Microbial Biofilms in Drinking Water Distribution Systems

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Water Quality Violations

- Rural, low-income communities disproportionately affected by violations of the Safe Drinking Water Act (SDWA)

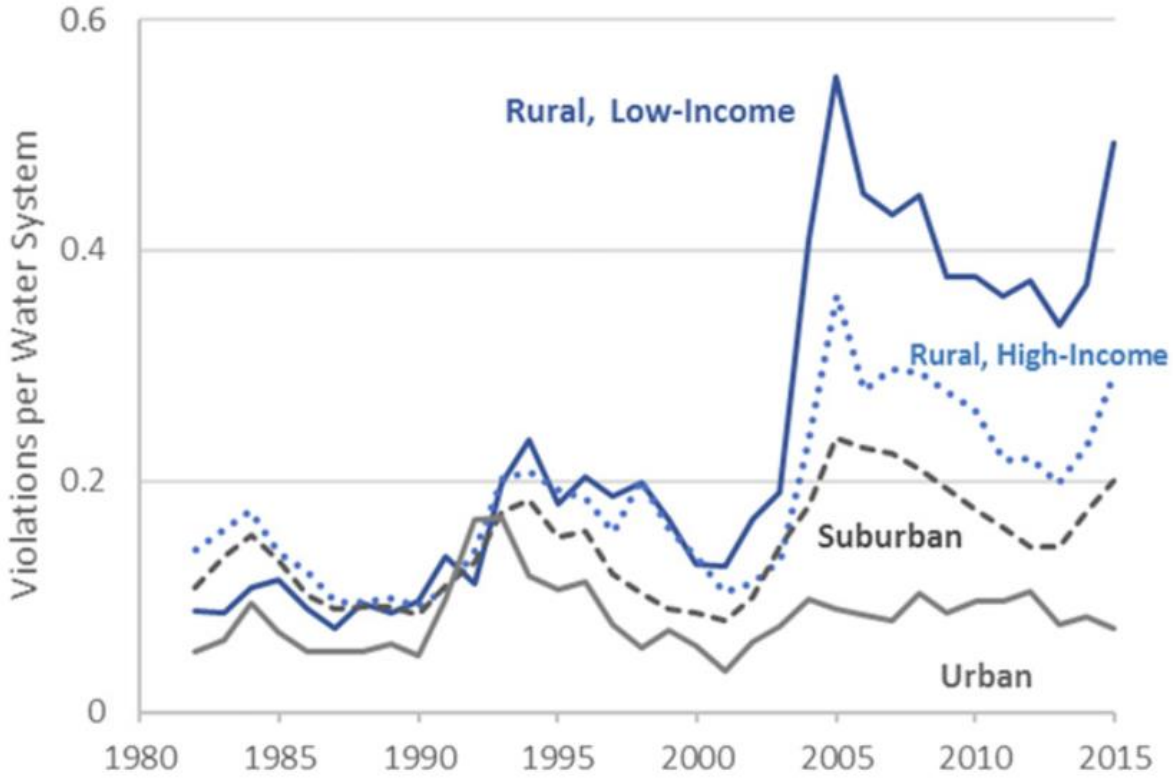


Fig. 3. Total violations per water system, by housing density category and income group. Low-income counties have median household income below 75% of national median household income. In year 2015, national median household income was $55,775 and 45% of rural CWSs are located in counties defined as low-income.

