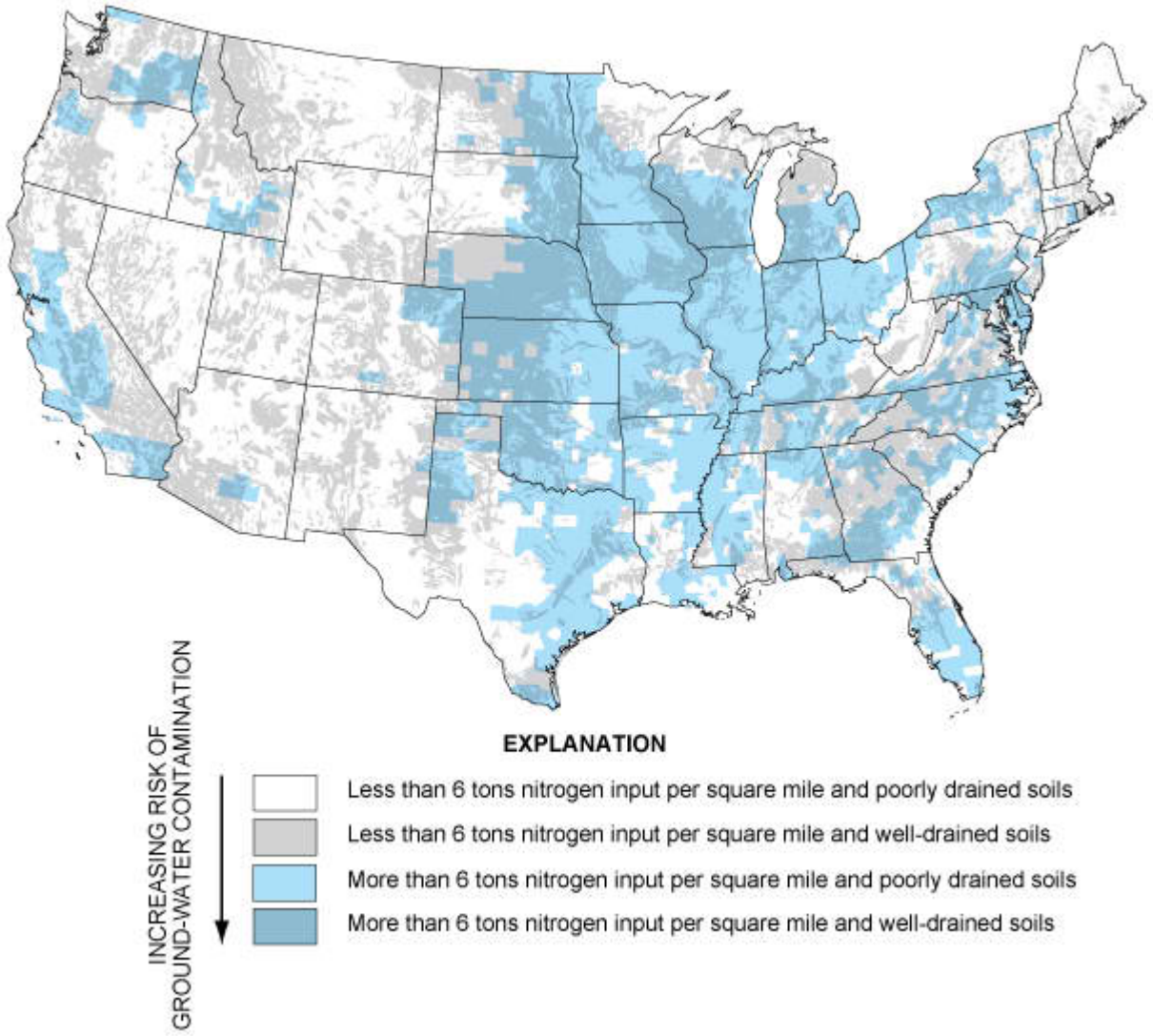
Biological Treatment of Nitrate and Perchlorate for Drinking Water Production

