



# USEPA Office of Research and Development HOMELAND SECURITY RESEARCH PROGRAM



## **DRINKING WATER PIPELINE AND PREMISE PLUMBING DECONTAMINATION OF *BACILLUS GLOBIGII***

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**Biofilm Technologies: Pathways to Product Development**  
**February 4-5, 2020**



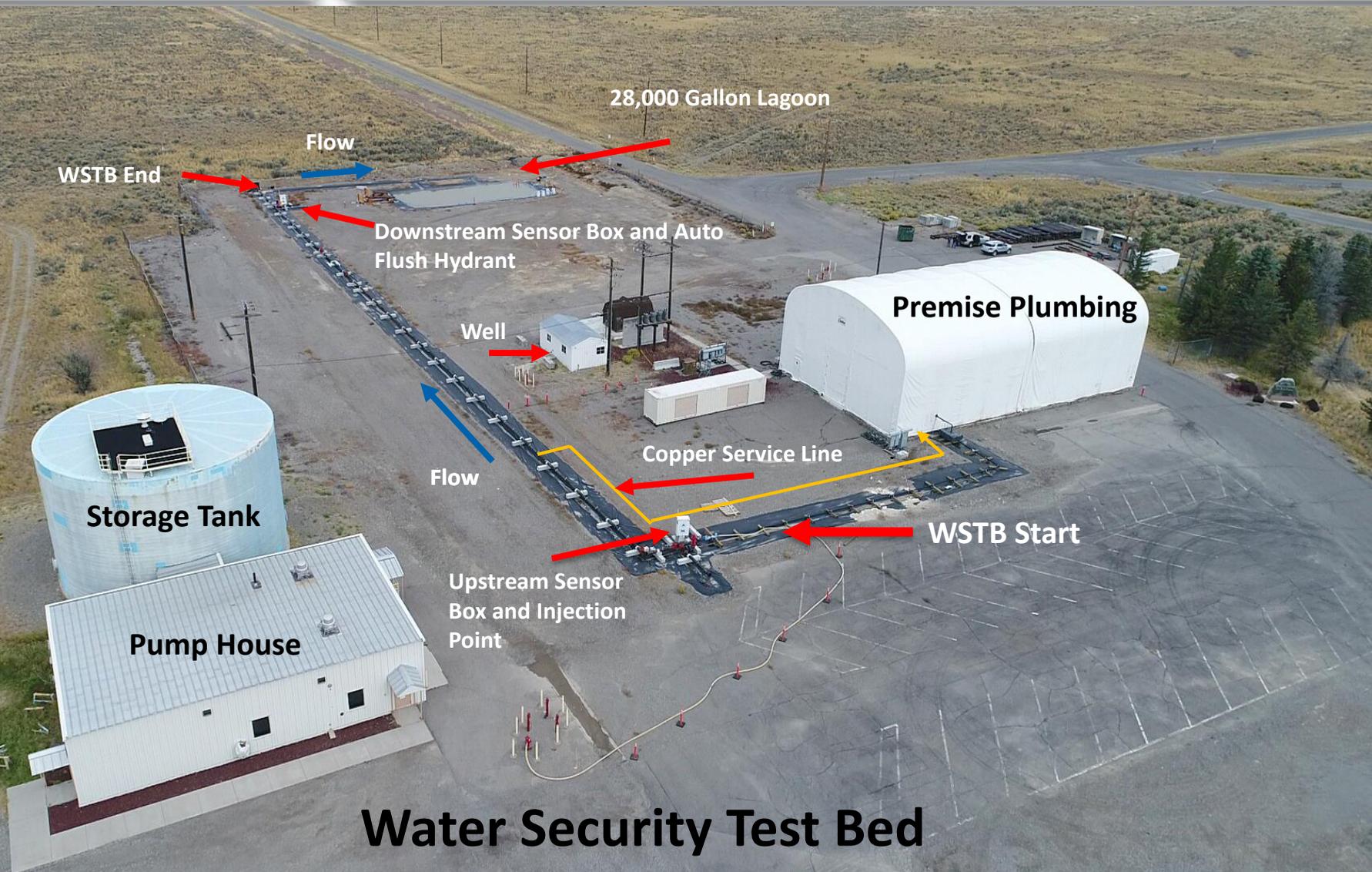
# Presentation Outline

- **Overview of Water Security Test Bed Research**
- **Decontamination of distribution system infrastructure with physical scouring (pigging)**
  - **Ice Slurry**
  - **Chain Cutter**
  - **Jet Sprayer**
- **Premise Plumbing Decontamination**
  - **Flushing and Disinfection**
- ***Legionella* Occurrence**
- **Summary**