Allaire et al. 2018, PNAS

SDWA Violations in Small Utilities

TCR Violations = Distribution System Deficiencies

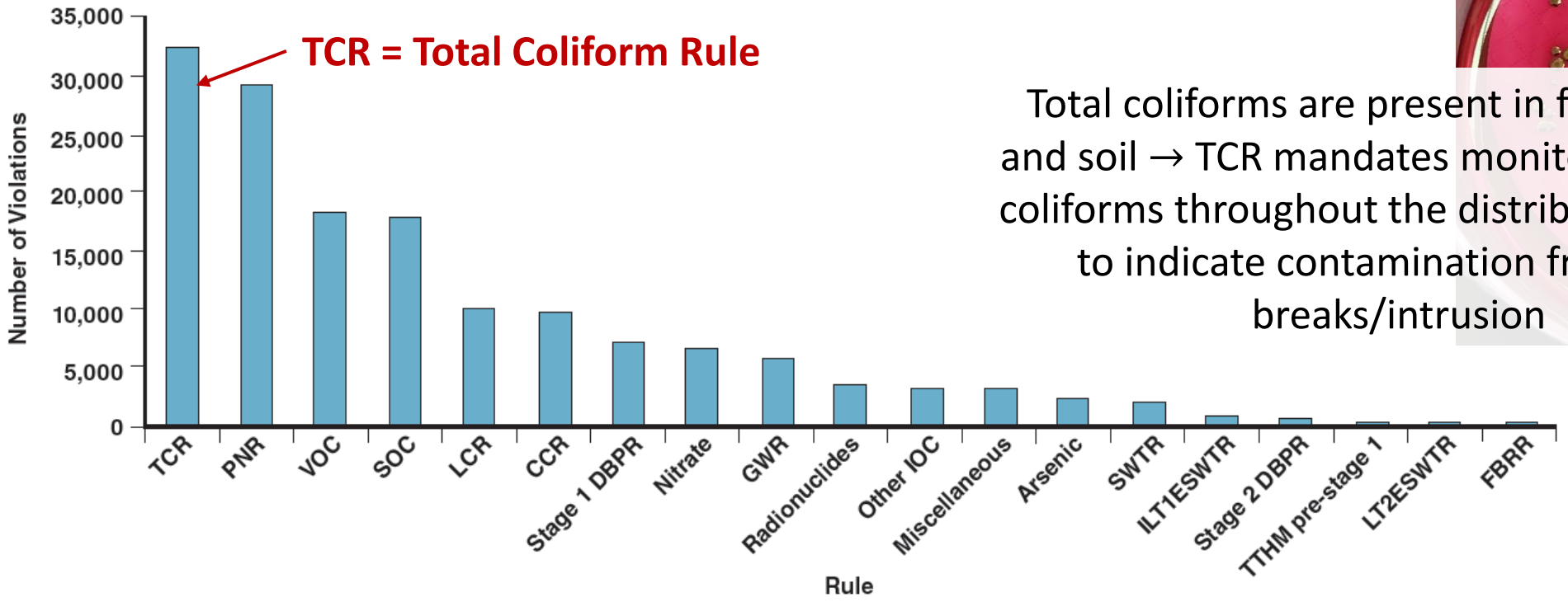
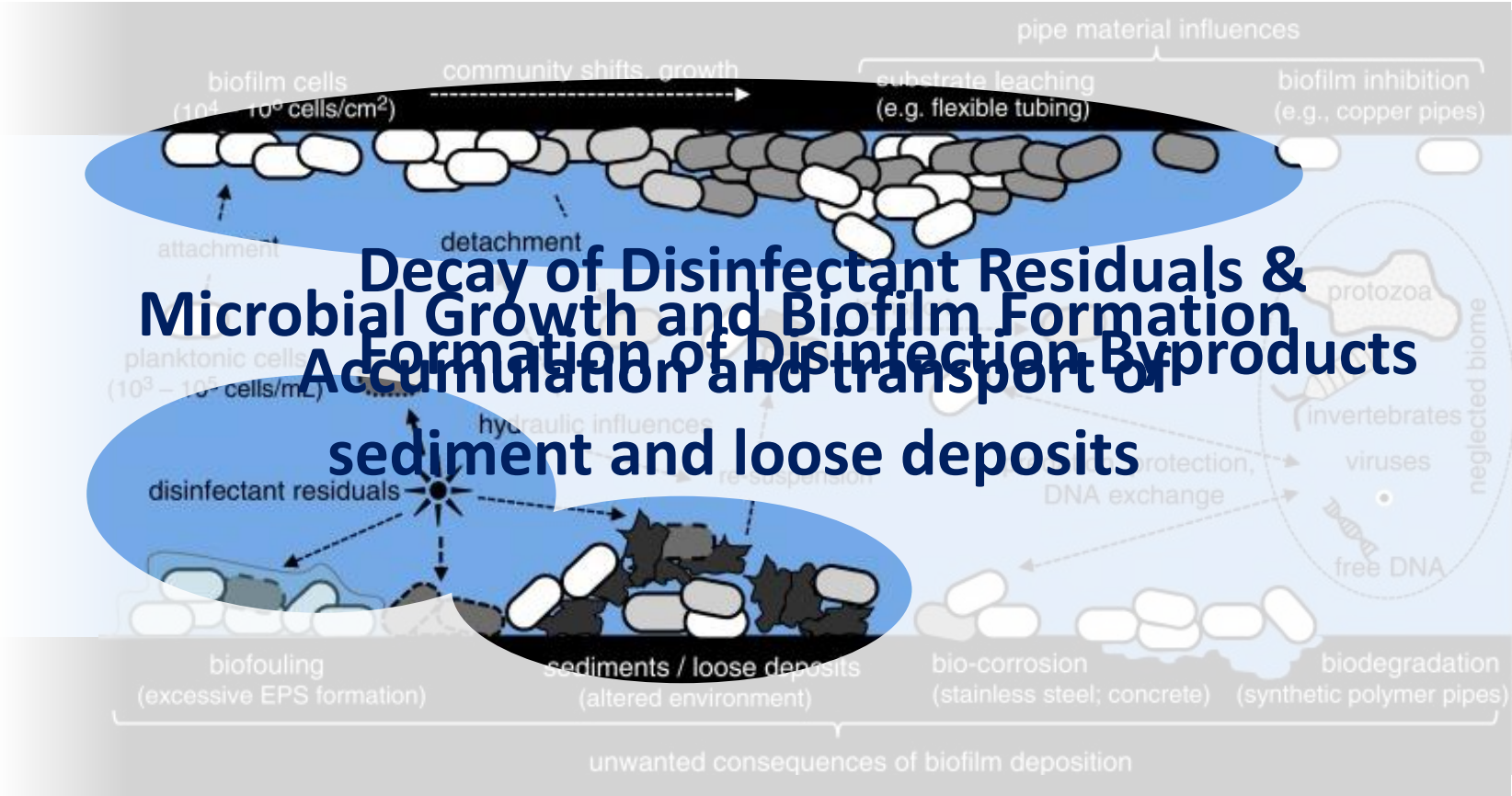


FIGURE 1 Number of violations in 2013 by rule for public water systems serving fewer than 10,000 people

Total coliforms are present in fecal matter and soil → TCR mandates monitoring of total coliforms throughout the distribution system to indicate contamination from pipe breaks/intrusion

Oxenford and Barrett, 2016, J. AWWA.

Drinking water distribution systems are complex ecosystems where water quality can change markedly from the treatment plant to the tap…

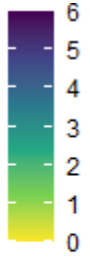


Proctor and Hammes, Curr Opin Biotech, 2015.

Osborne et al., 2022, *Frontiers in Water.*

DWDS Bacteria

Total Bacteria (log_{10} 16S rRNA genes / mL)