Patrick Evans
Bruce Rittmann
David Friese
Jennifer Smith

April 24, 2014

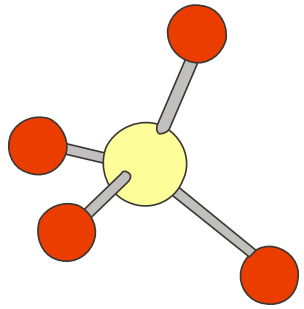
CDM Smith

Potential for Nitrate in Groundwater

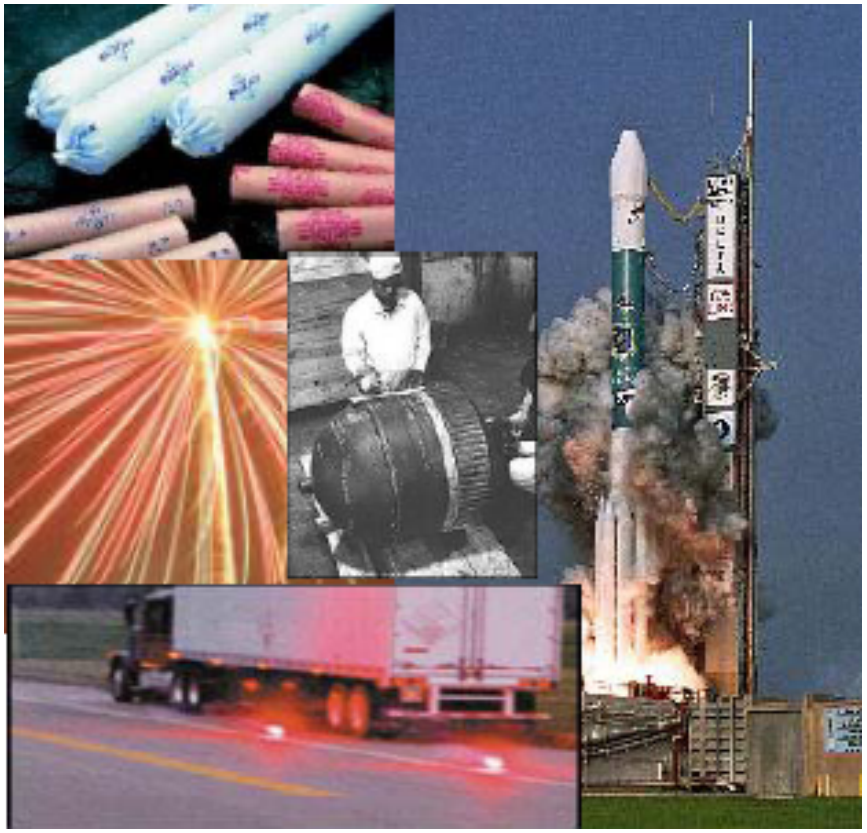


http://pubs.usgs.gov/fs/1996/fs-092-96/fs092-96.html

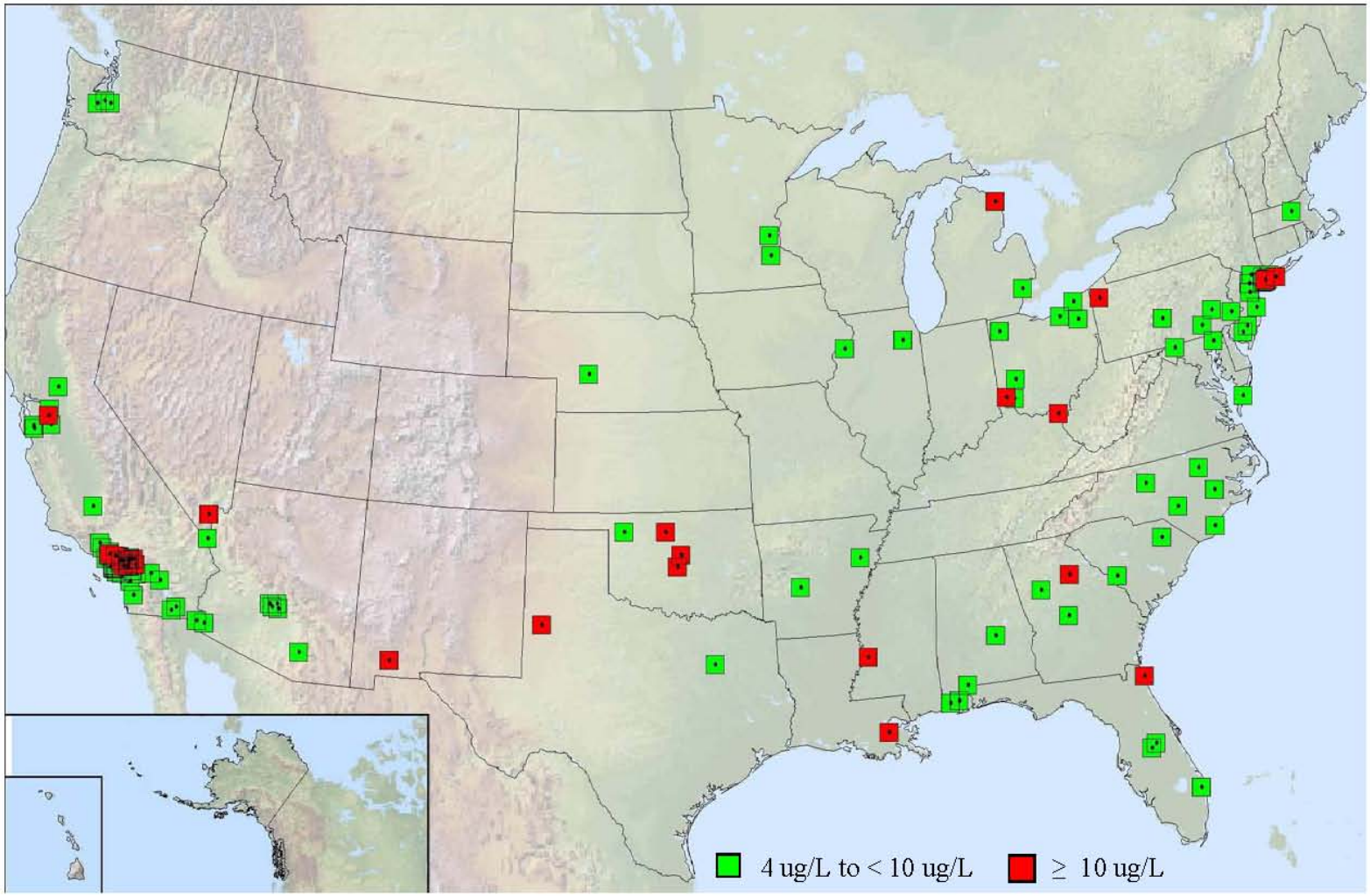
Perchlorate (ClO_4^-) Sources



- Naturally occurring – Chilean caliche
- Manufactured – oxidizing agent

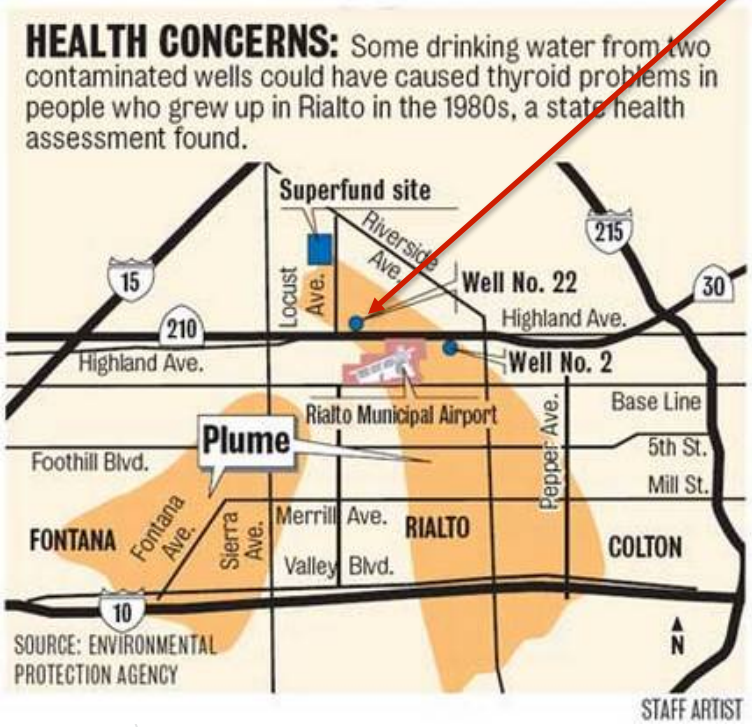


Perchlorate UCMR Detections



Brandhuber and Clark, 2005, Perchlorate Occurrence Mapping, AWWA

West Valley Water District (WVWD) Site; Rialto, CA

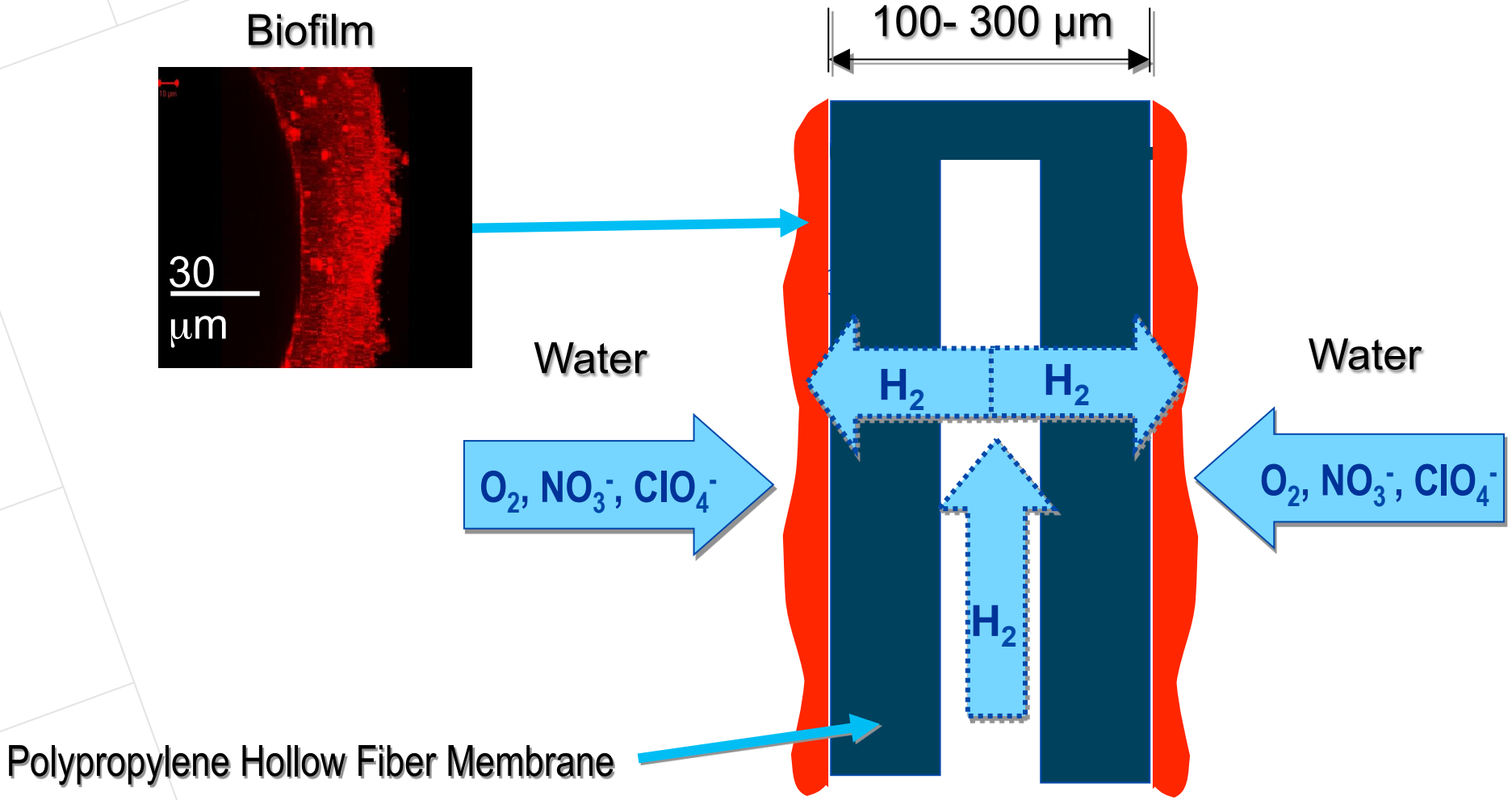


Source: Press Enterprise, 8/26/11

