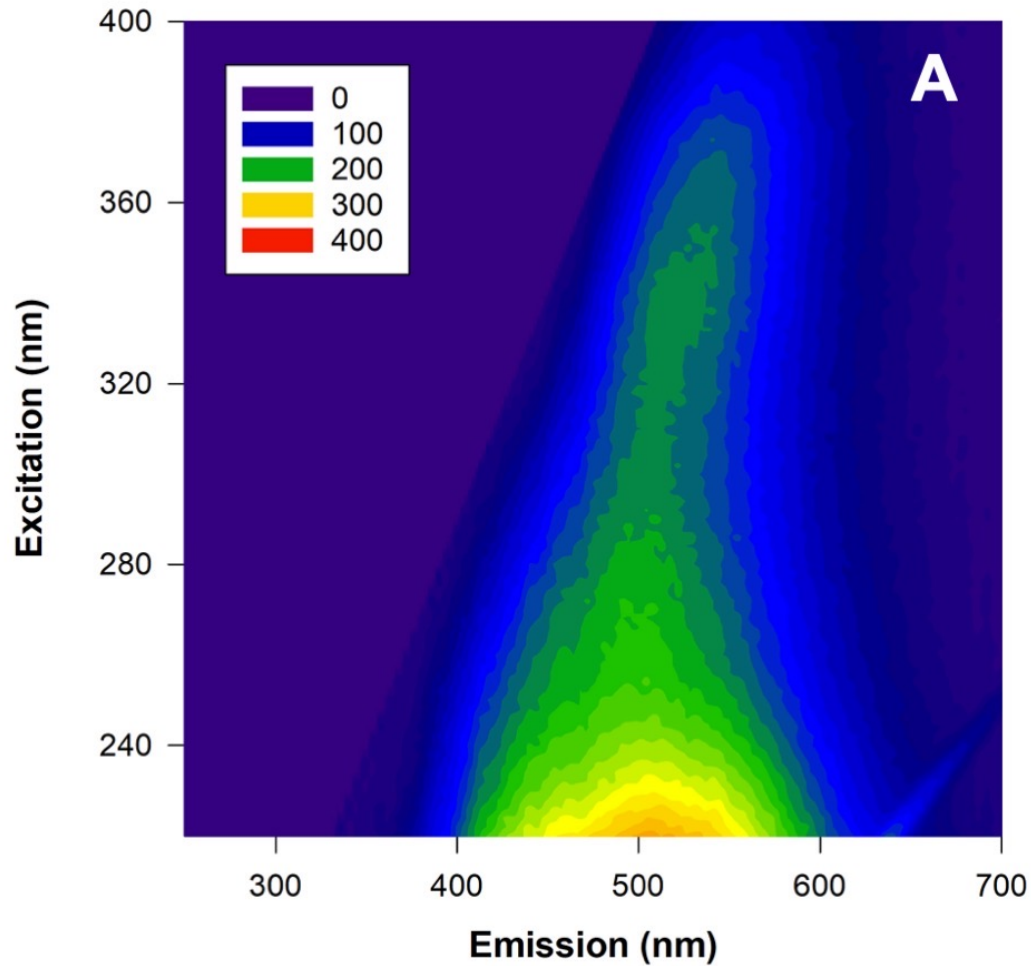


Effluent Quality

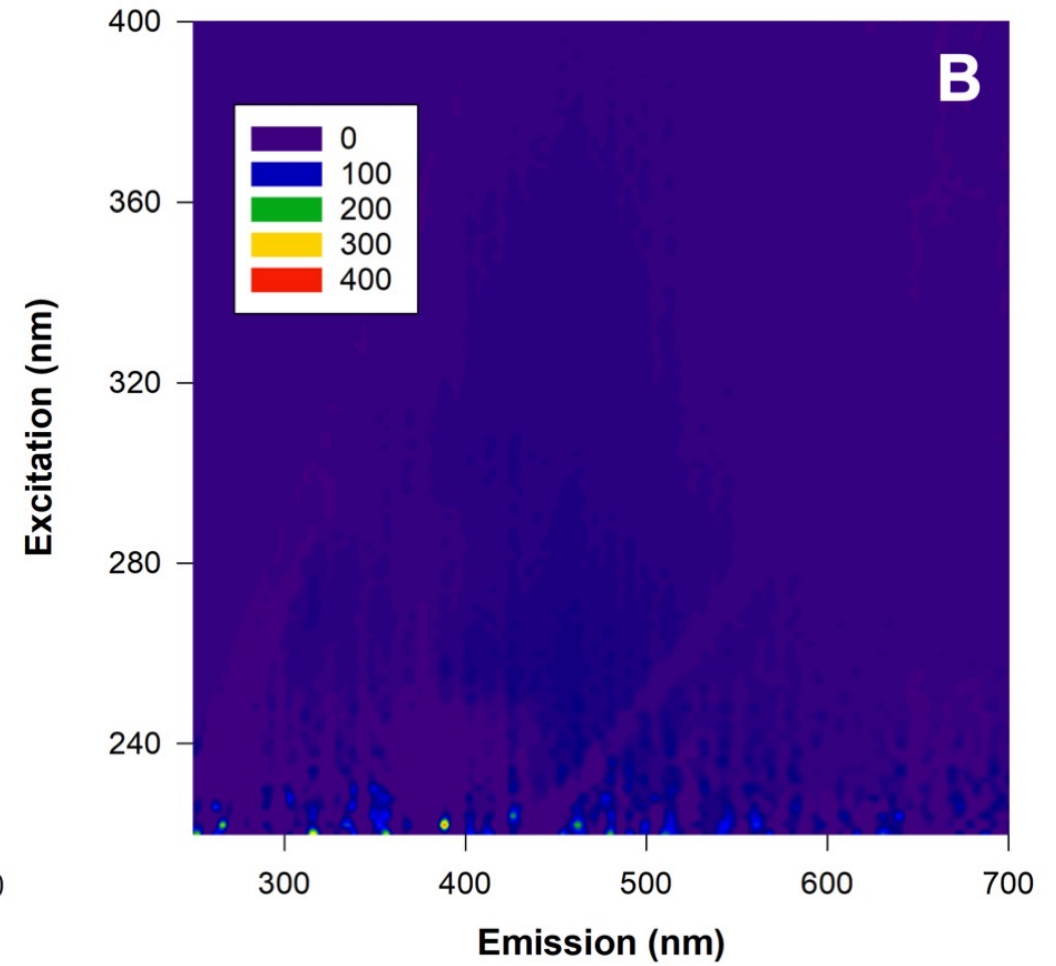


Organic Carbon Fluorescence