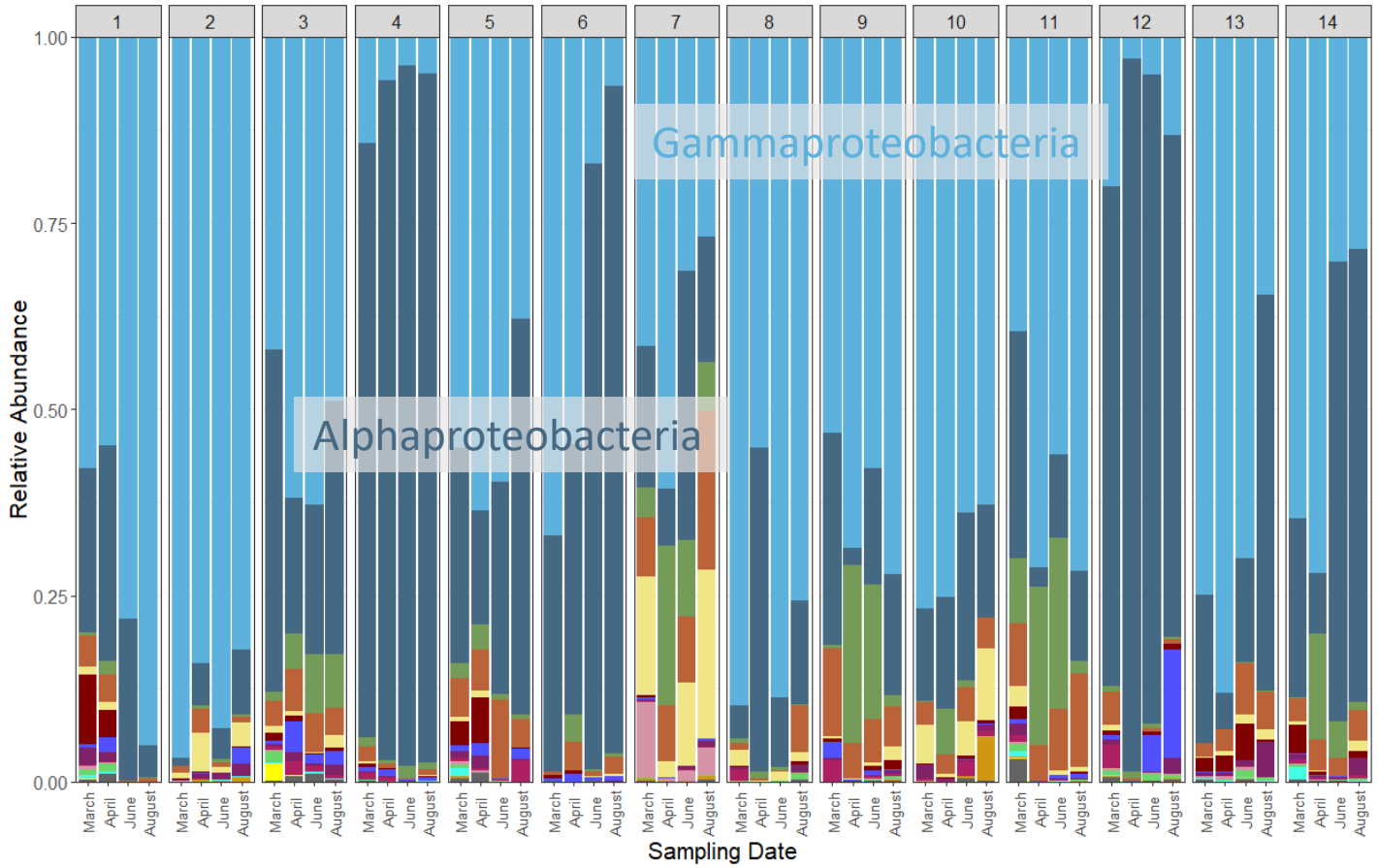


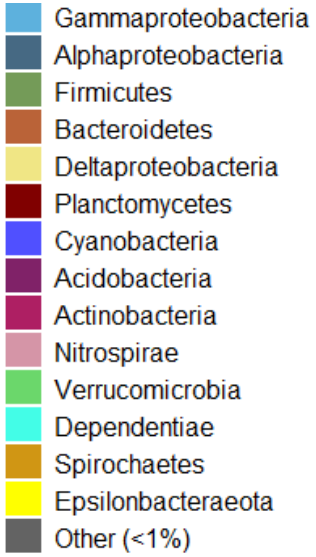
Treatment Plant

Tank

Erika Osborne

Gammaproteobacteria and Alphaproteobacteria dominated the DWDS

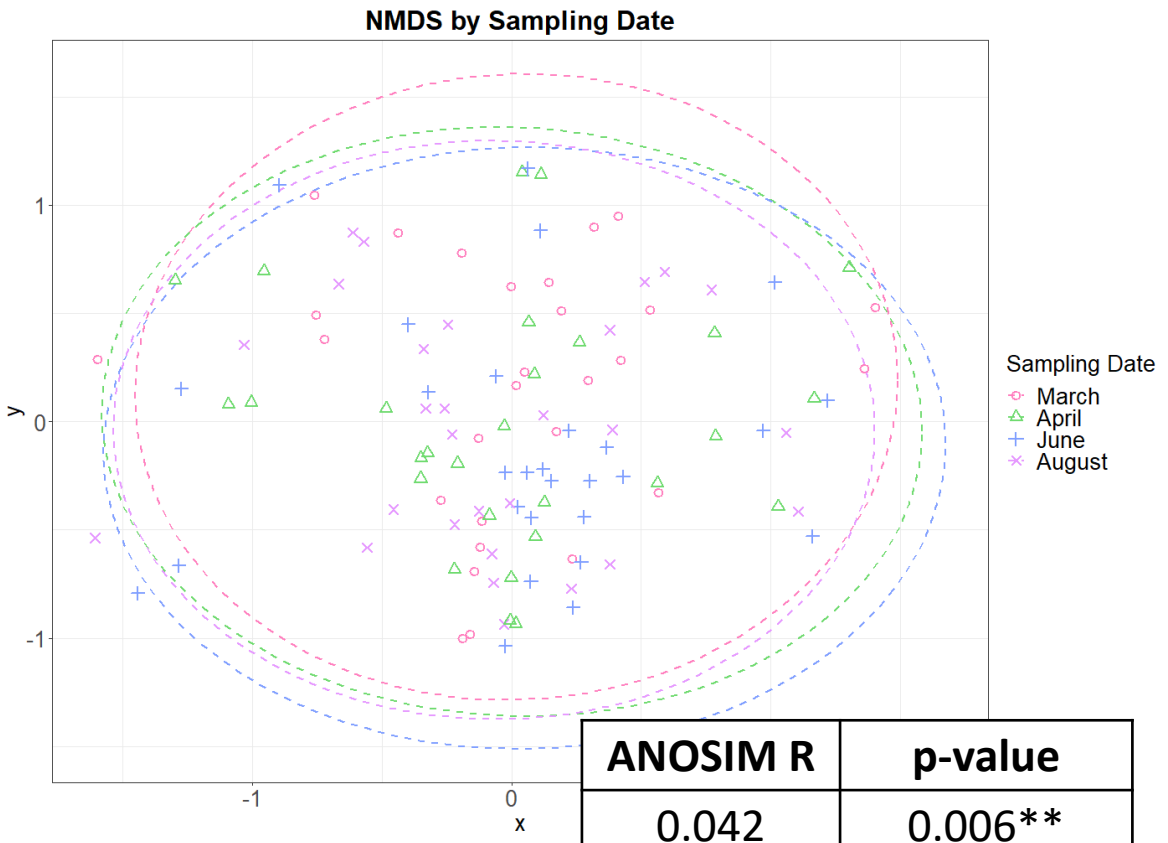




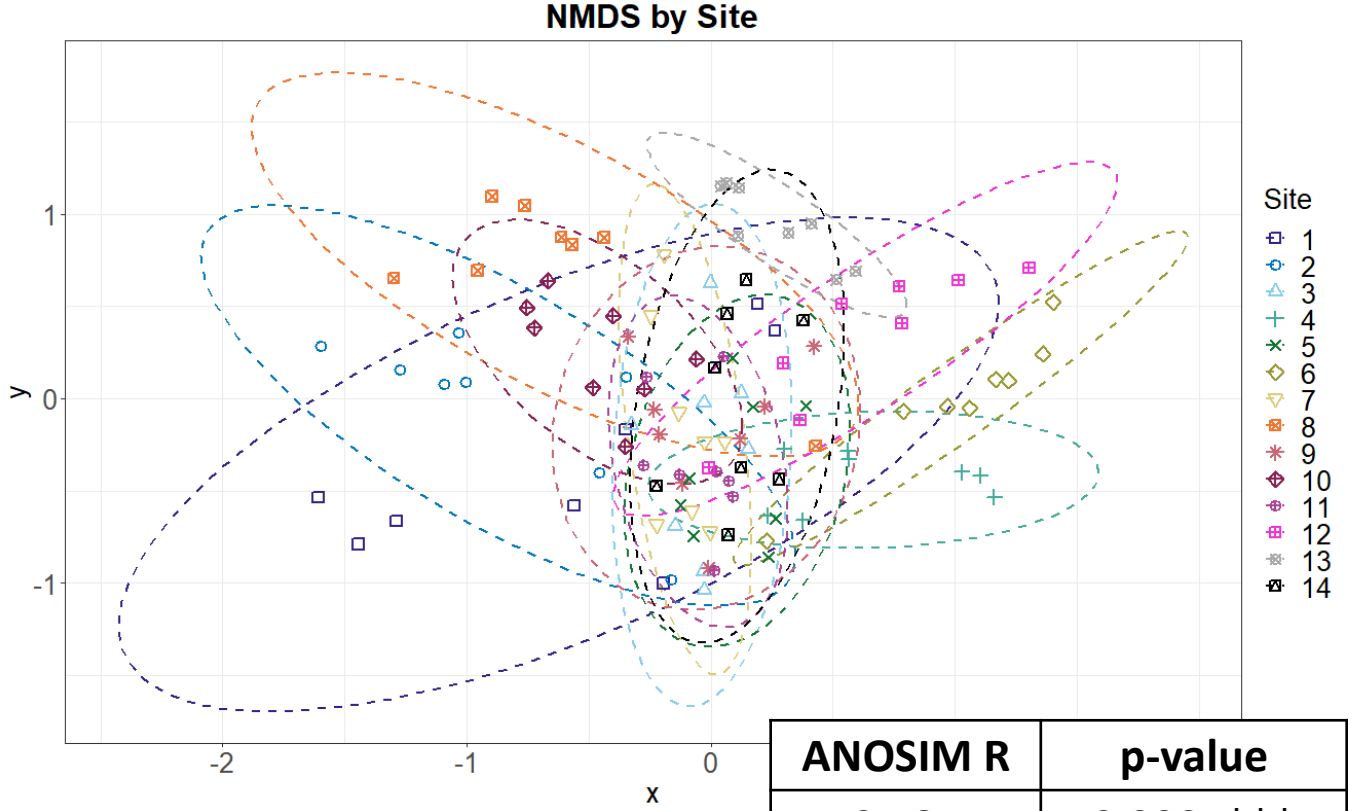
Maddie Ferrebee

Ferrebee et al., 2023, *PLOS Water.*

Spatial variations are stronger drivers of microbial community than temporal variations



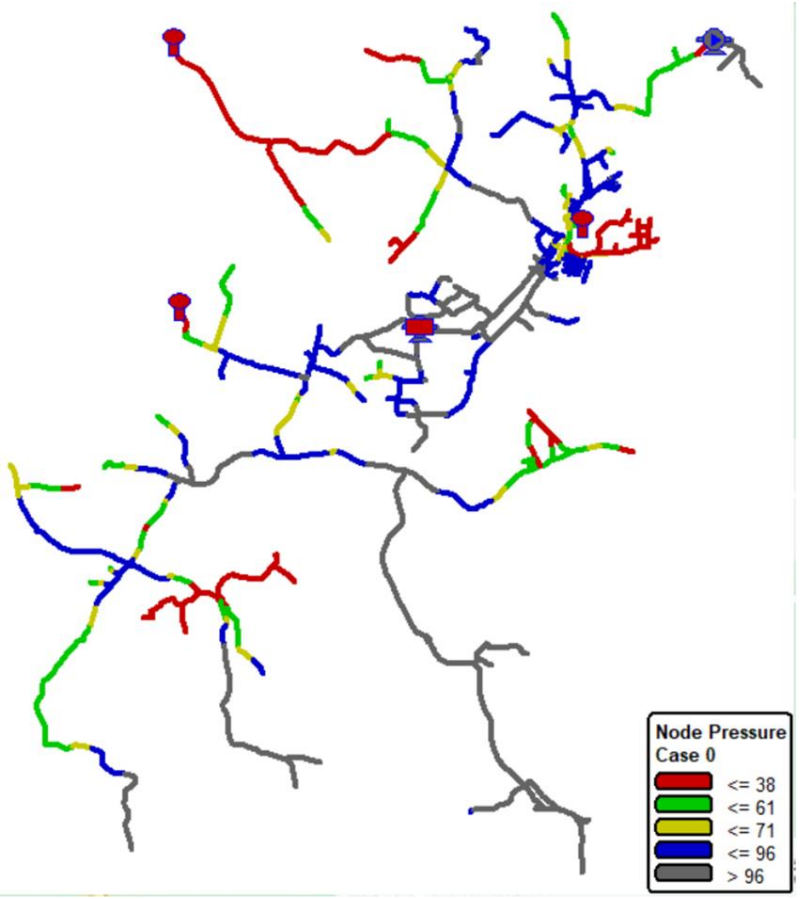
ANOSIM R	p-value
0.042	0.006**



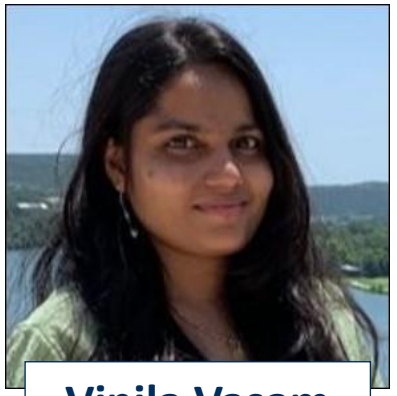
ANOSIM R	p-value
0.581	0.0001***

Hydraulic parameters are stronger drivers of microbial community than water quality parameters

- Velocity, flowrate, and pressure were all correlated with bacterial diversity
- Changes in pressure, velocity, or flow may cause biofilms and loose deposits to detach from the pipe wall and contribute to an increased diversity within the system
- Hydraulic factors vary widely between sites in the DWDS, potentially explaining the role of spatial variations as drivers of microbial community