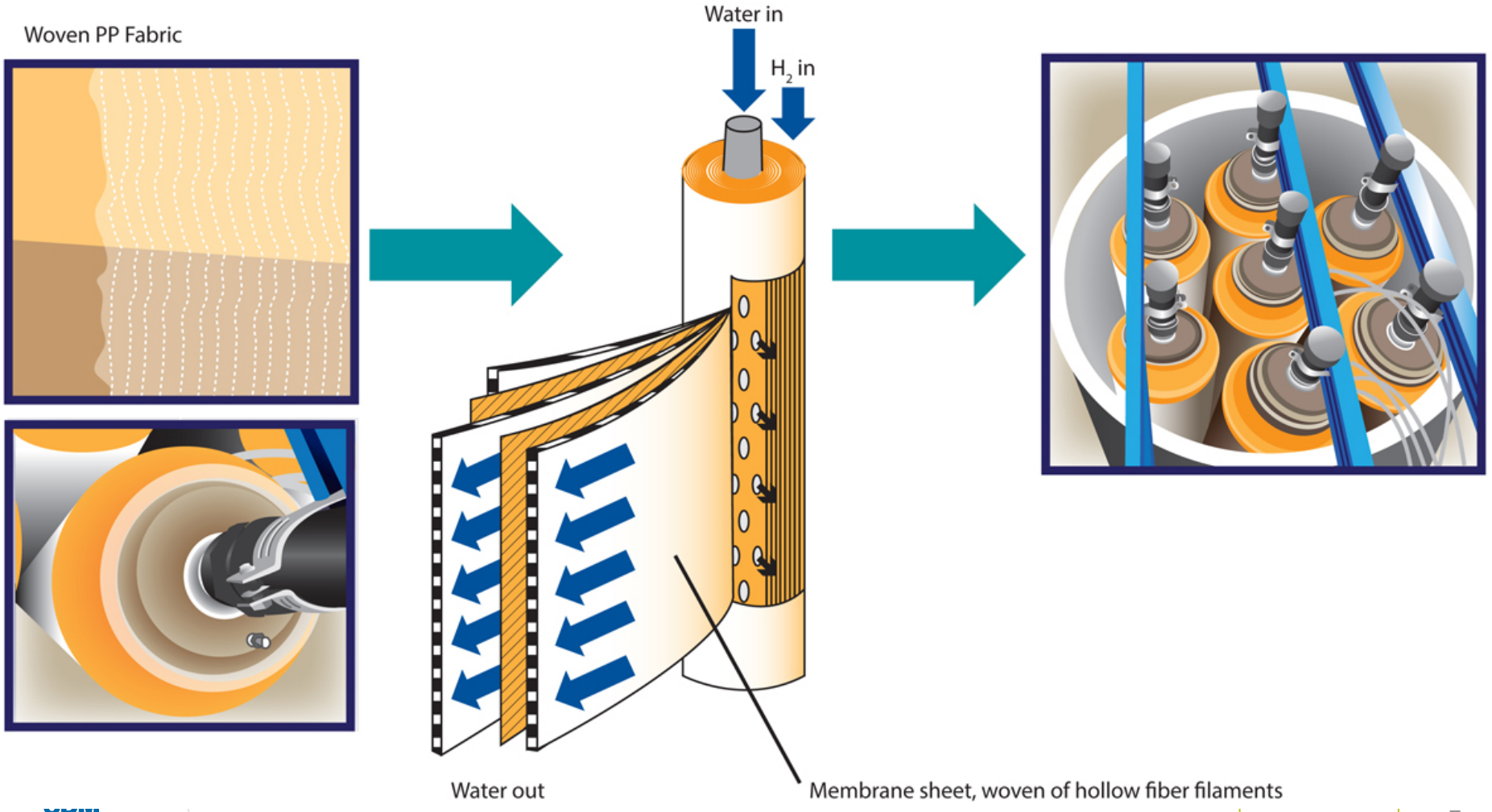
Well No. 22: Converted agricultural well

Analyte	Range	Units
Perchlorate	150±11	µg/L
Nitrate	8.9±0.4	mg-N/L
Sulfate	21±0.9	mg/L
Alkalinity	150±11	mg $CaCO_3$/L
Hardness	200±8	mg $CaCO_3$/L
TDS	260±15	mg/L
TCE	54±7	µg/L
pH	7.5±0.1	s.u.

Membrane Film Reactor (MBfR) Technology Description



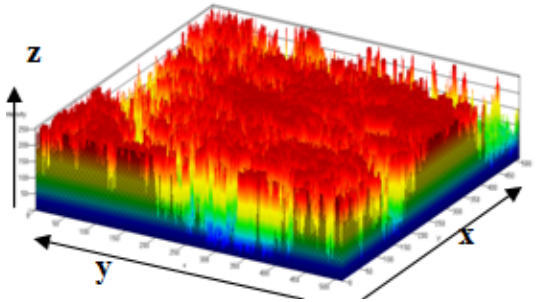
MBfR Technology Description



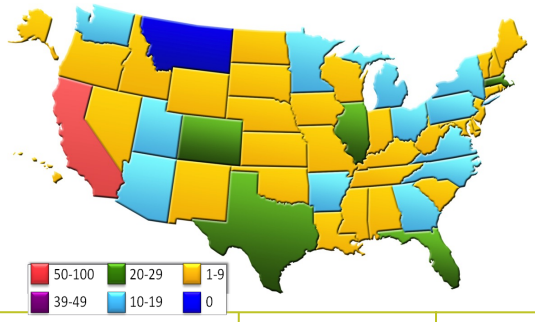
Technical Objectives

- Demonstrate the cost and performance the MBfR.

- Conduct in-depth laboratory studies and mathematical modeling to better understand technology limitations and identify practical solutions.