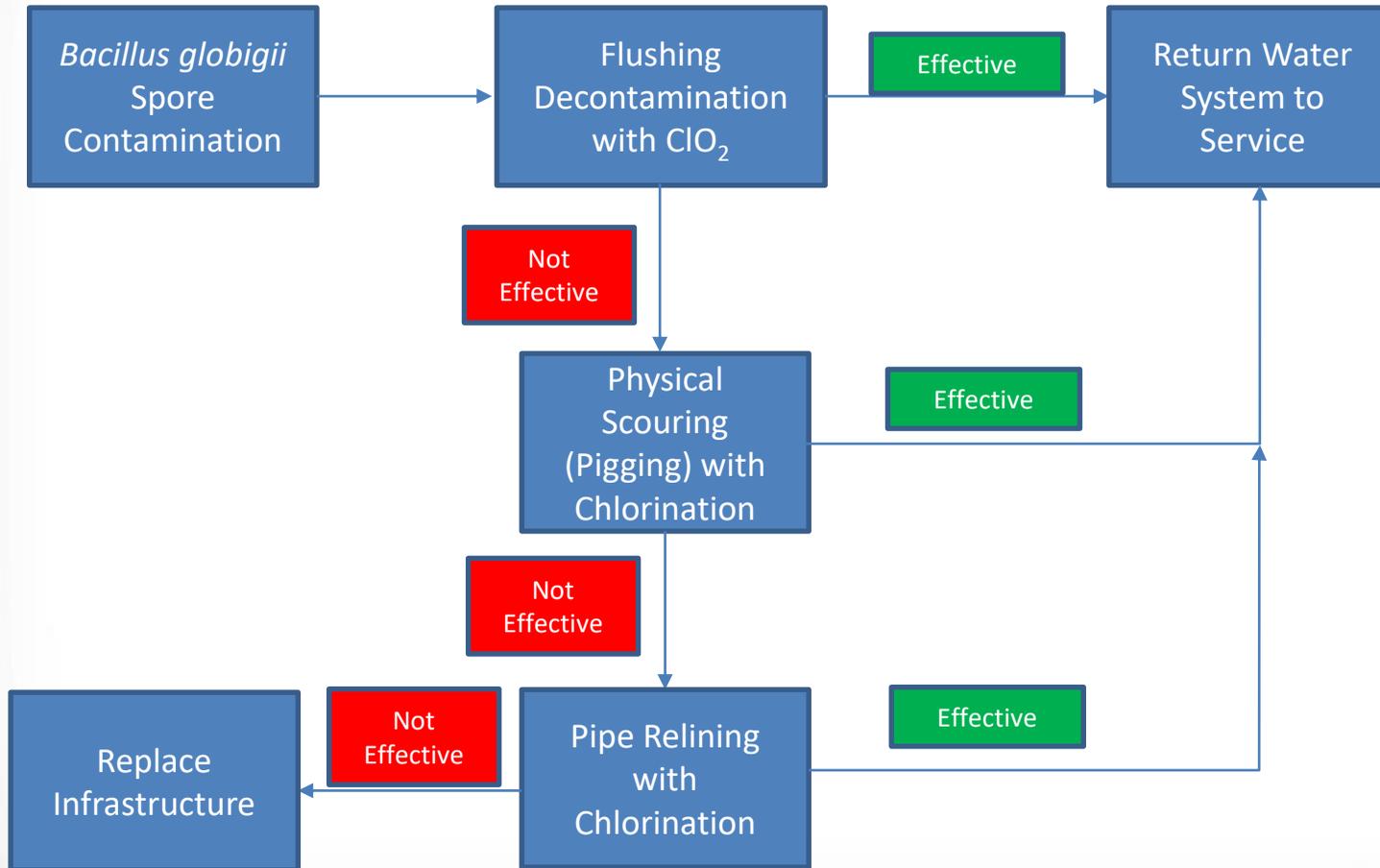
# Water Security Test Bed Capability

Water Security Test Bed Video: <https://www.youtube.com/watch?v=pQvsBC-U4a8>





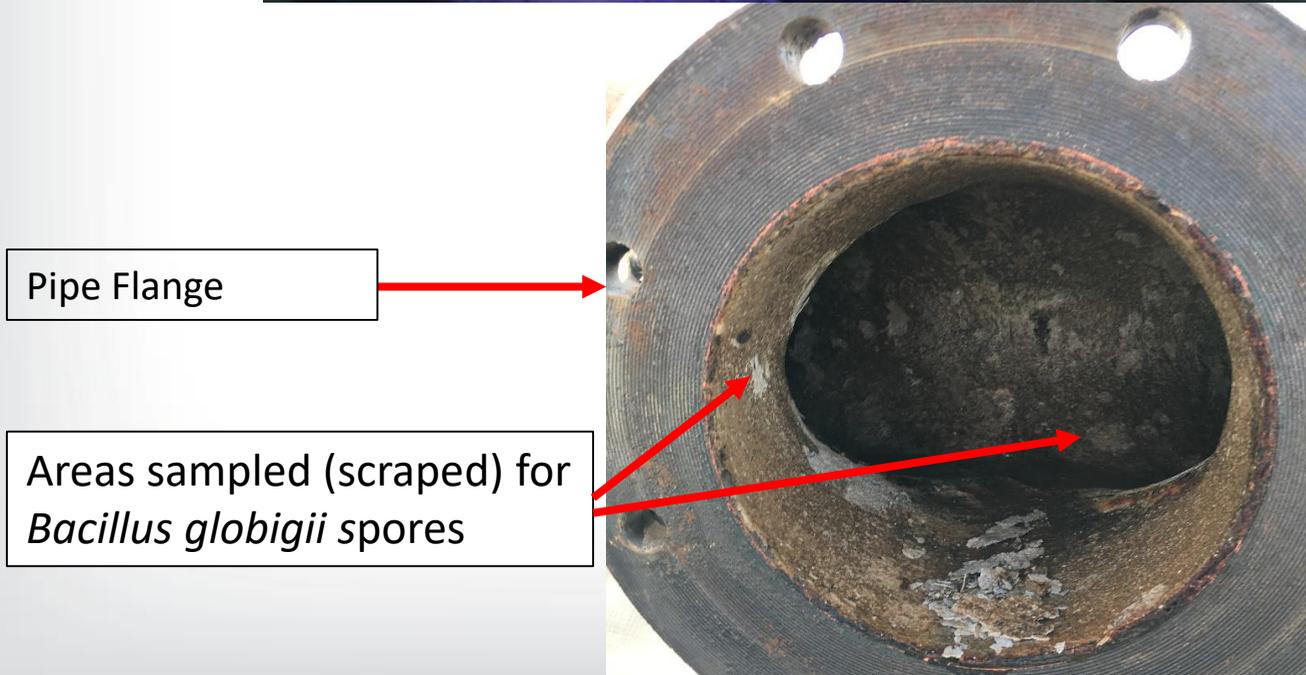
# Microbial Pipe Decontamination Approach



- WSTB pipe was contaminated with *Bacillus globigii* (BG) spores
  - BG injected at  $10^6$  cfu/ml in the bulk water phase
- Decontamination with chlorine dioxide
  - Target concentrations
    - 25 mg/L per pilot experiments
    - 100 mg/L in the field
  - Chlorine dioxide concentration difficult to maintain due to heat and pipe demand
  - Only 2-log reduction in spores compared to 5-log in the pilot scale experiments

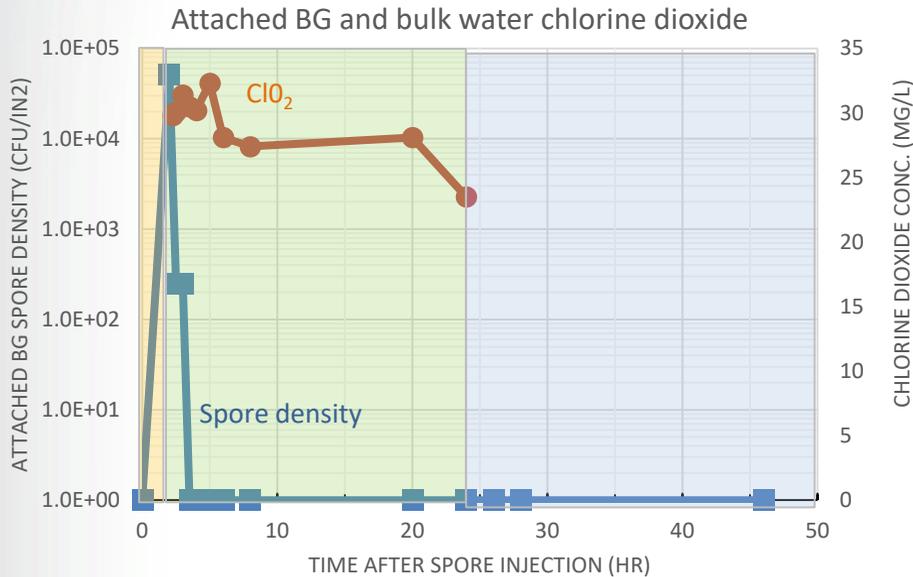


# Microbial Sampling



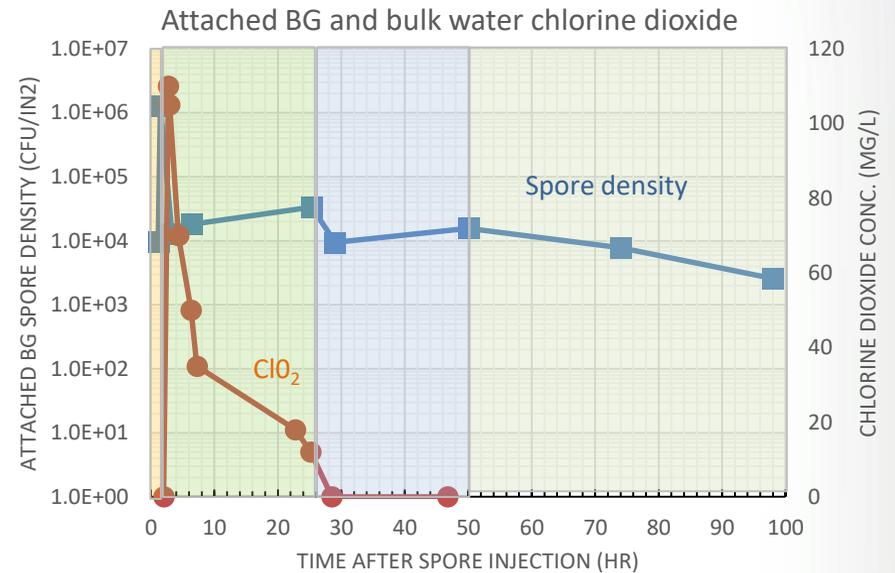


# Bacillus globigii Experiments



## Data from Pilot Scale Decontamination Loop at EPA's Test & Evaluation Facility

- No spores detected on cement-mortar after treatment with 25-30 mg/L ClO<sub>2</sub>