Research Goal



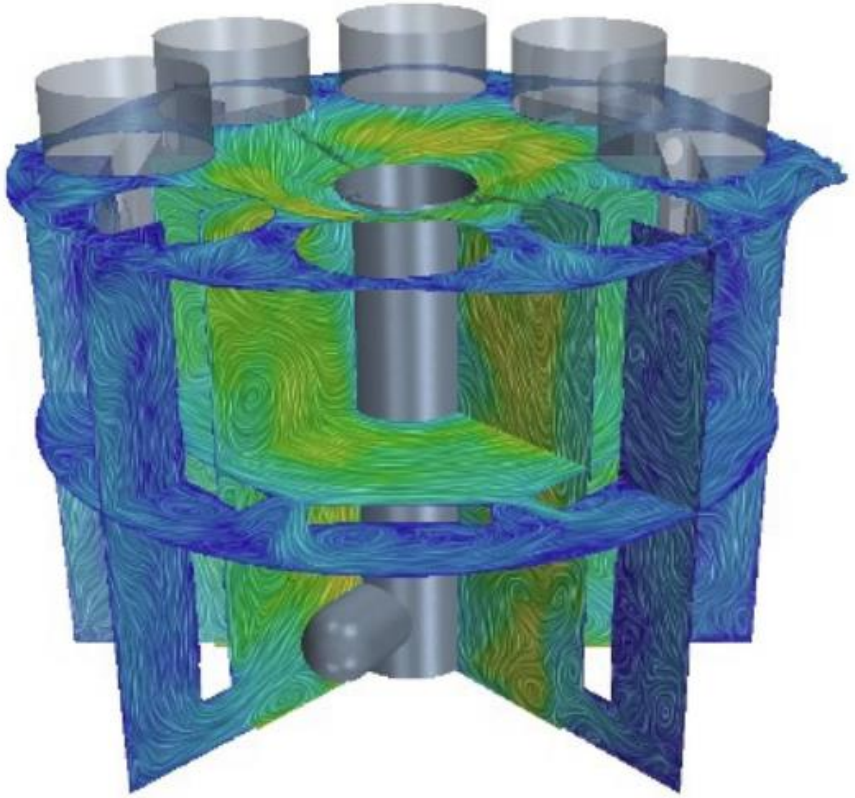
Vinila Vasam

- Evaluate the role of hydraulic conditions in drinking water distribution systems on biofilm formation and associated impacts to water quality.

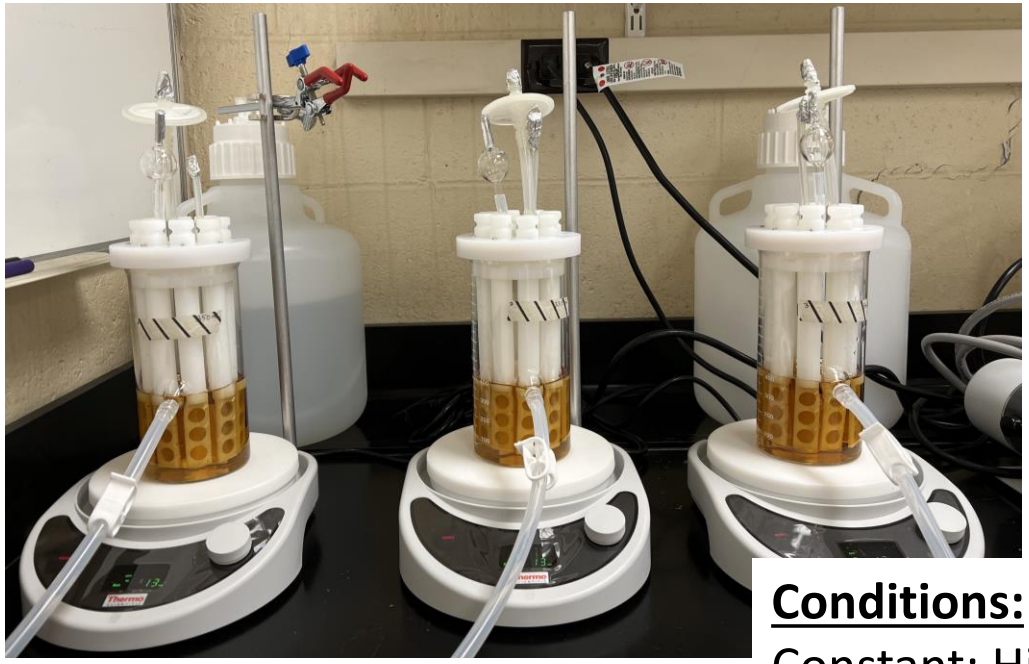
Pseudomonas fluorescens: Model Drinking Water Organism

CDC Biofilm Reactor (Biosurface Technologies Corp.)

Simulating DWDS Hydrodynamic Stresses



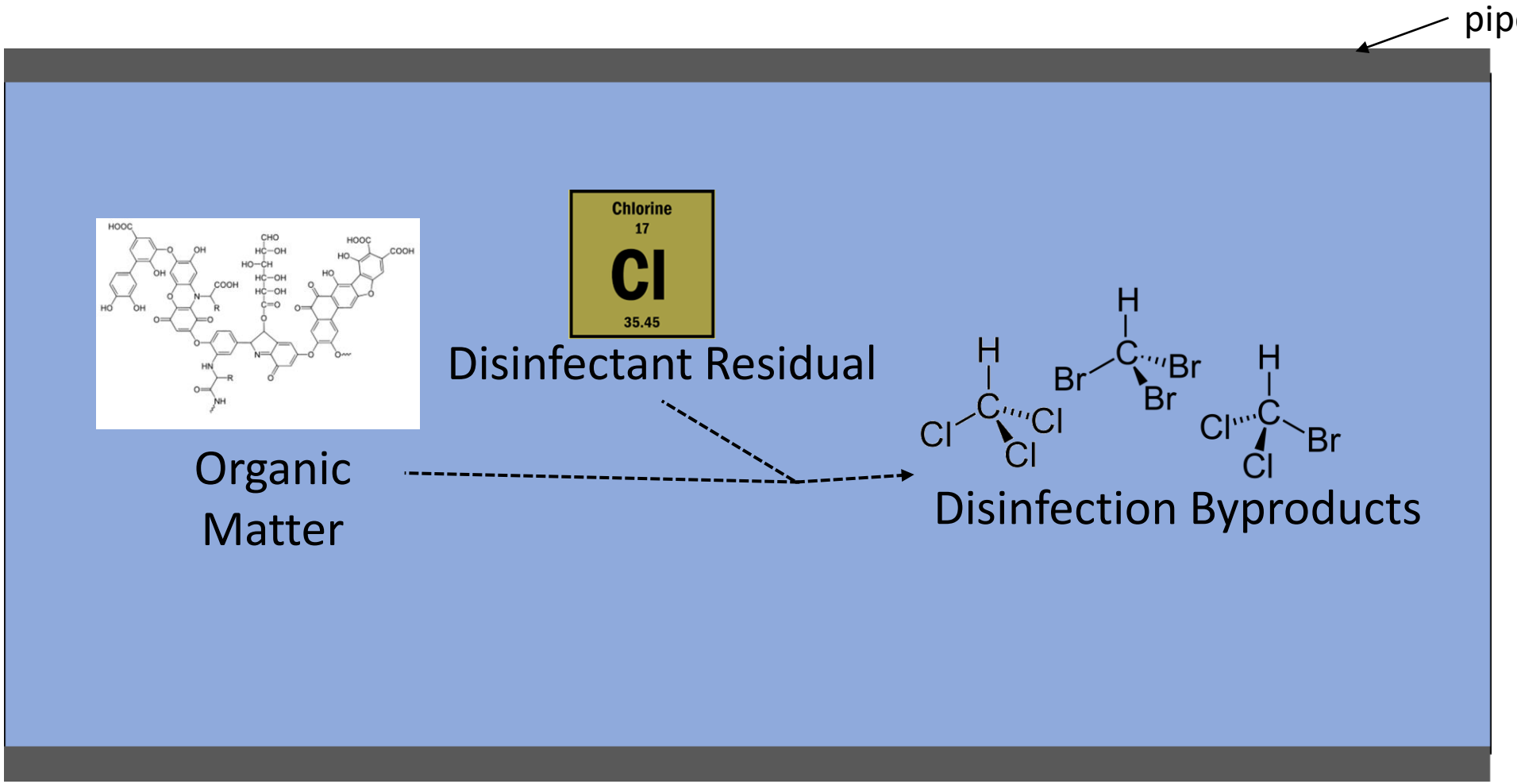
Johnson et al., 2021, *Microorganisms*.