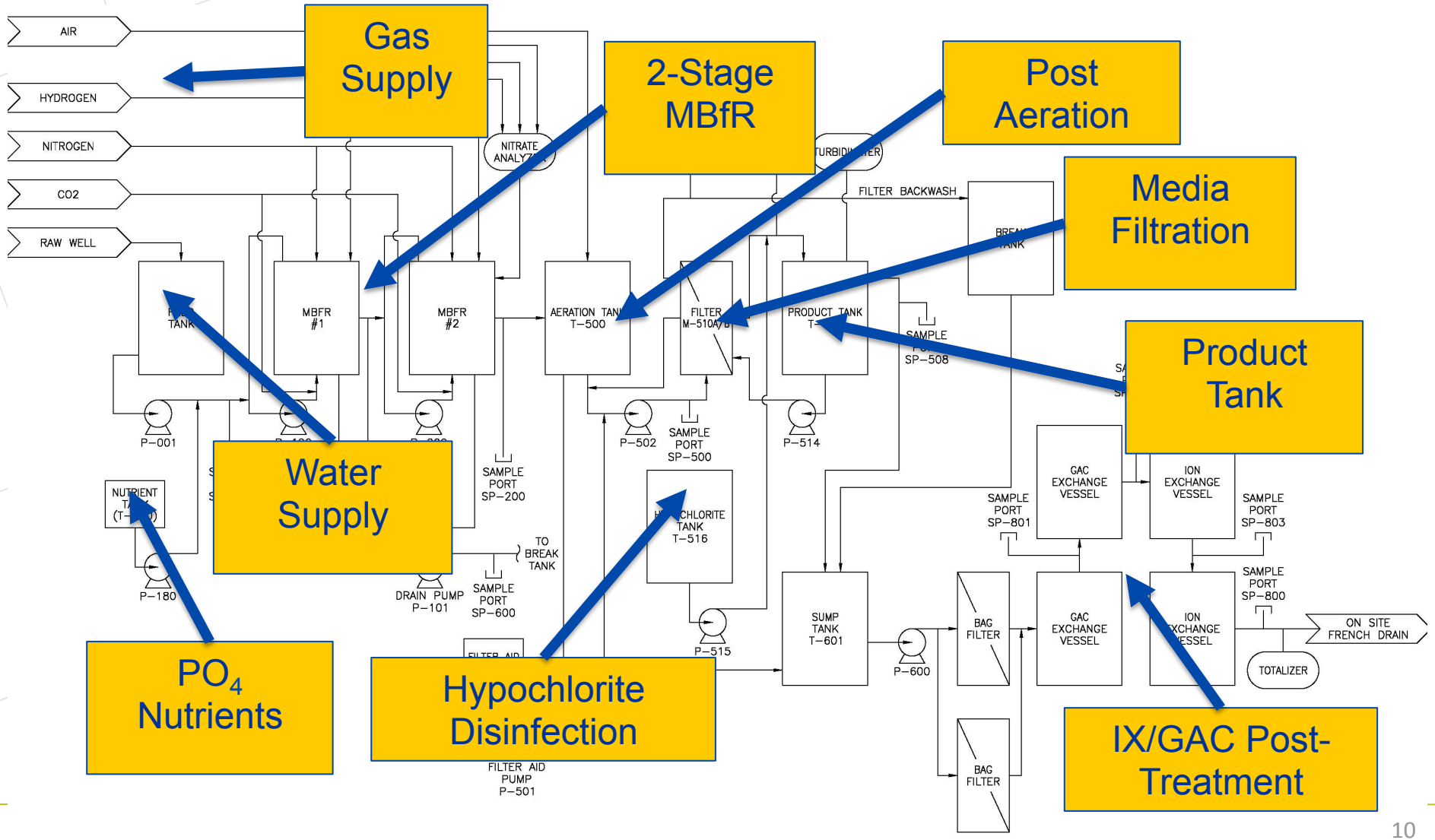


- Conduct a nationwide survey on biological drinking water treatment to increase technology acceptance and implementation.



Test Design

Test Design – Process Flow Diagram



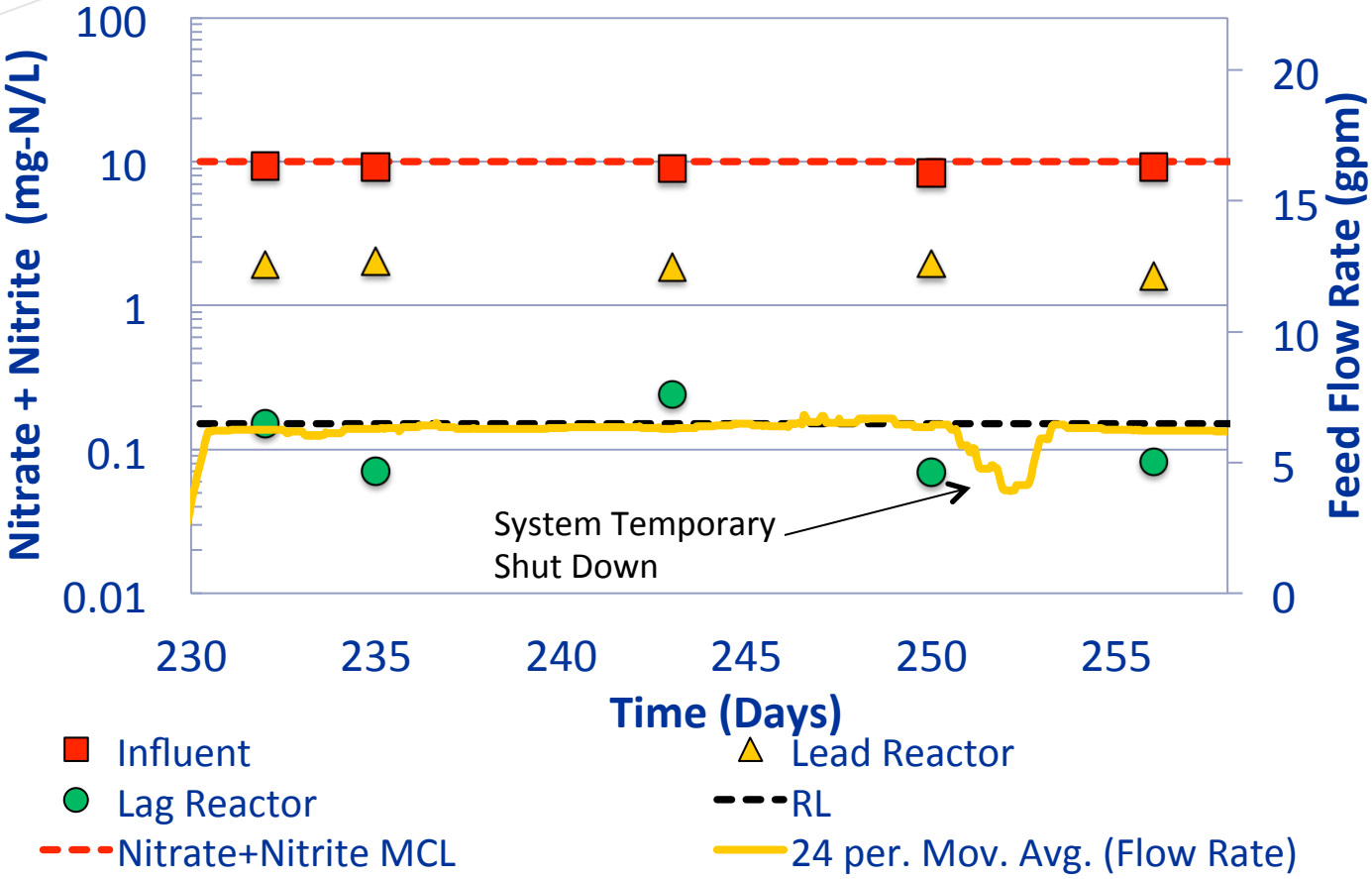
Test Design – System Photos

Test Design – Experimental Sequence

Start-Up	• Constructed system and initiated operations • Colonized reactors with indigenous bacteria • MBfR effluent goal of 6 µg/L perchlorate and 0.5 mg-N/L nitrate • Tracer Testing
Optimization	• Varied feed flow rates • Varied recycle ratios • Batch Testing
Steady State	• Operated at optimal conditions for one month • Full characterization of system performance
Challenge	• Perturb MBfR system through series of upsets: • Loss of electron donor - shut off hydrogen • Power failure - shut off system