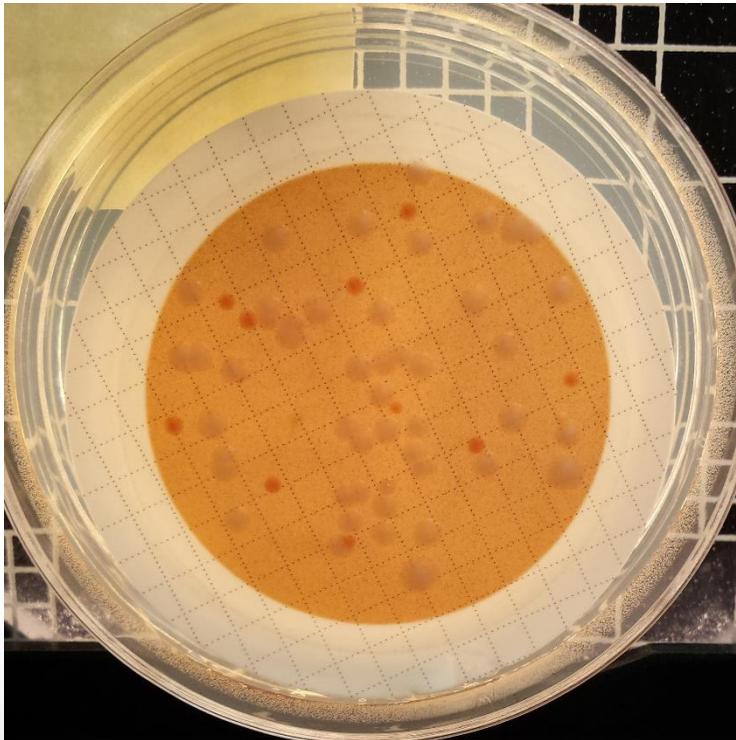


## Data from Full Scale WSTB at INL

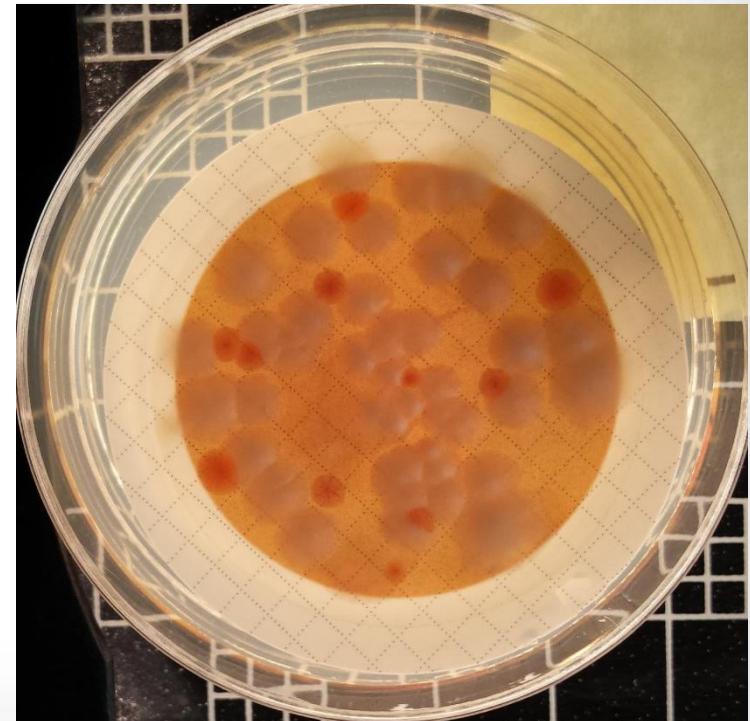
- Spores persisted on cement-mortar in the presence of up to 100 mg/L ClO<sub>2</sub>
- Pipe demand, temperature fluctuation and dead end spaces impacted decontamination
- Spores found on surfaces even after WSTB was mothballed for winter

- Flushing plus disinfection still leaves spores behind
- Spores still viable after winter in dry pipe