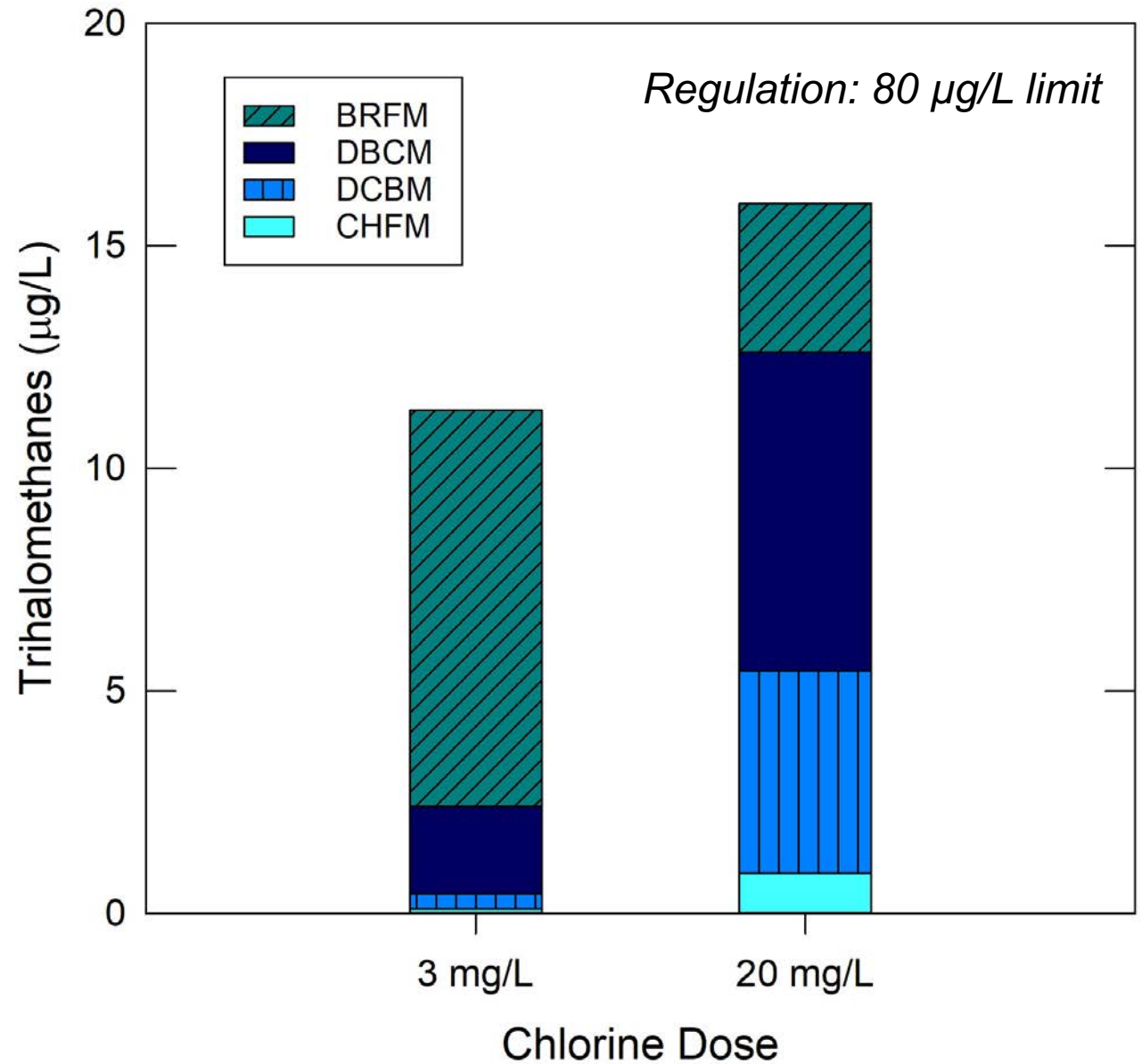
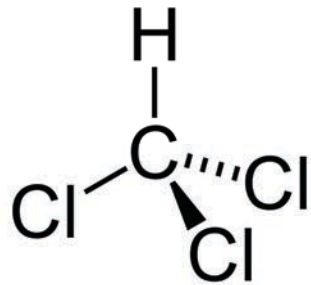
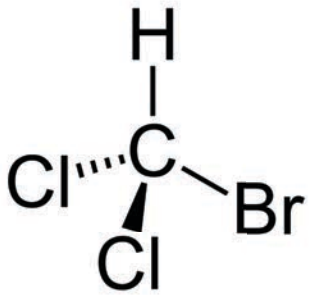
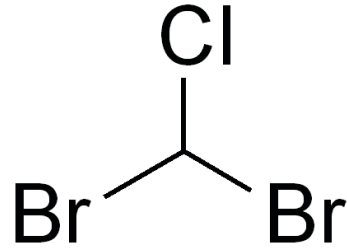
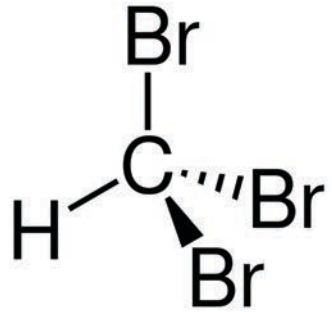
System Influent