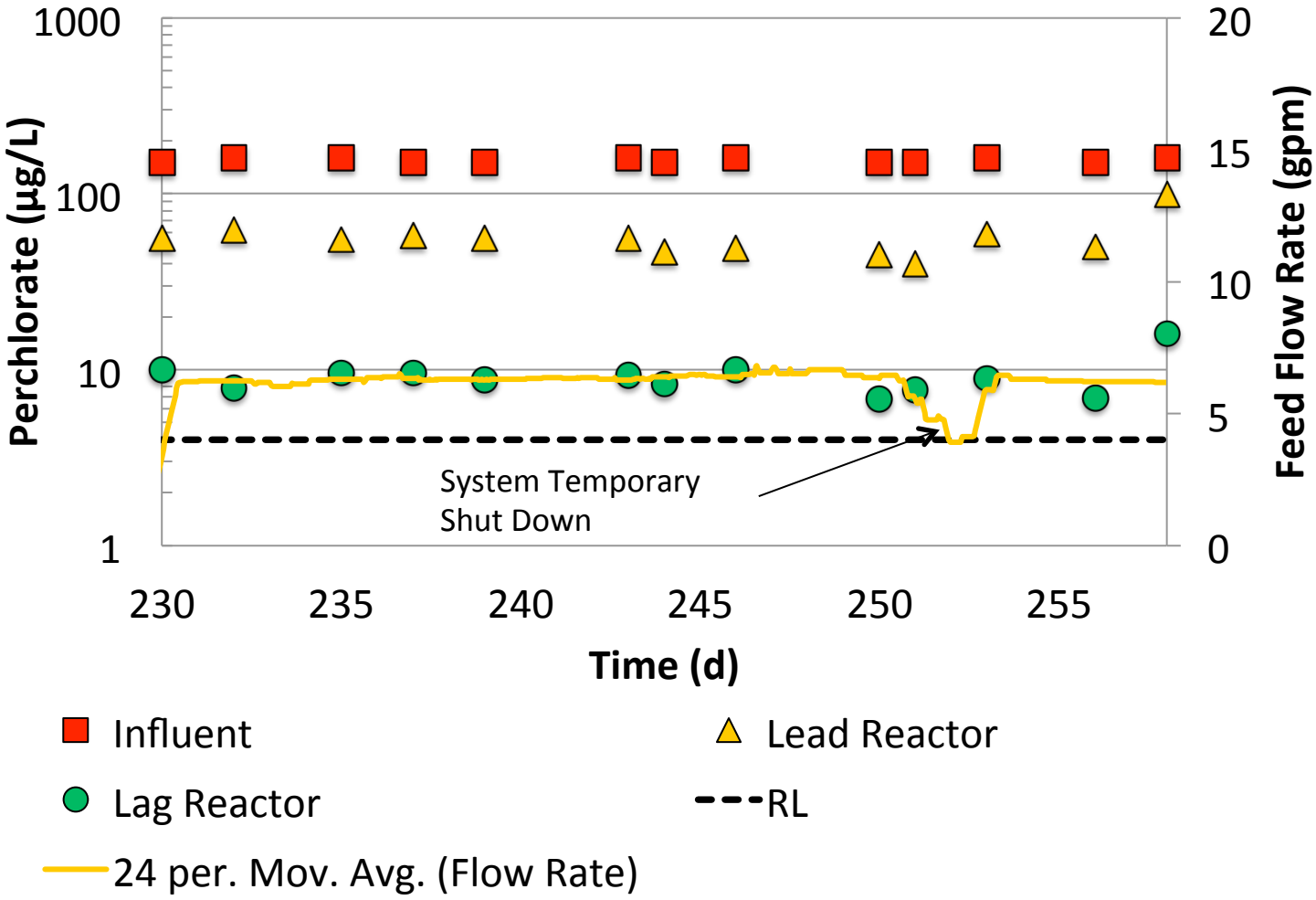
Performance Assessment

Nitrate Removal



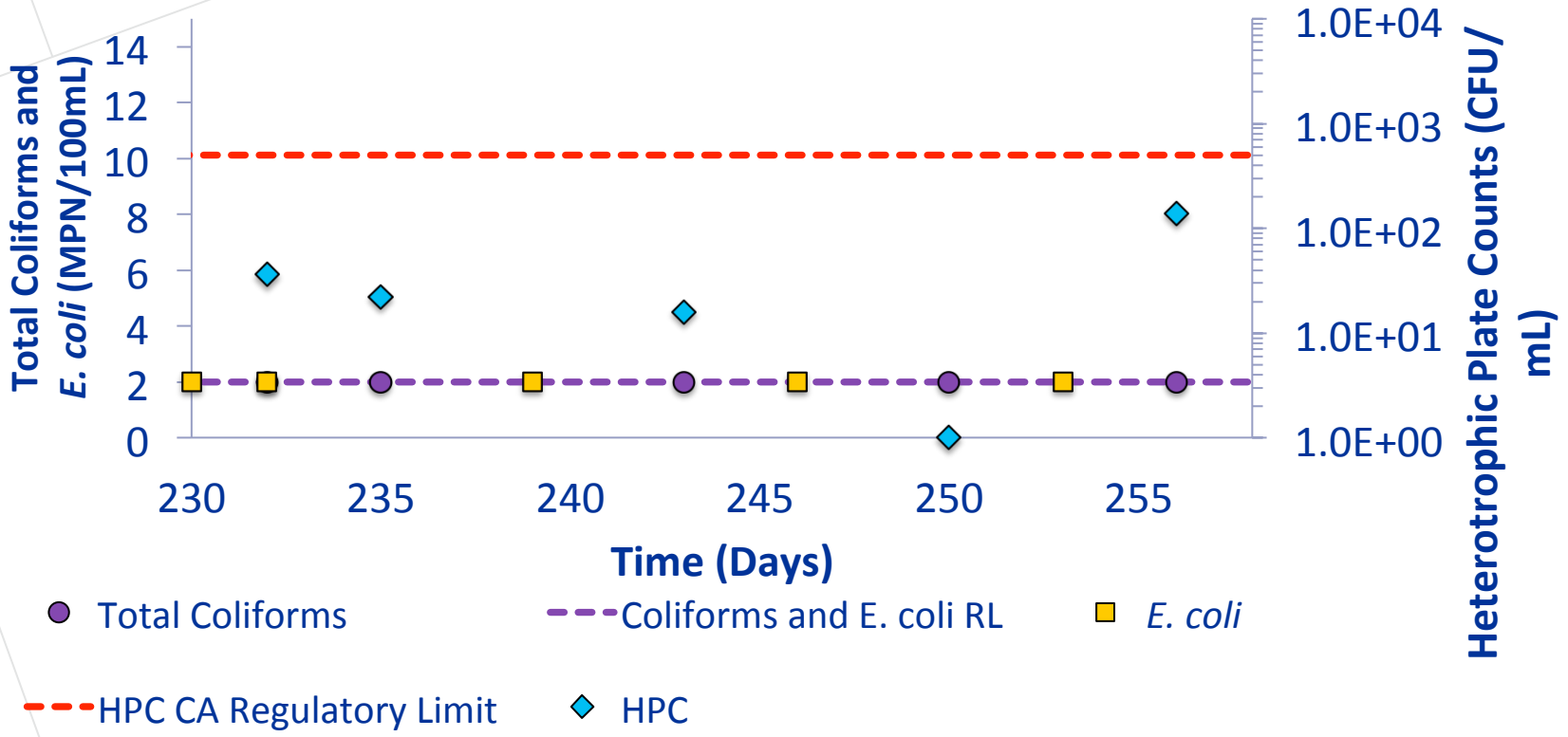
Performance Objective ≤ 0.5 mg-N/L
Actual Performance 0.12 ± 0.07 mg-N/L
(98.3% removal)