24  
hours



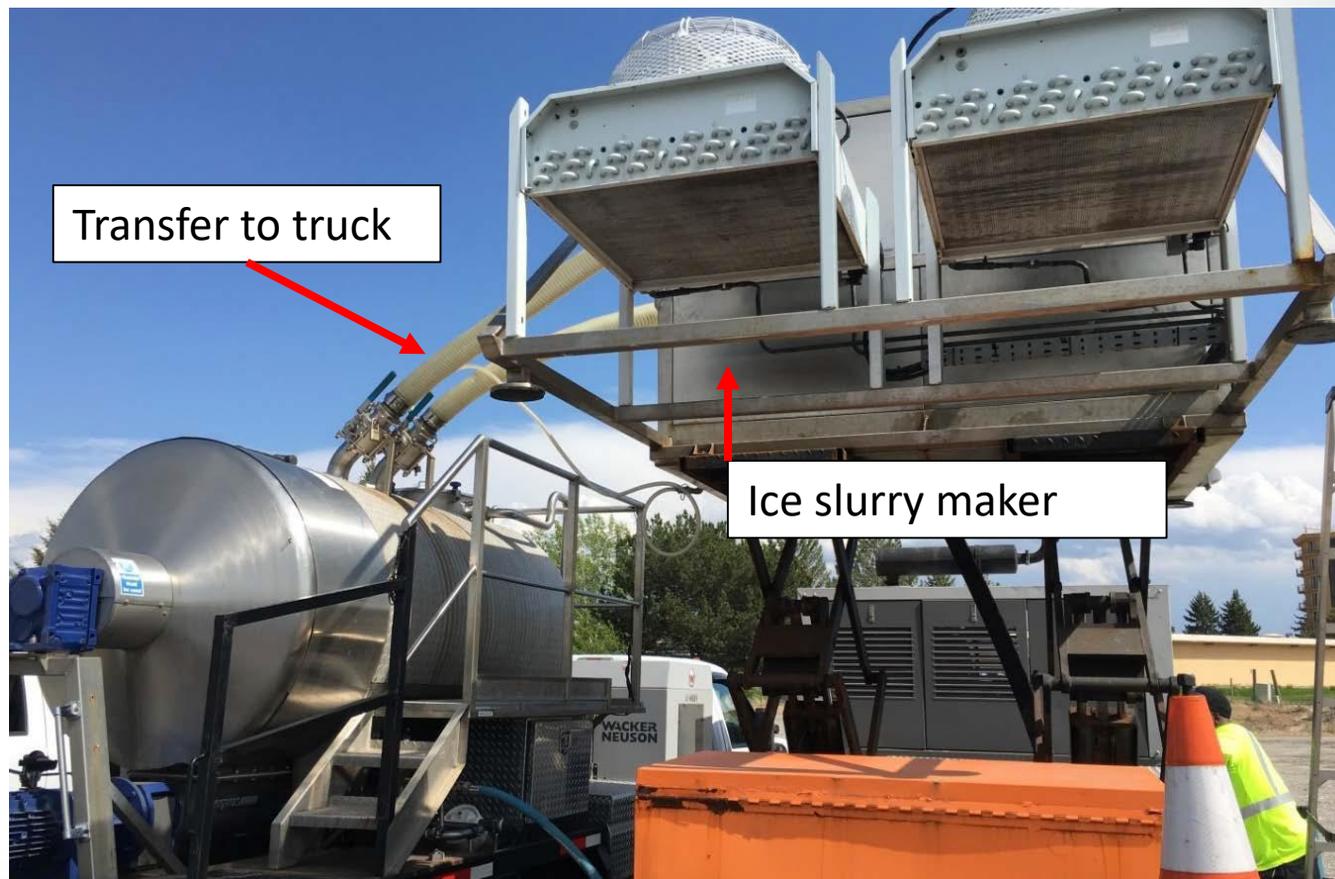
48  
hours



Investigate physical scouring to follow  
flushing plus disinfection

- Ice Slurry
- Chain Cutter
- Jet Sprayer

## Ice Slurry





# Decontamination Using Ice Pigging



Ice slurry mix connection to upstream fire hydrant

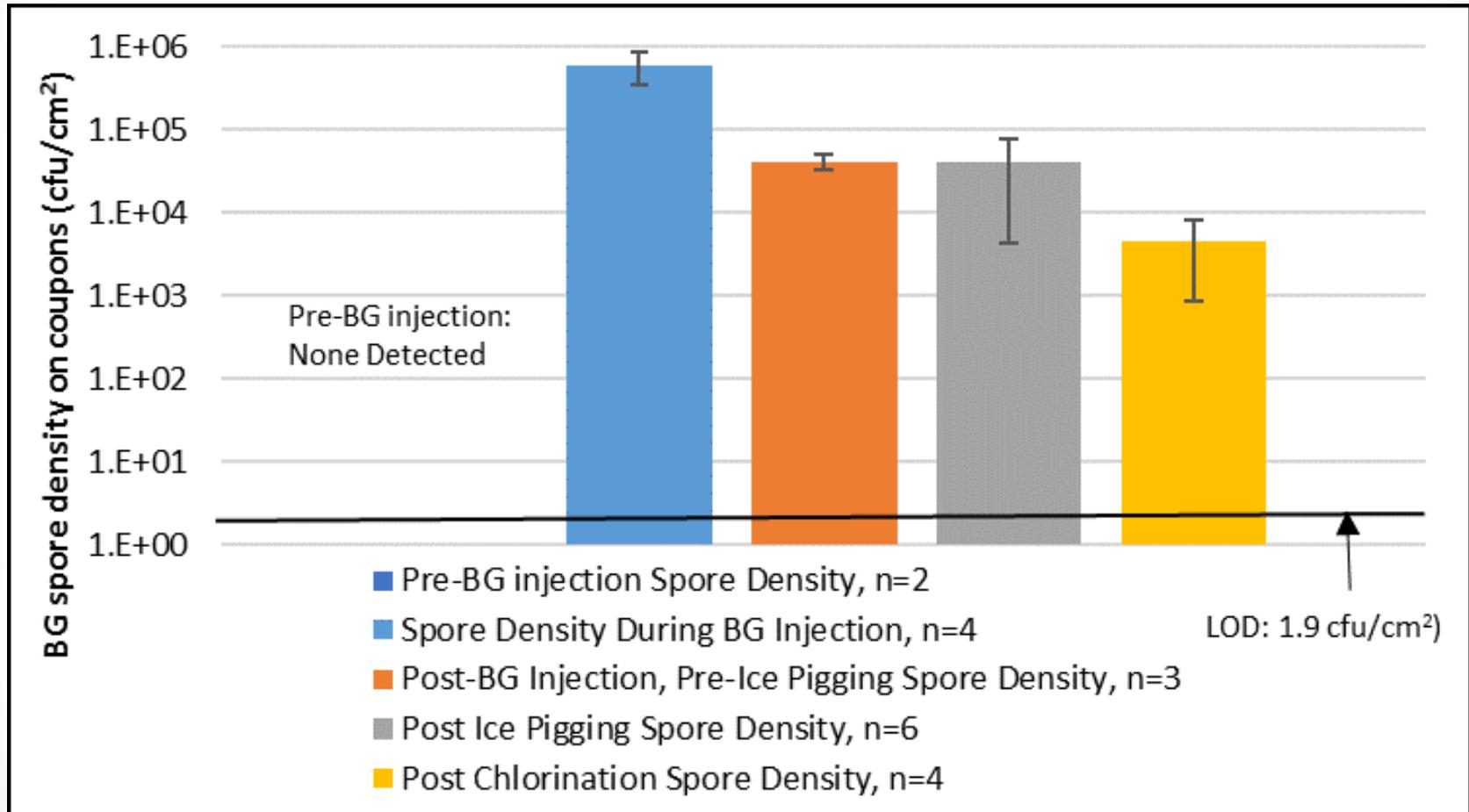




# Decontamination Using Ice Pigging



# Ice Pigging Decontamination Data



# Chain Cutter

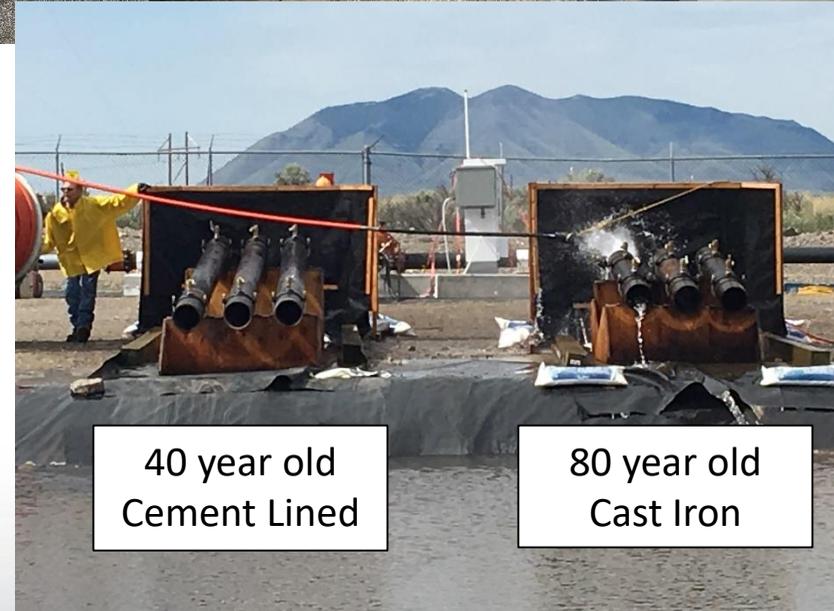




# Decontamination with Chain Cutter



Sewer Vacuum and storage tank



40 year old  
Cement Lined

80 year old  
Cast Iron



# Decontamination with Chain Cutter

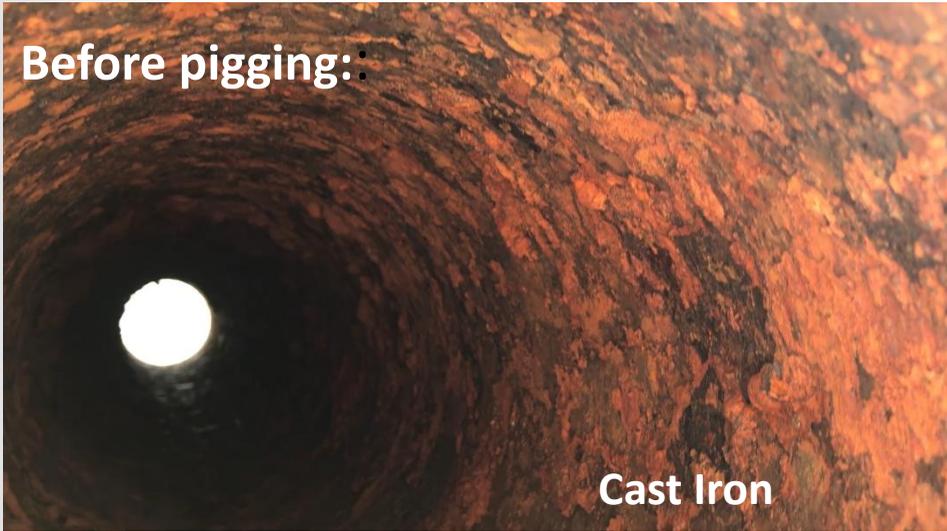






# Pipe Interior Before and After Pigging

Before pigging:



Cast Iron

Before pigging:



Cement Lined

After pigging:

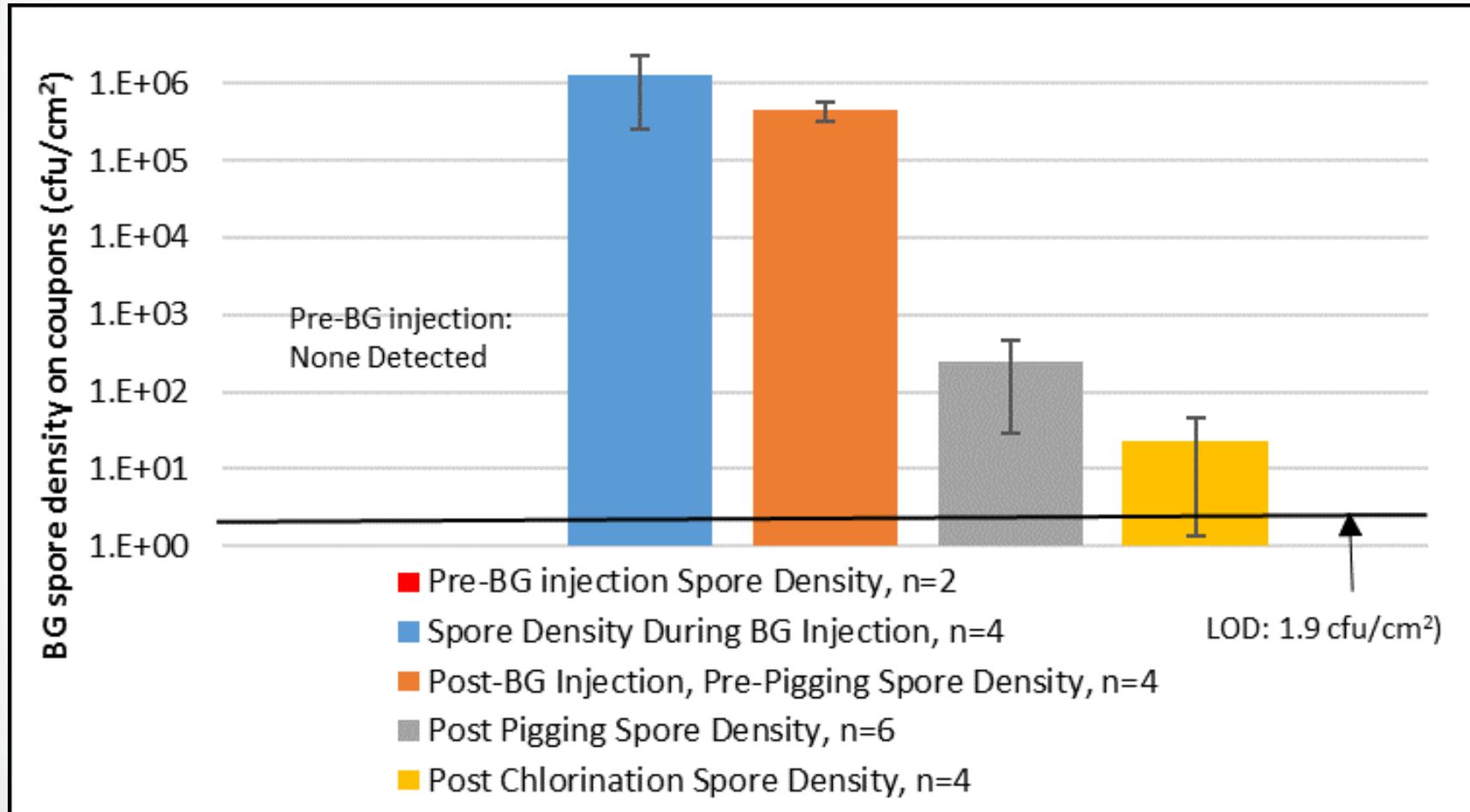


After pigging:



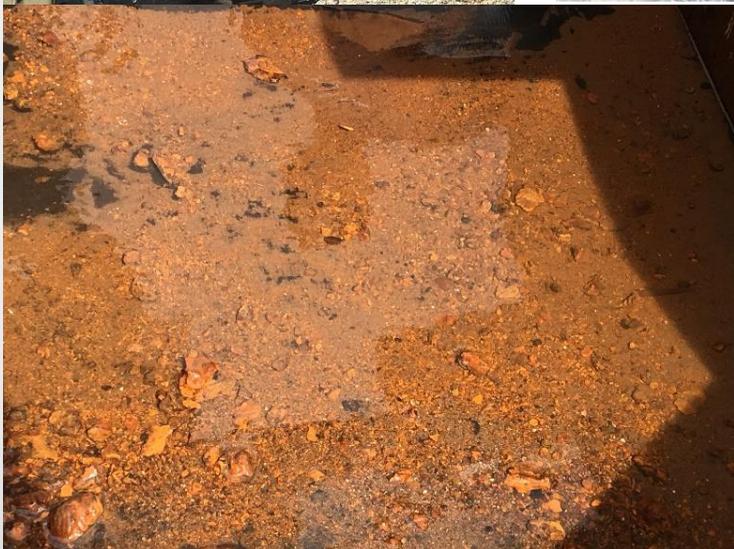


# BG Decon with Chain Cutter Pigging



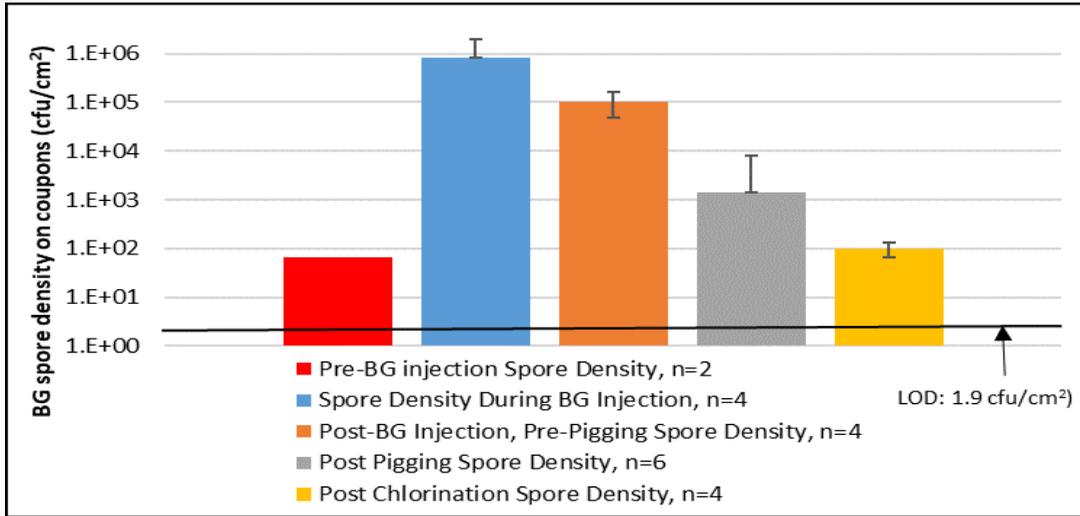


# Decontamination with Jet Sprayer

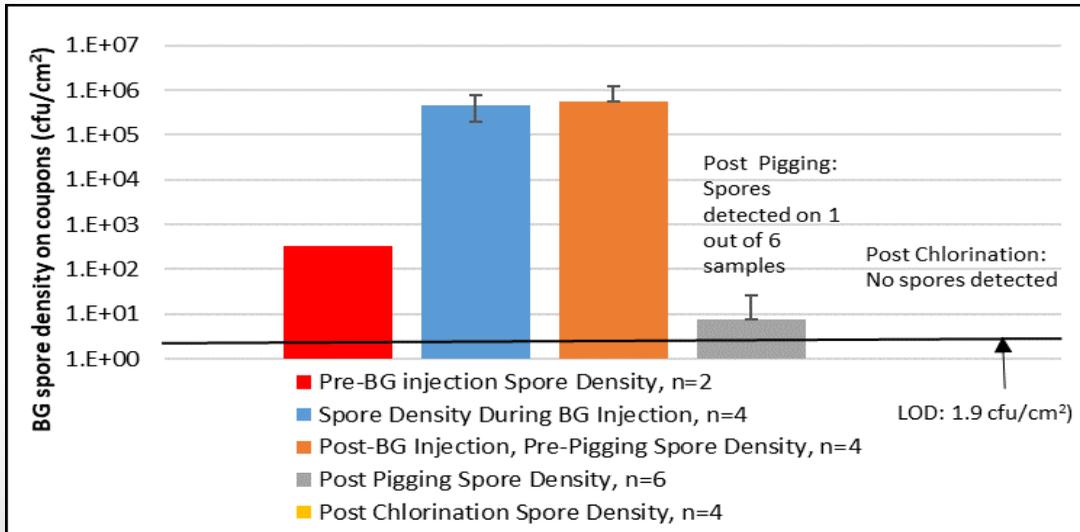


# Jet Sprayer Video





*Bg* decon from cement mortar-lined pipe section



*Bg* decon from DC Water corroded cast iron pipe

# Cast Iron Pipe



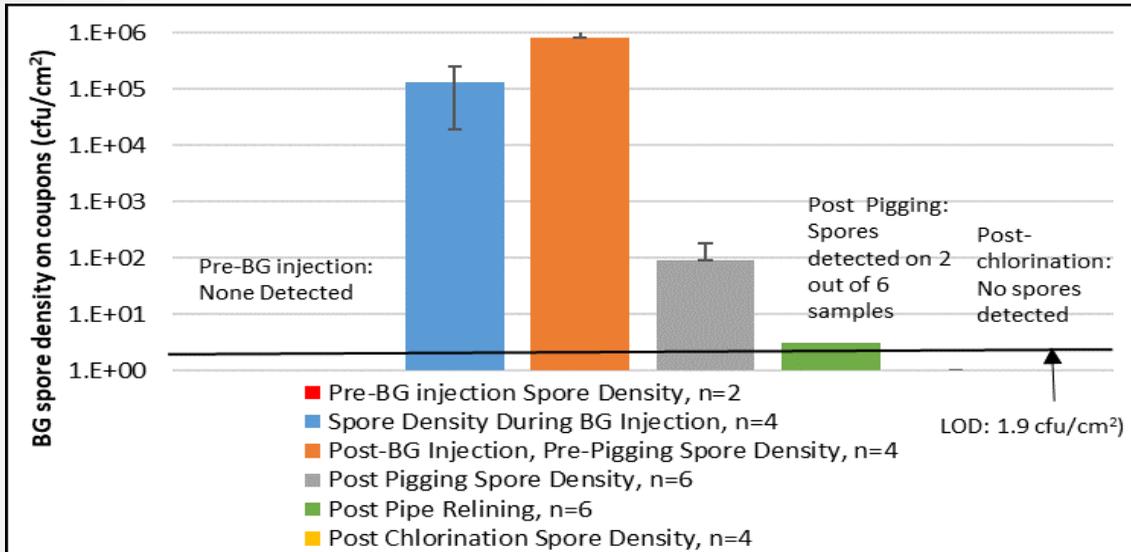
# Chemical Pipe Re-lining



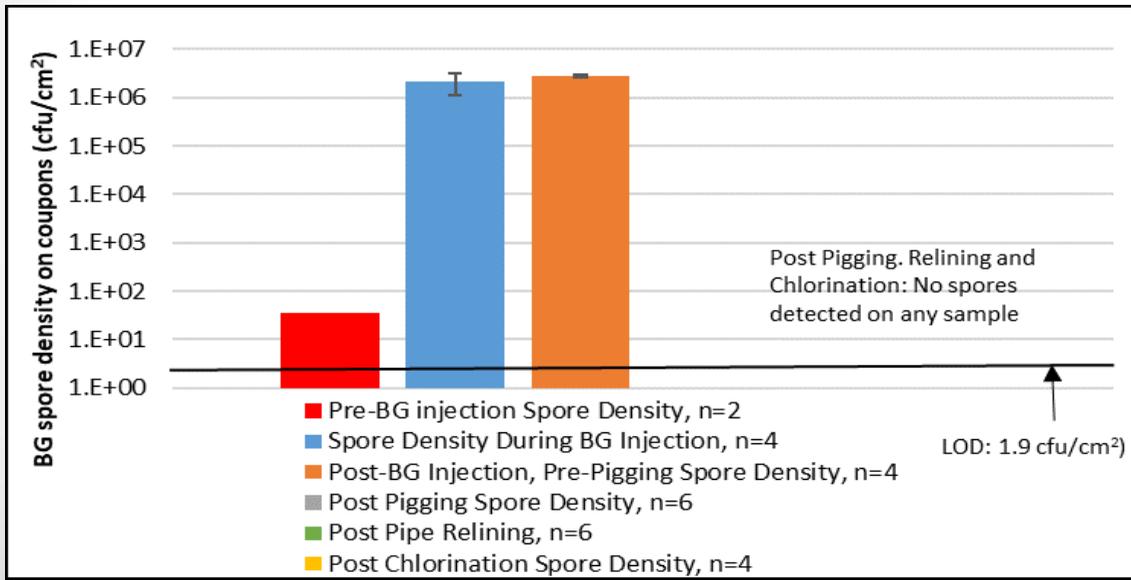
- *BG* spore scrapings and swabs being analyzed
- Pipes lined with chemical mixture
- Post pigging chlorine residuals ranged from 60 to 120 ppm
- Post lining chlorine residuals nearly doubled in pipe
- No need to open service connections