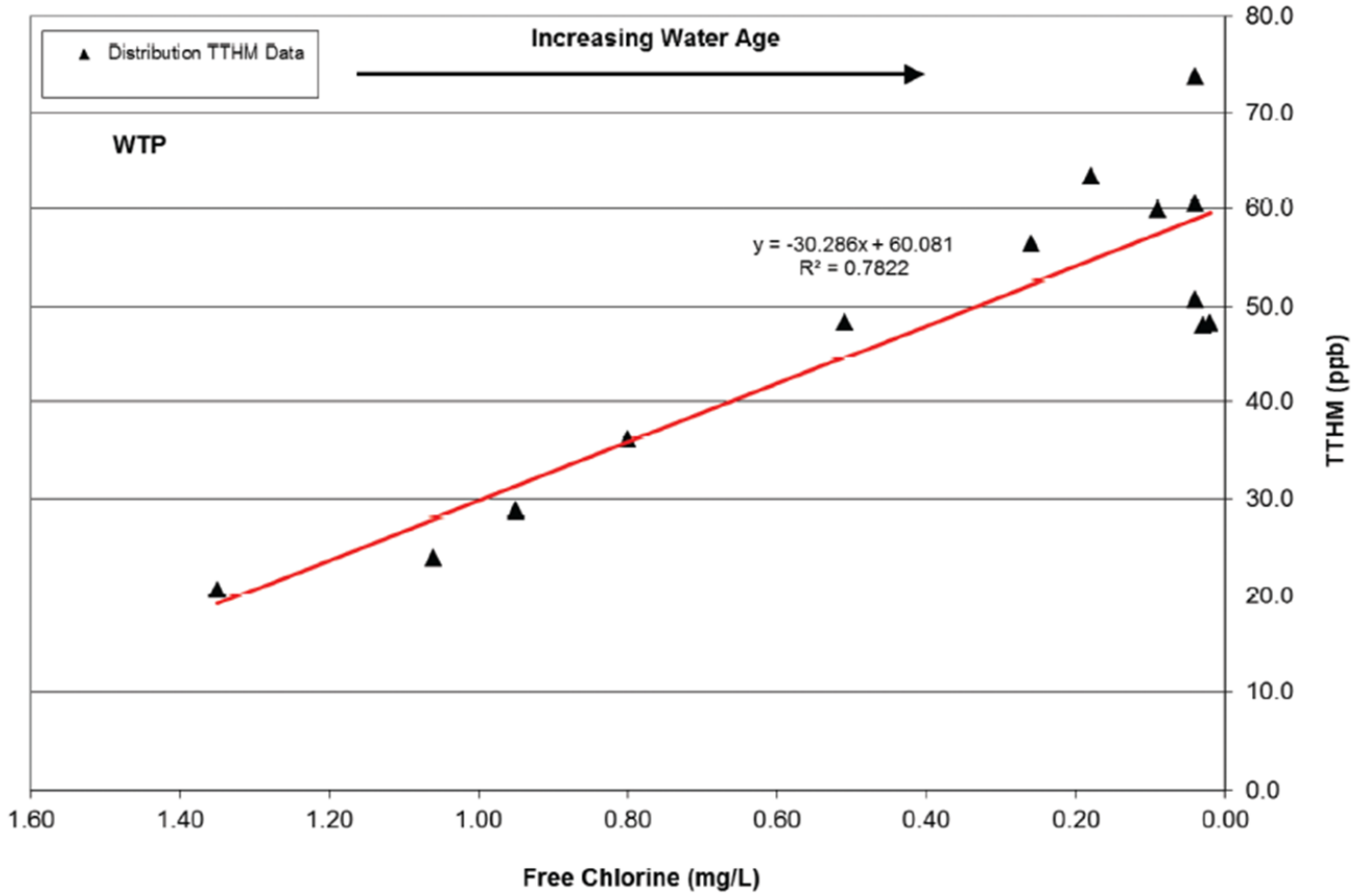
Conditions:

Constant: High shear stress
Constant: Moderate shear stress
Constant: Low shear stress
Variable: Low/moderate shear stress
Variable: Low/high shear stress