Perchlorate Removal



Performance Objective ≤ 6 µg/L
Actual Performance 9.2 ± 2.3 µg/L
(94.4% removal)

Pathogens & Heterotrophs



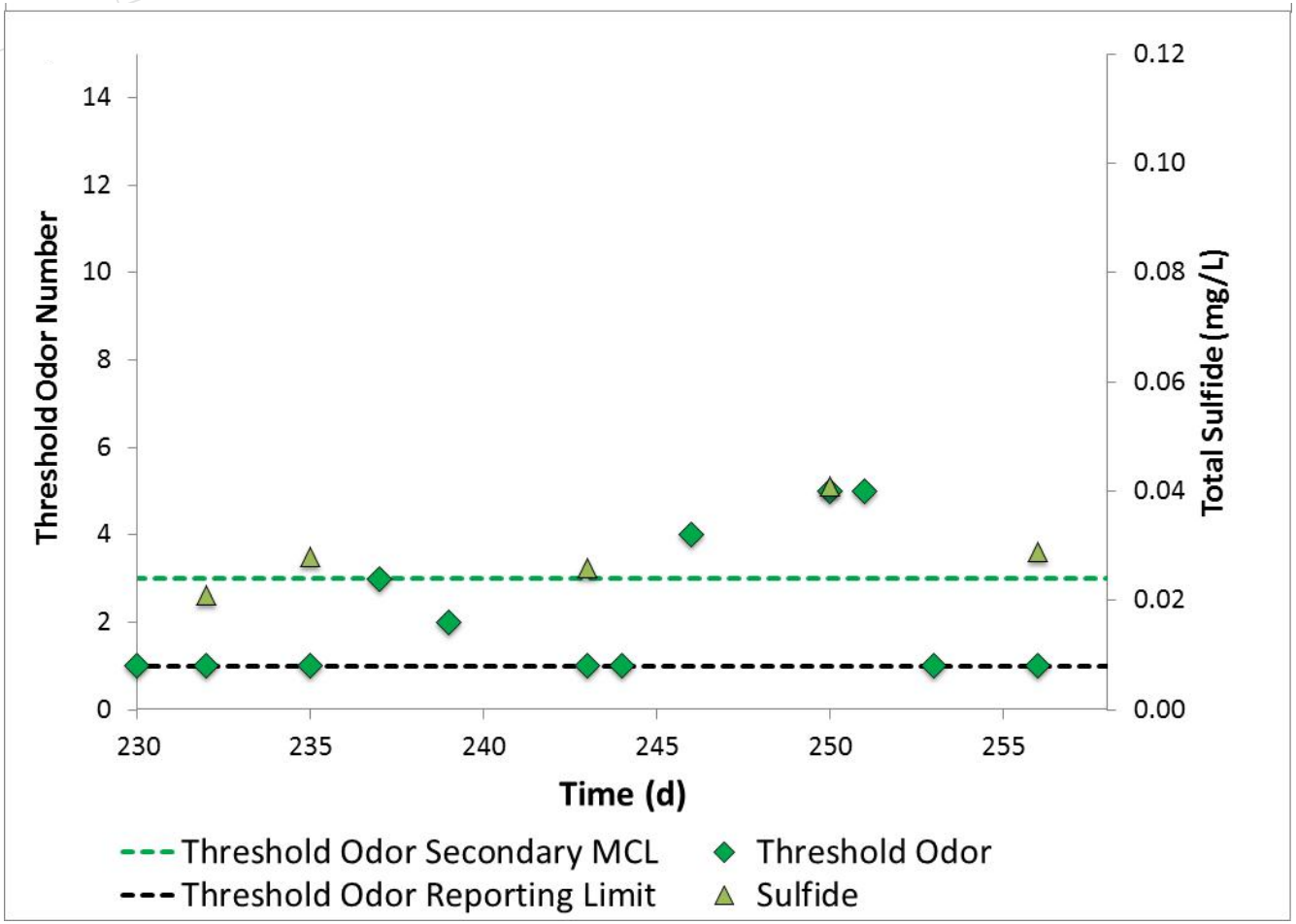
Analyte	*E. coli* (MPN/100 mL)	Total Coliforms (MPN/100 mL)	Heterotrophic Plate Counts (CFU/mL)
Performance Objective	< 2 (ND)	< 2 (ND)	< 500
Actual Performance	< 2 (ND)	< 2 (ND)	43

Disinfection By-Product (DBP) Formation

Analyte	Average	Max	MCL/Performance Objective
HAA5 (µg/L)	< 6	< 6	60
TTHM (µg/L)	4.8	12	80
THM-FP (µg/L)	15	47	NA
Nitrosamines (µg/L)	< 0.0019	< 0.0019	NA

HAA5 – 5 Haloacetic acids (monochloro-, dichloro-, trichloro, monobromo-, and dibromo-acetic acid)
TTHM – Total trihalomethanes (chloroform, bromoform, bromodichloromethane, dibromochloromethane)
THM-FP – THM formation potential
Nitrosamines – NDMA, NDEA, NDPA

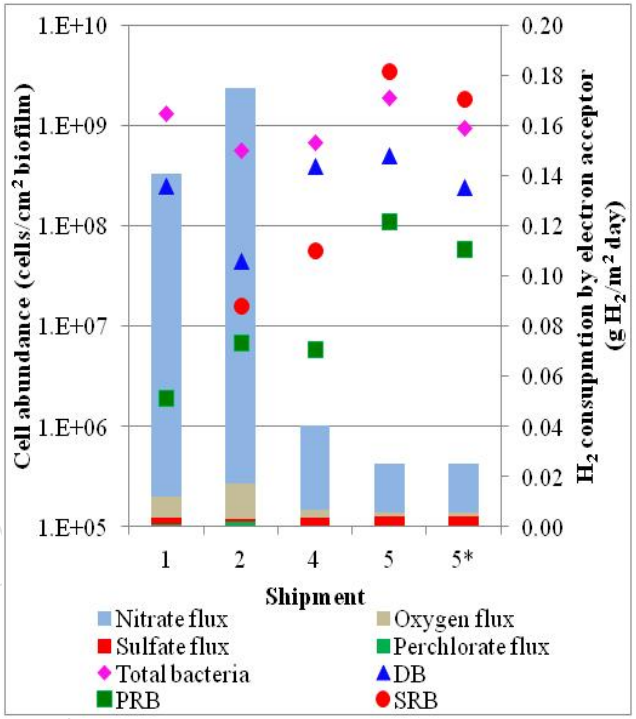
Threshold Odor Number (TON)