# BG Decon with Chemical Pipe Re-lining



*Bg* decon from cement mortar-lined pipe section



*Bg* decon from DC Water corroded cast iron pipe



# Cured-In-Place Pipe (CIPP) Re-lining





# Cured-In-Place Pipe Re-lining

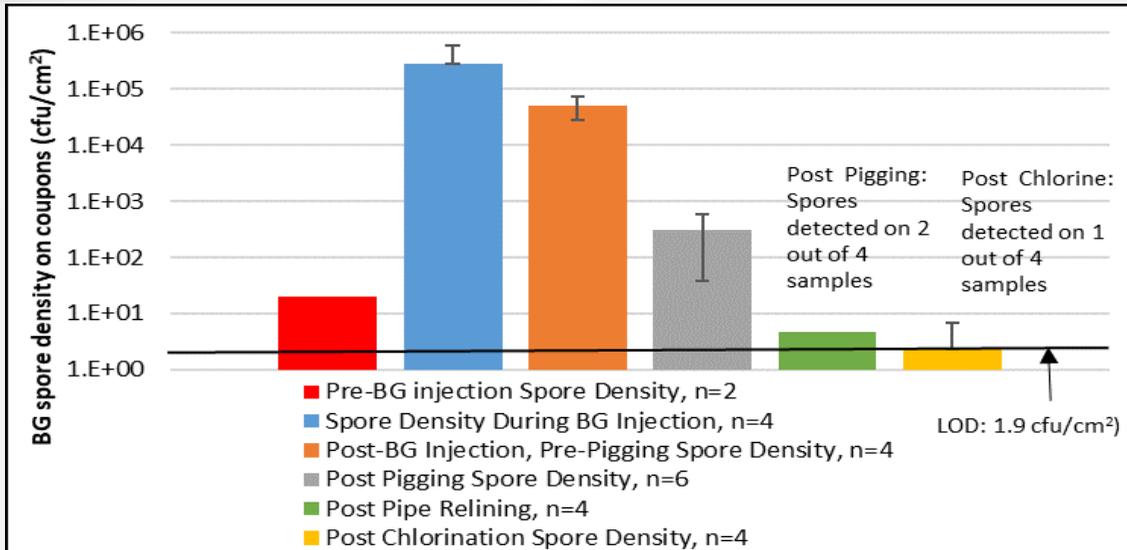


# Cured-In-Place Pipe Re-lining

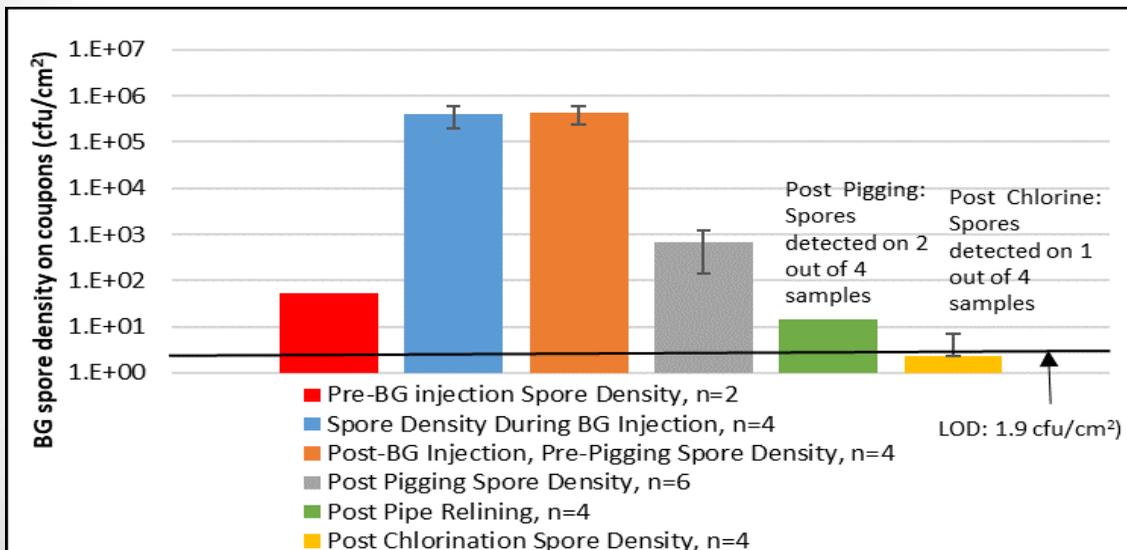




# BG Decon with CIPP Re-lining

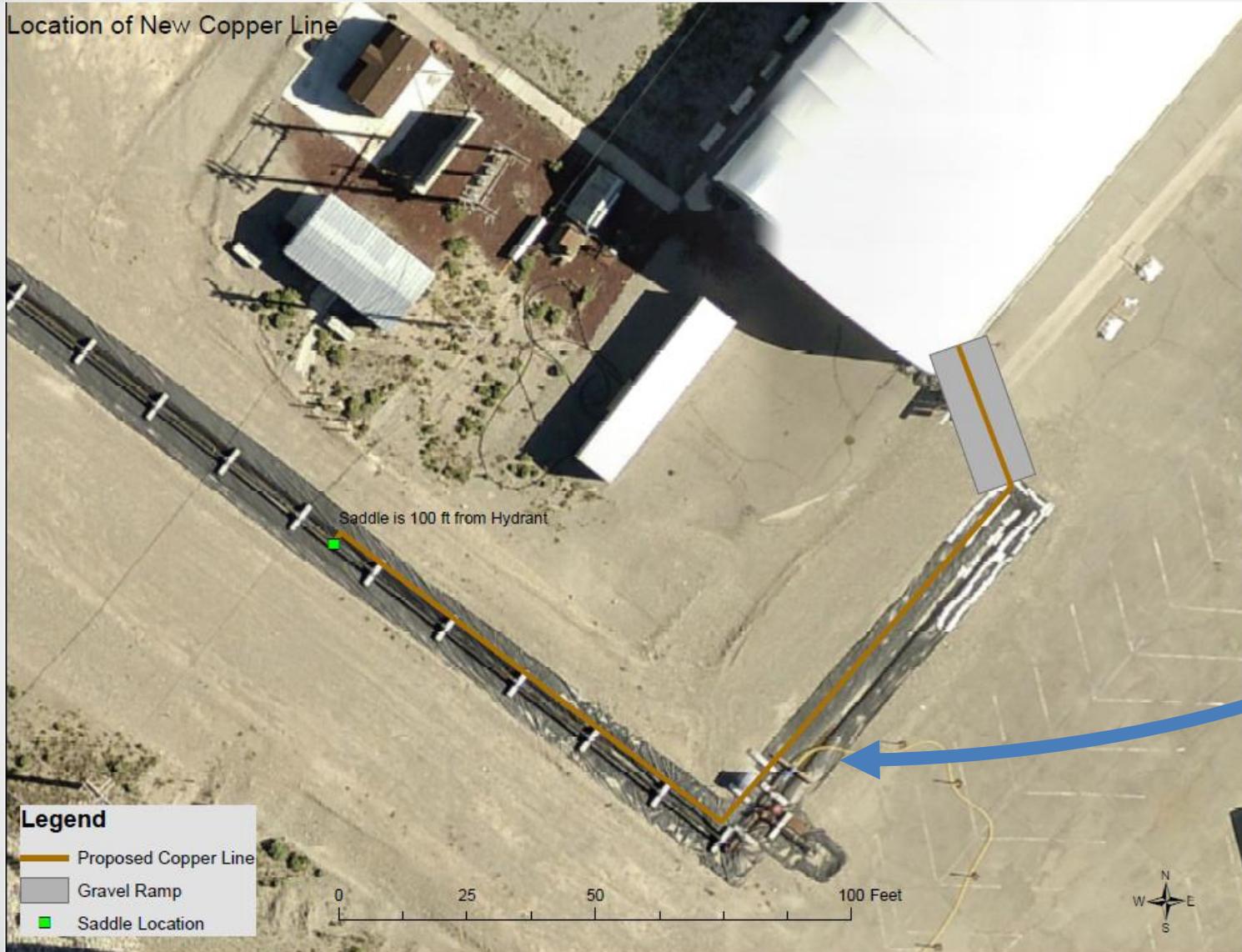


*Bg* decon from cement mortar-lined pipe section



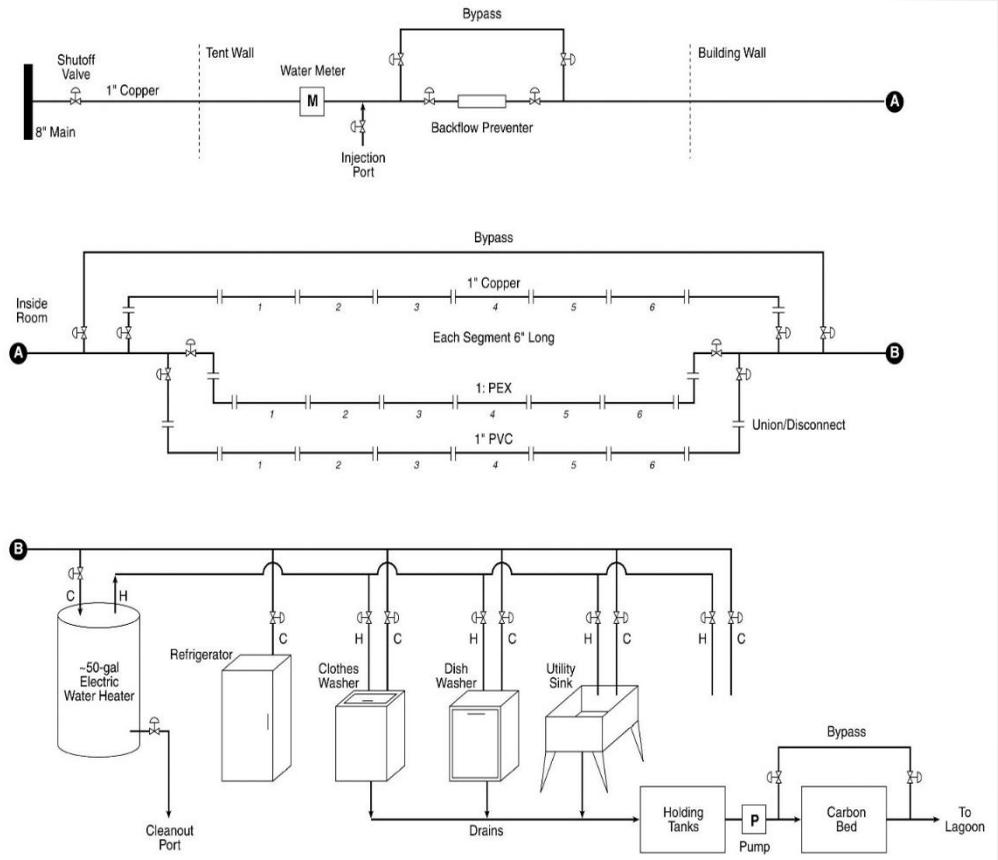
*Bg* decon from DC Water corroded cast iron pipe

Location of New Copper Line



**1" (2.54 cm)  
Copper Service  
Line to Indoor  
Plumbing  
(~ 200', 61m)**

# Premise Plumbing Decontamination



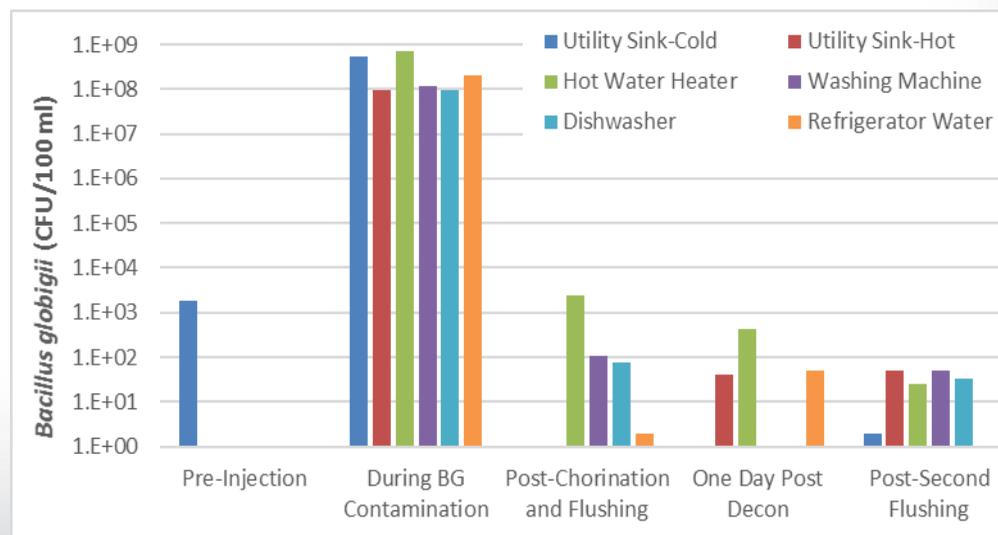
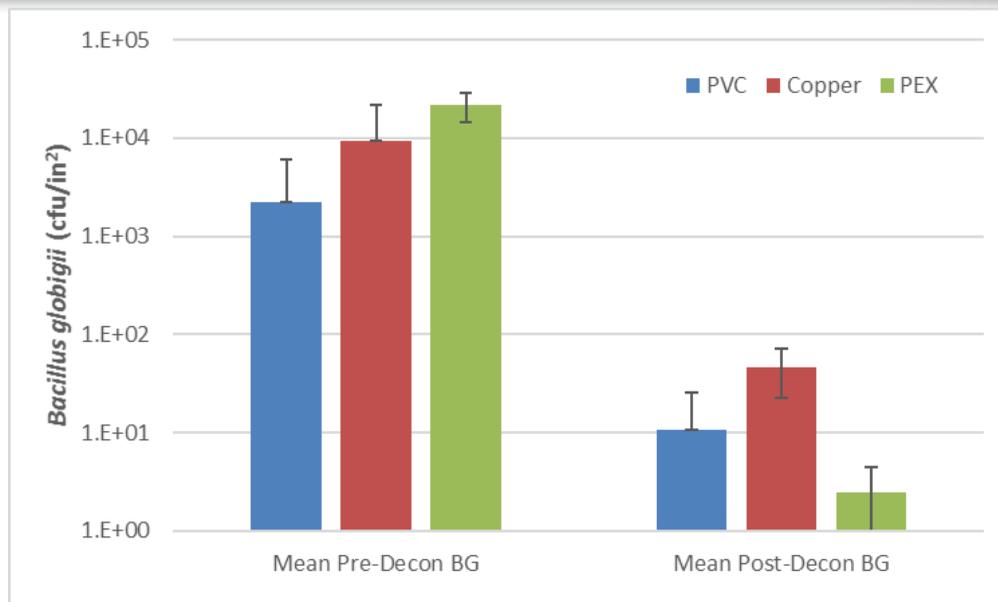
# Premise Plumbing Setup