DBP Formation in the Distribution System

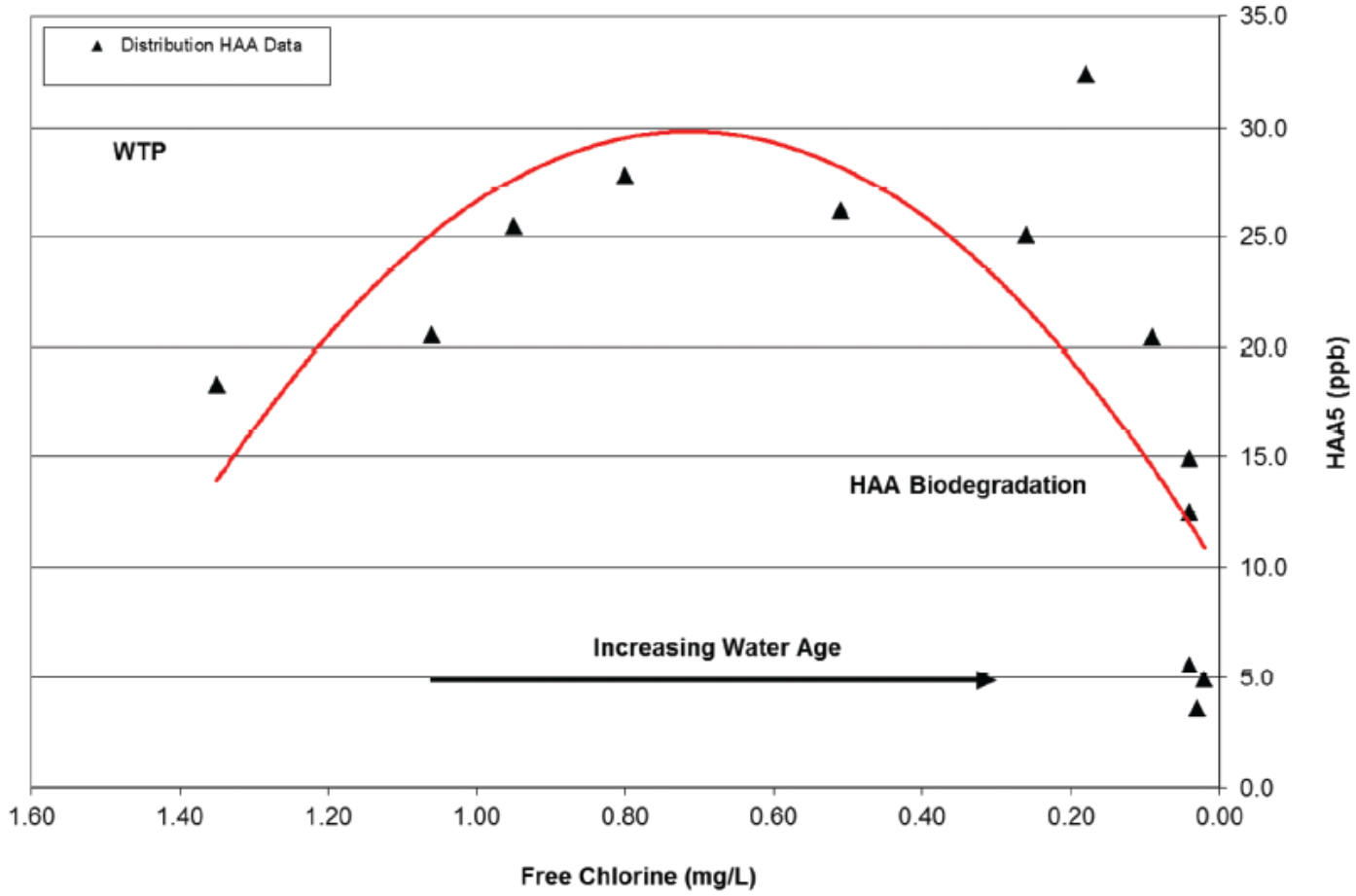


Disinfection Byproduct Formation in the Distribution System



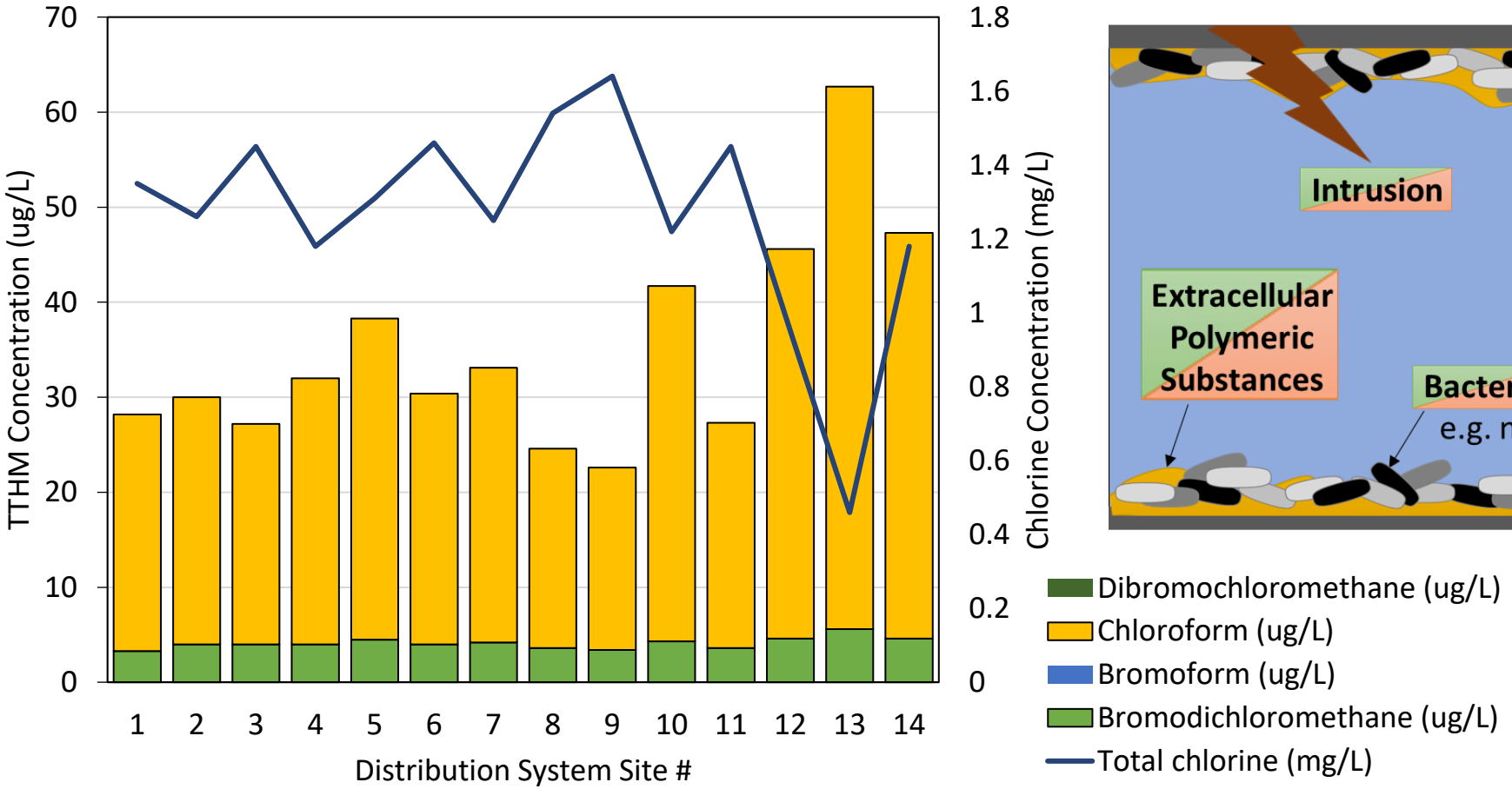
Source: USEPA 2013.