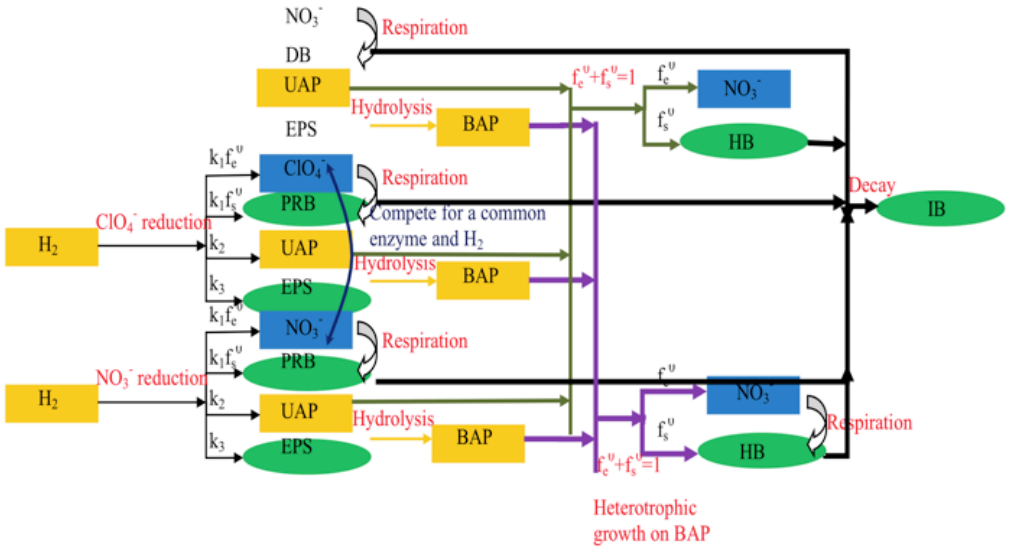


Performance Objective < 3
Actual Performance = 2.2

ASU Studies

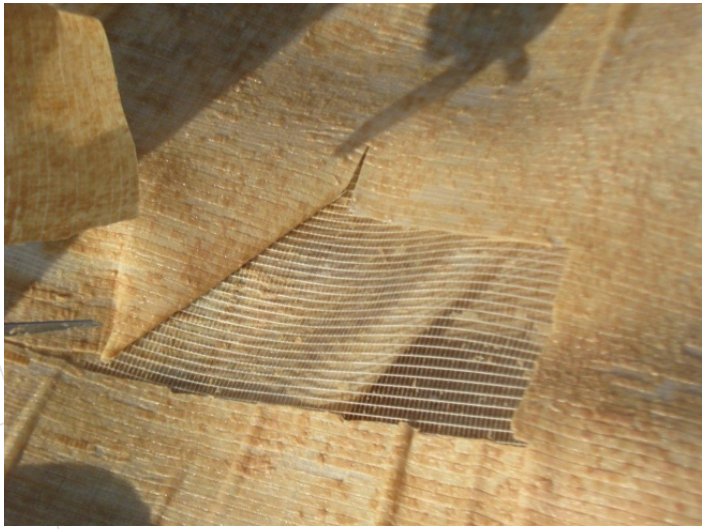
Biofilm Microbial Ecology
Biofilm Physical/Chemical Characteristics
Biofilm Process Modeling