# Plumbing Microbial Decontamination

- BG spores injected at  $10^6$  cfu/ml
- Disinfection and Flushing:
  - Amended bleach added to plumbing and allowed to sit for 1 hour (1-part bleach:11.75-part water:1-part vinegar)
  - Cold water and refrigerator flushed for 20 min (hot water off)
  - Hot water heater drained, refilled, then hot water flushed for 75 min
  - The flushing process was repeated the next day





# Legionella Sampling Results

Location	No.	Location Description	Quantitative PCR				
			<i>V.vermiformis</i>	<i>Acanthamoeba</i> spp.	<i>M. intracellulerae /chimera</i>	<i>Legionella</i> spp.	<i>L. pneumophila</i>
Connection Port	1	-A port where the 1 in (2.54 cm) copper service connection comes off of the 8 in (20 cm) pipe	not detected	not detected	not detected	not detected	not detected
Meter	2	-Ports at the water meter before the plumbing	not detected	detected	not detected	detected	not detected
HWH	3	-Hot water heater	not detected	not detected	not detected	not detected	not detected
Dispenser	4	-Refrigerator water dispenser	detected	not detected	not detected	detected	not detected
Laundry	5	-Washing machine (requires dipping sample bottle into a pool of water)	not detected	detected	not detected	not detected	not detected
Dishwasher	6	-Dishwasher (requires using a plastic bag to scoop the water from the bottom of the dishwasher)	detected	detected	not detected	not detected	not detected
Sink Cold	7	Cold tap in the utility sink.	not detected	not detected	not detected	not detected	not detected
Sink Hot	8	Hot taps in the utility sink. (collection after 10-15 seconds of running the tap)	not detected	not detected	not detected	detected	not detected

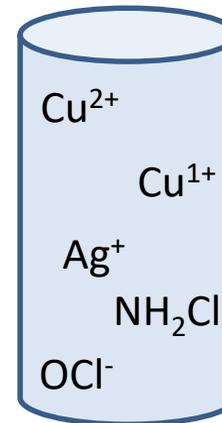
All bulk water samples were *Legionella* spp. and *L. pneumophila* negative by culture (traditional and Legiolert<sup>®</sup>, respectively)



## WSTB Decon Key findings (so far)

- Simple flush and /or over chlorination methods for *Bacillus globigii* (anthrax surrogate) are not effective.
- Physical pigging /scouring improves *Bacillus globigii* removal but not to non-detect.
- Pipe re-lining may be necessary after pigging.
- Appliances hold up contaminants and are difficult to decon, especially hot water heater tank.
- More?? Legionella different species important, locations?

Current study: determining the effectiveness of metal ions and various water quality parameters on *L. pneumophila* inactivation (bench scale and pilot scale studies)



- $\text{Cl}_2$  + Cu/Ag metal biocides effectiveness
- monitor water quality
- pathogen quantification (culture and molecular)
- microbial community analyses (bulk and biofilm phase)

Bench scale: evaluate combinations of microbes and inactivating agents

Evaluating decontamination technologies for drinking water distribution systems

➤ **Evaluating the effectiveness of flushing for controlling *Legionella pneumophila* growth in building water systems and reducing their levels in premise plumbing**

- Conduct longitudinal study on the impacts of flushing and thermal inactivation on *L. pneumophila*, *Pseudomonas aeruginosa*, and NTMs in hot water heaters, plumbing, and fixtures
- Study design: four hot water heaters, two of conventional design and two prototypes with passive control of microbial growth



University of Colorado Boulder

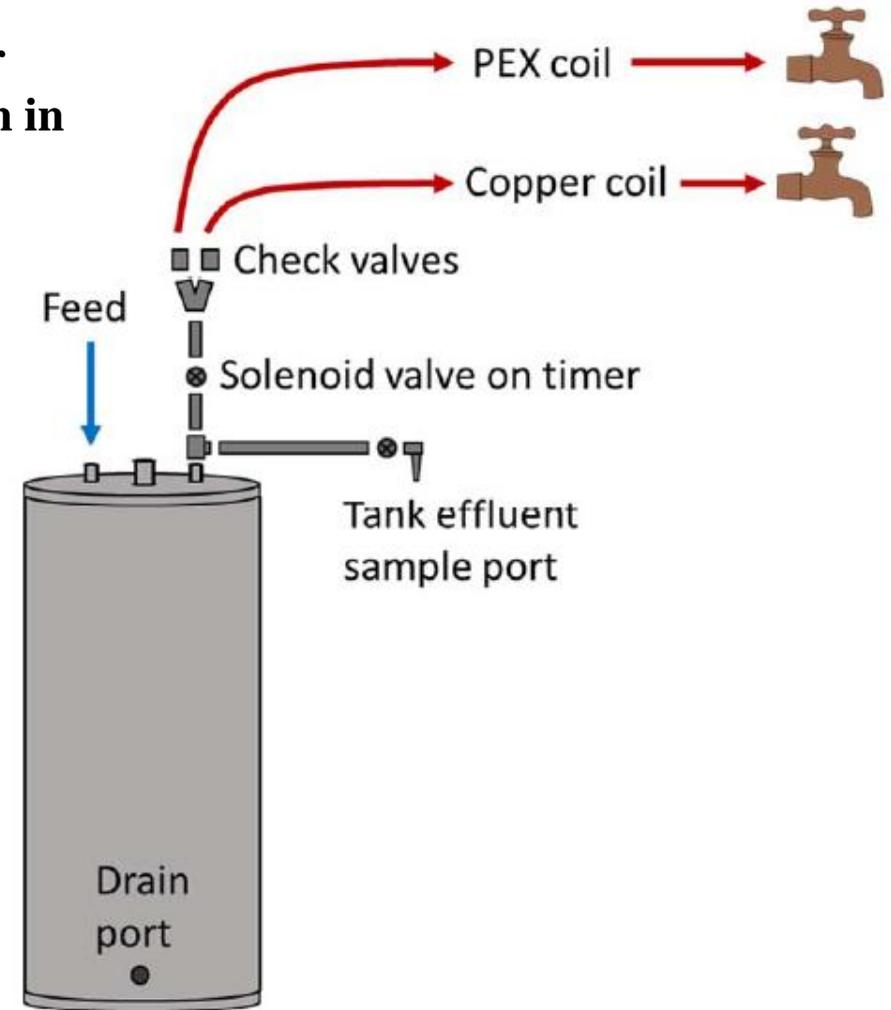


Figure 4. Hot Water Experiment Plumbing



# Thank you

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