System Effluent



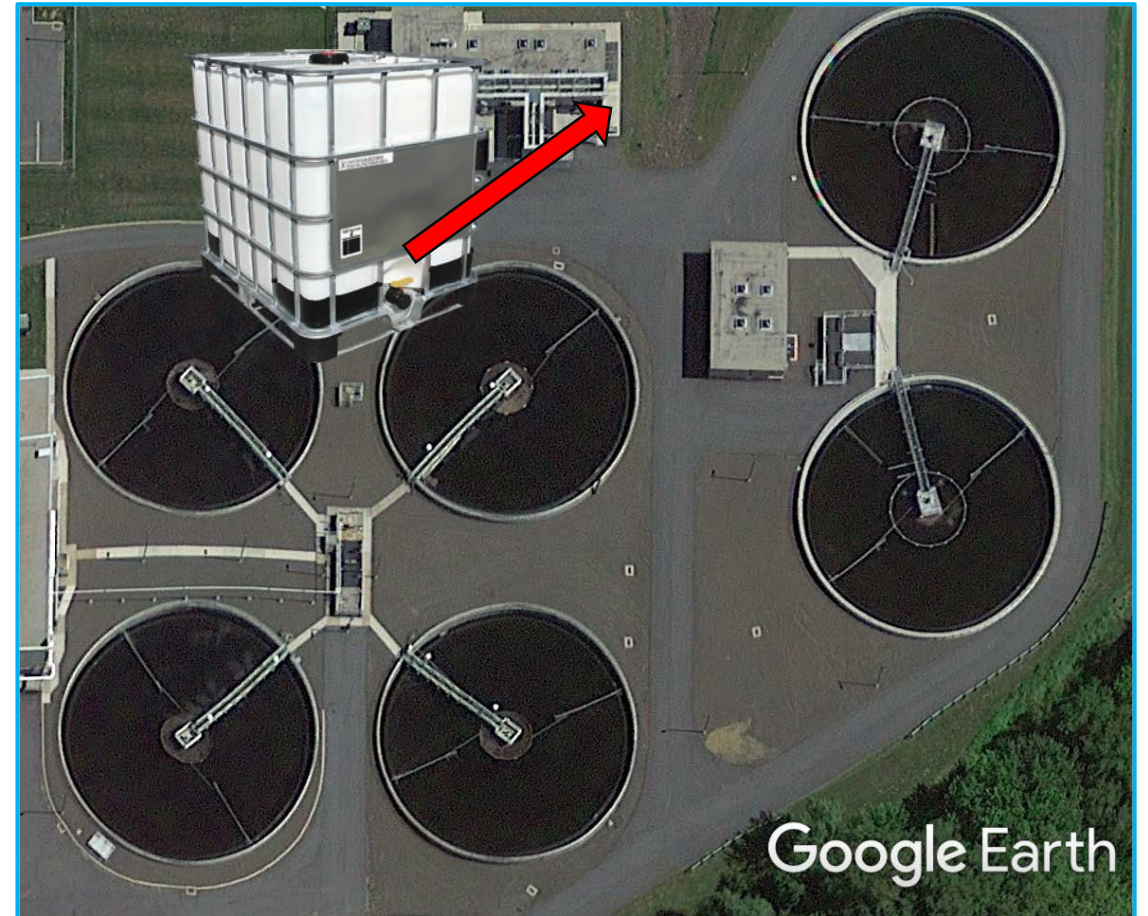
Disinfection Byproducts (Trihalomethanes)