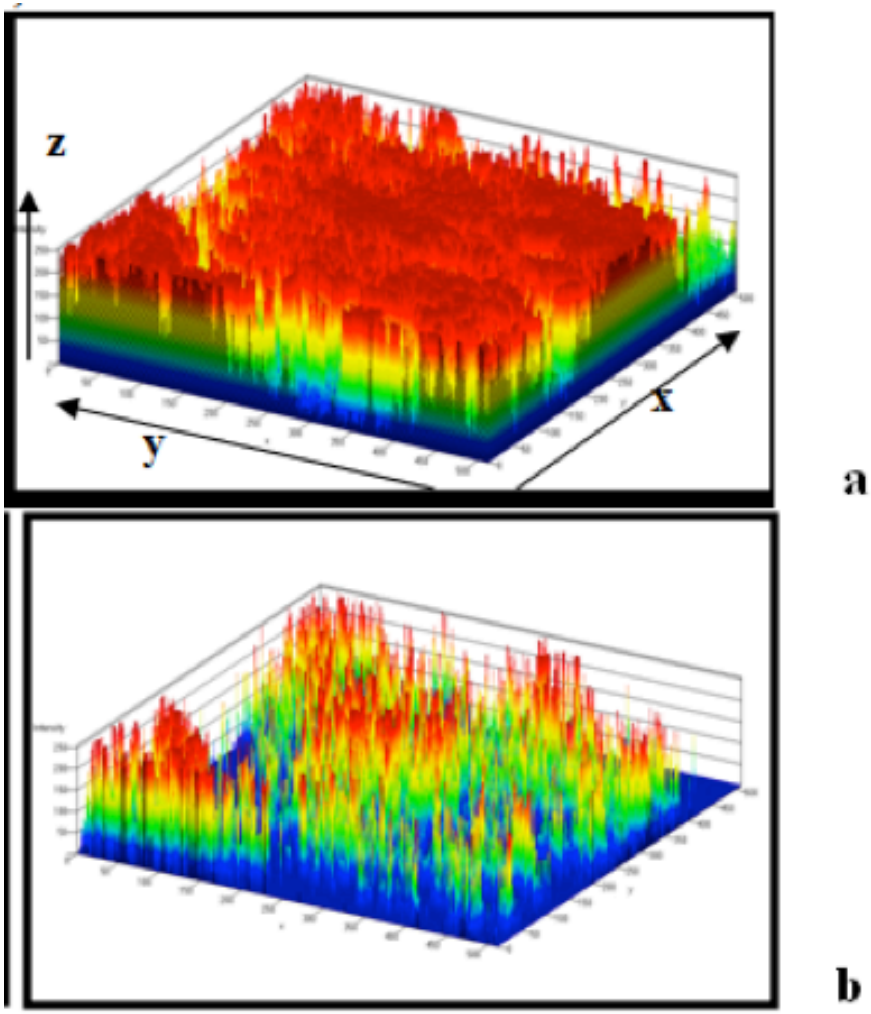


Confocal Laser Microscopy Indicated a Health Biofilm

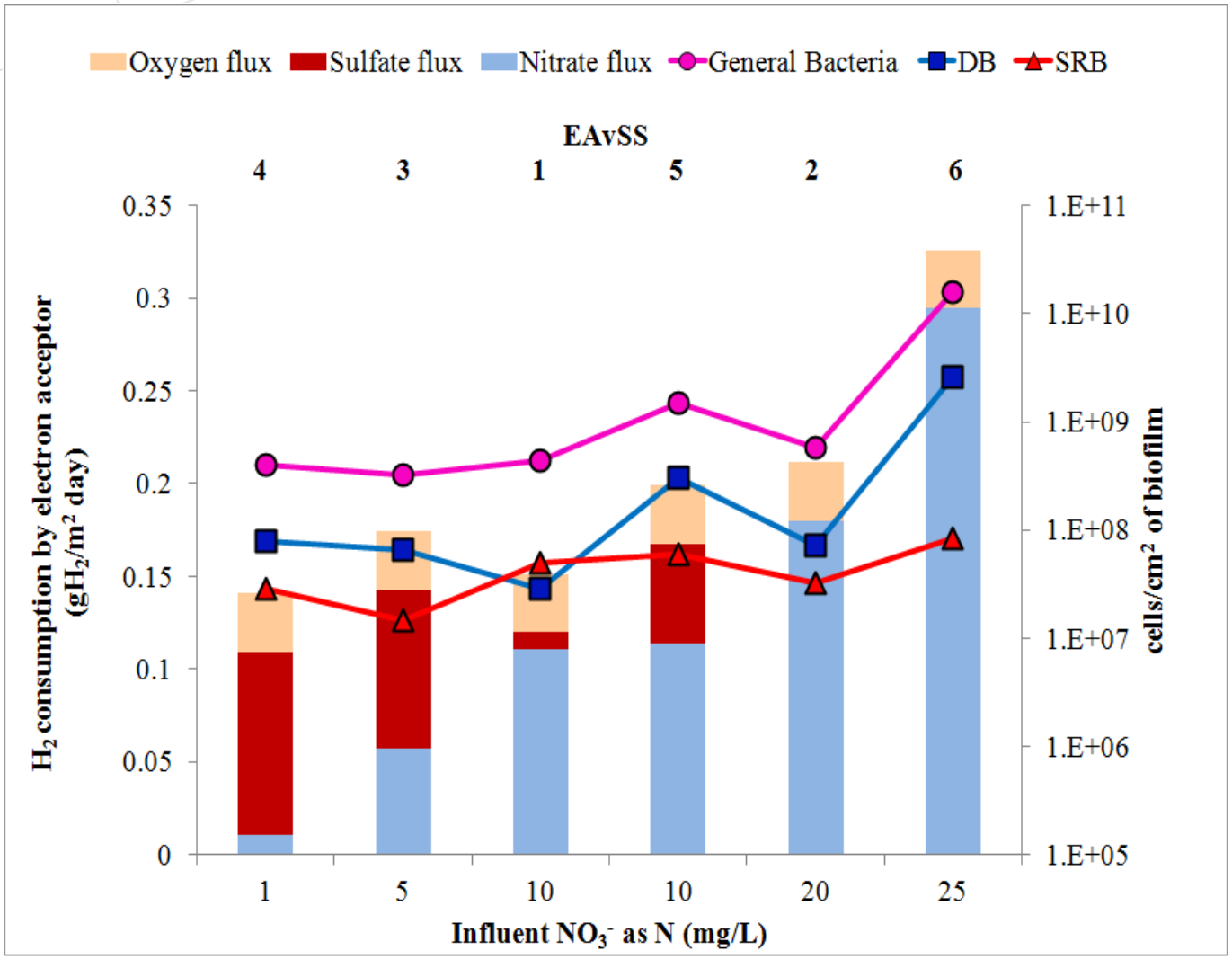
Live



Dead



Controlling Oxygen and Nitrate Flux Limits Sulfate Reduction



Practical solution to attainment of lower perchlorate in effluent

Key Conclusions

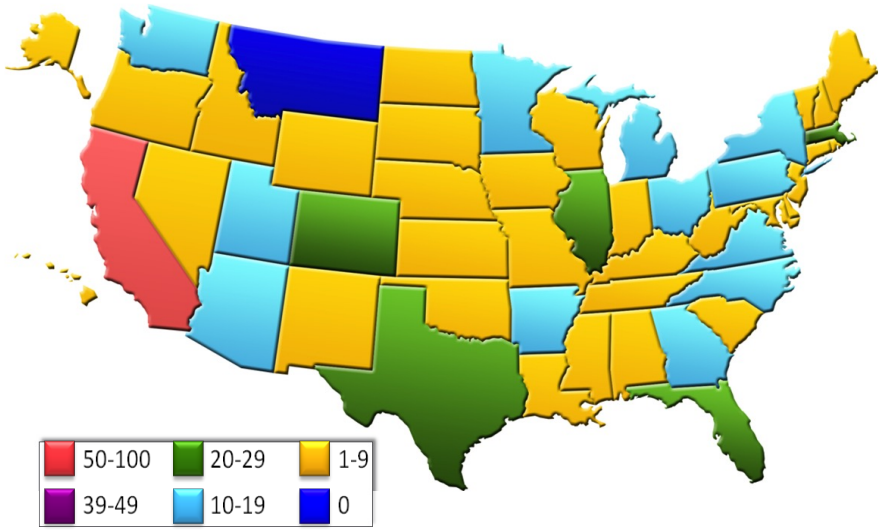
- The MBfR is effective and for treatment of nitrate and production of drinking water.
- Most perchlorate was removed and effective strategies were identified for process improvement.
- The MBfR technology has been granted condition acceptance by the California Department of Public Health.

Joint ESTCP – Water Research Foundation National Survey

Technical Objectives

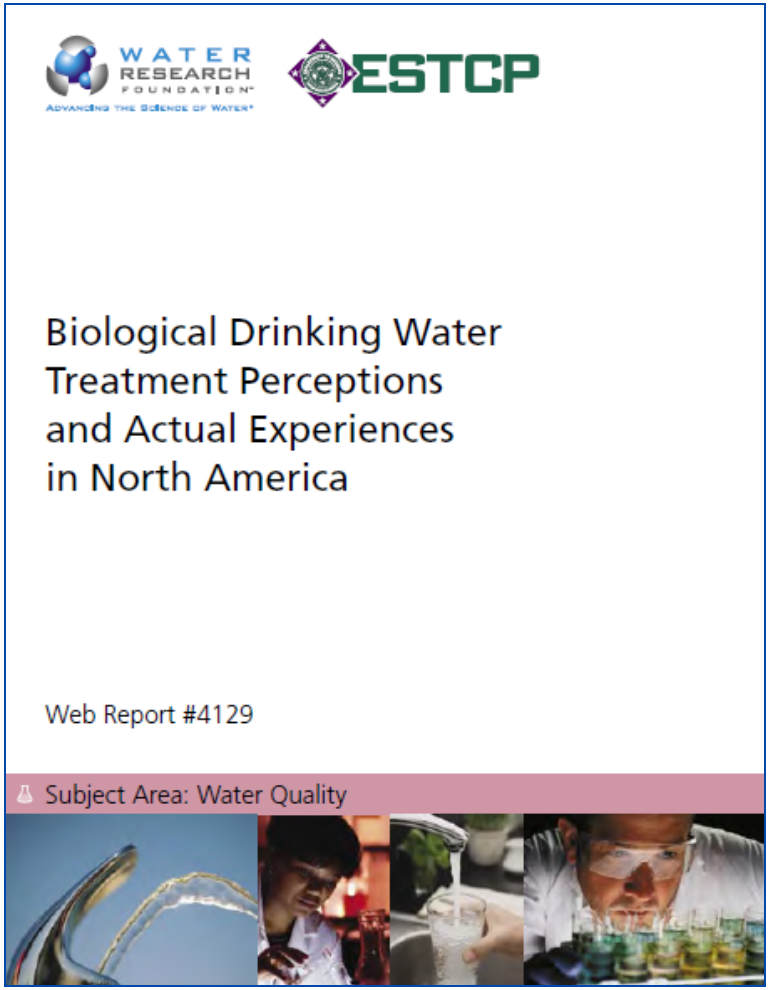
- Conduct a nationwide survey on biological drinking water treatment
  - Identify barriers to acceptance
  - Identify approaches to increasing acceptance and use

- Responses received from 49 states
  - DoD
  - Regulators
  - Water utilities
  - Consultants
  - Academicians



Survey Findings and Report

- Biological treatment is more readily accepted by consultants and academicians than by utilities and regulators.
- Actual performance of biological filters is greater than perceived
- Actual operational concerns are less than perceived
- Increased acceptance can be achieved by:
  - Better education
  - More full-scale case studies
  - Better monitoring and control tools

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