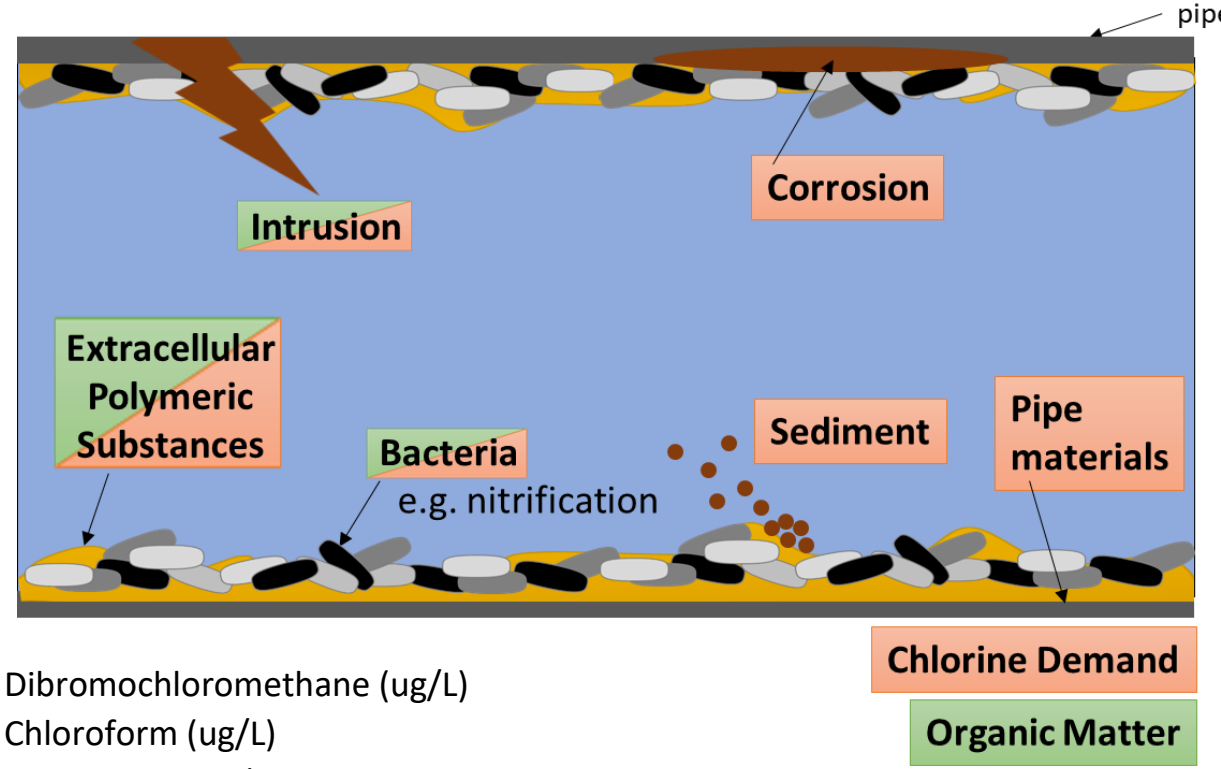
Disinfection Byproduct Formation in the Distribution System



Source: USEPA 2013.

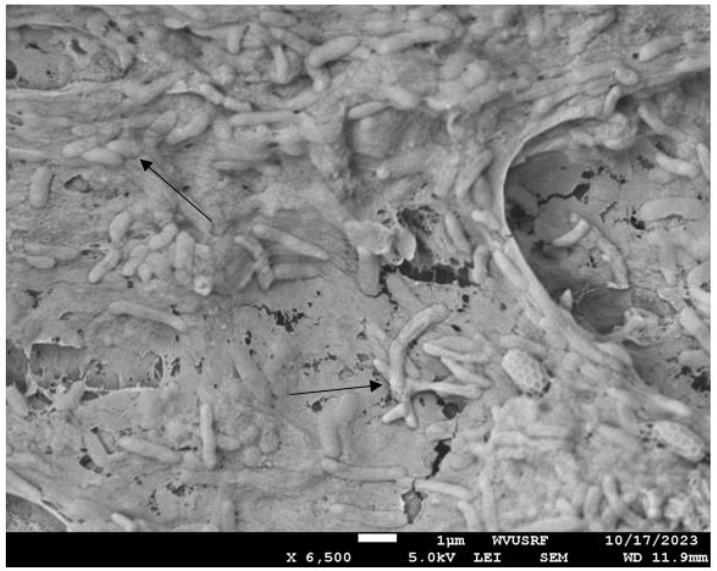
Disinfection Byproduct Formation in the Distribution System

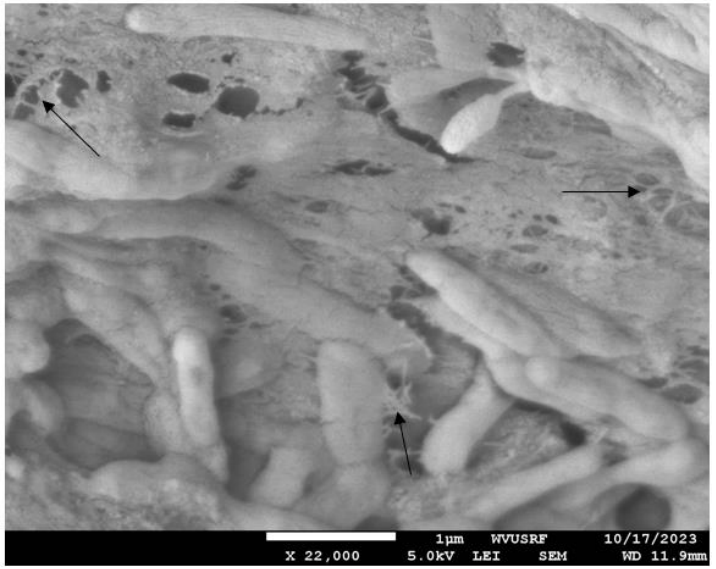




Method Development

- Reactor operation optimization to select for *P. fluorescens* biofilms
- Extraction of extracellular polymeric substances for quantification and characterization from biofilms
- Disinfection byproduct formation potential
- Scanning electron microscopy for biofilm visualization





Next Steps

- Preliminary data and “proof of concept” from this study were the basis for part of my recent NSF CAREER award: “Elucidating hydrodynamic drivers of microbial water quality in drinking water distribution systems”

- We will continue to investigate the role of biofilms in shaping drinking water quality, particularly disinfection byproducts, through field and lab scale studies.

Thank you!

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