Pilot Runs 2 & 3: Comparing Activated & Non-Activated Fe(VI) w/ Field Wastewater



Raw Water Collection

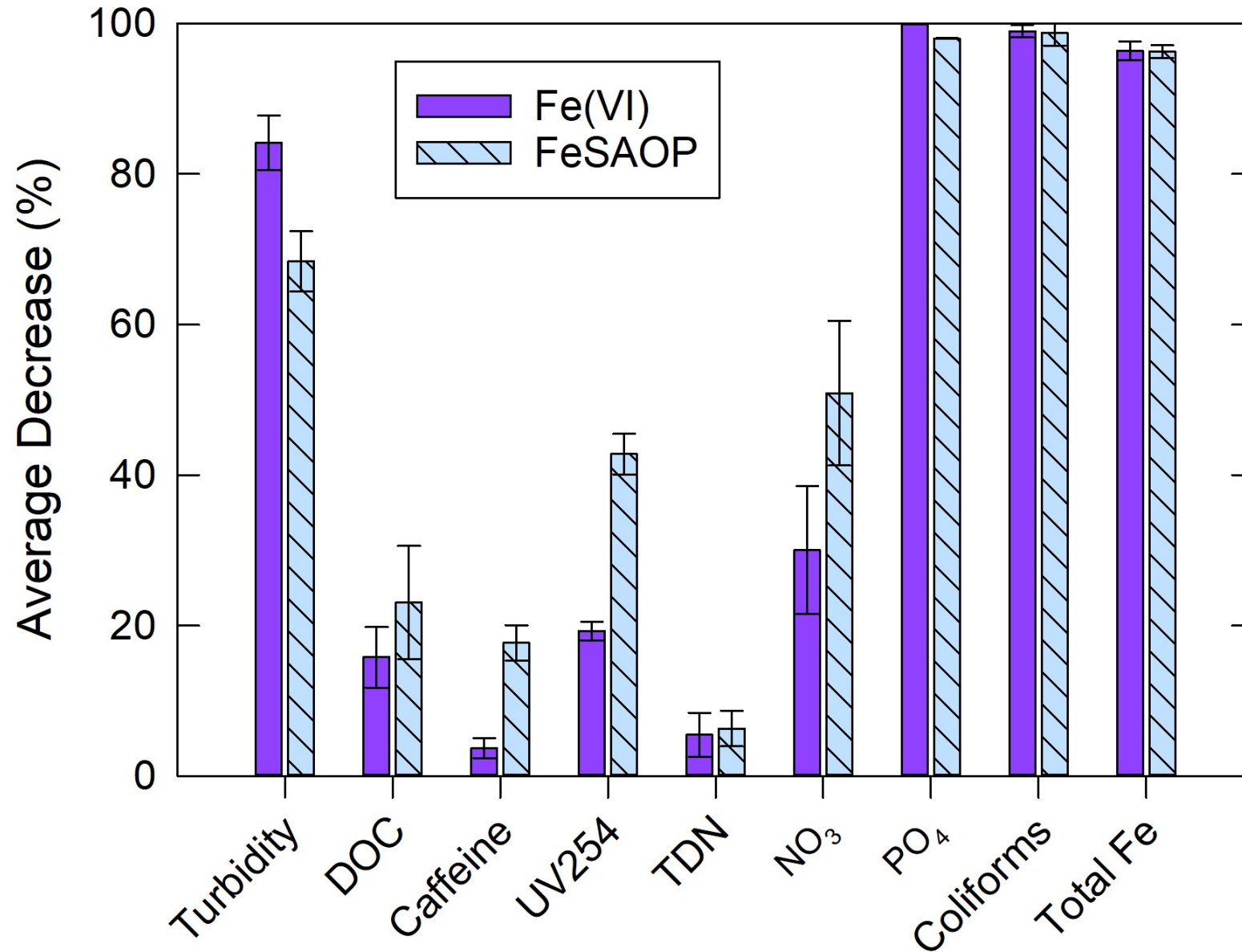


Collected 275 Gallons of non-chlorinated effluent from secondary effluent flume

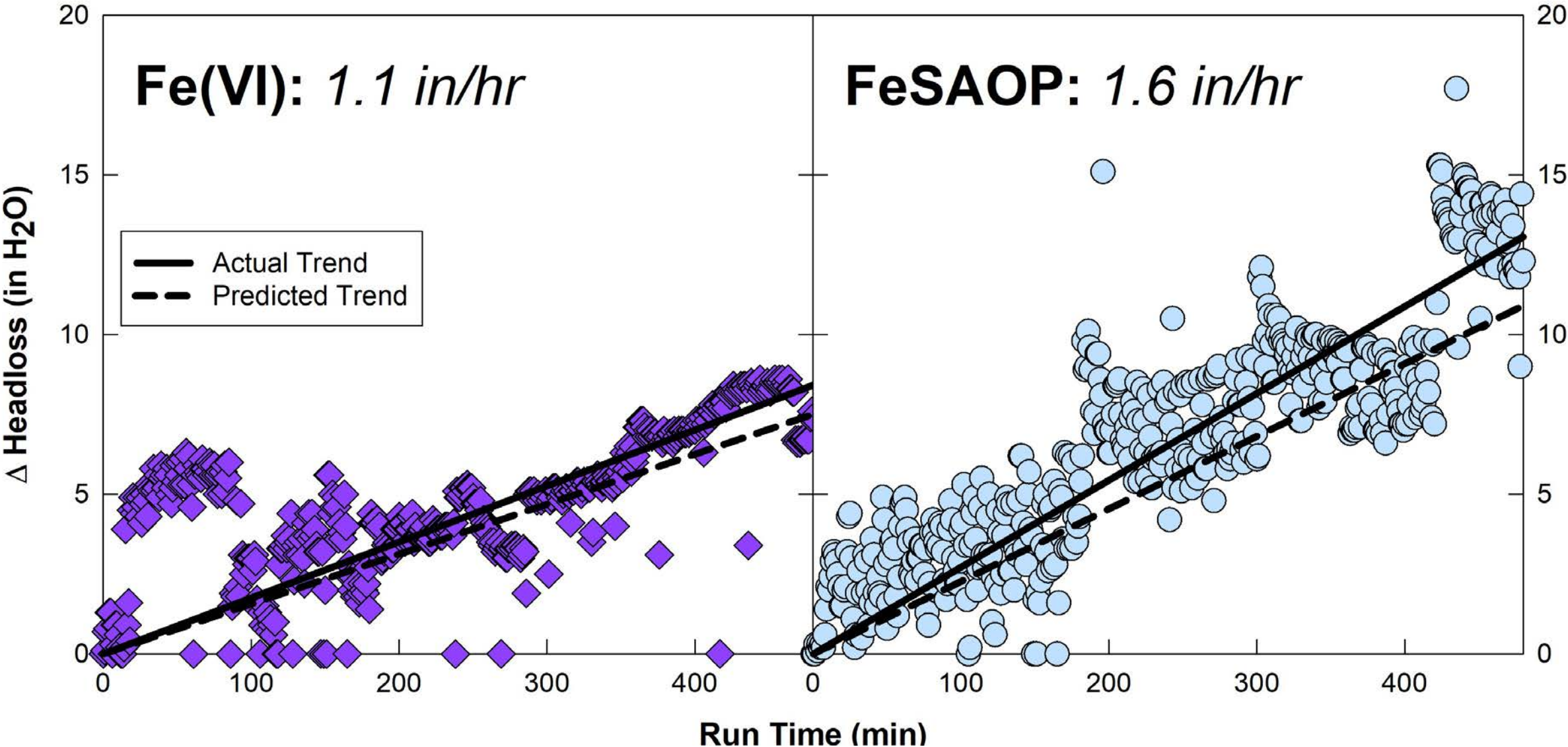
System Treating Mattabasset Effluent



Contaminant Removal Comparison



Headloss Across Media Filter



Piloting Conclusions

- Fe(VI) for water reuse is feasible
 - *>80% removal of coliforms, PO₄, and turbidity*
- FeSAOP improves target pollutant removal
- No “deal breaker” operational impacts downstream
- However, further pilot studies needed before full scale application



Project Support



— BUREAU OF —
RECLAMATION



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Element 26
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MATTABASSETT DISTRICT

The logo for Mattabasset District features two stylized green trees above a thick, blue, wavy horizontal line.

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ORTHOS
LIQUID SYSTEMS

Design, Construction, & Operation Team

- Design
 - Alex Bishop, P.E.
- Construction
 - Pam Franco
 - Kevin Broccolo
 - Isabella Silverman
- Operation
 - Steve Lucier
 - Jack Spiegel



Thank you! Questions?

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