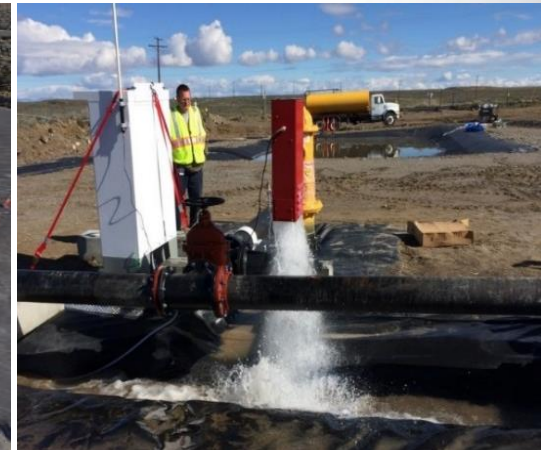
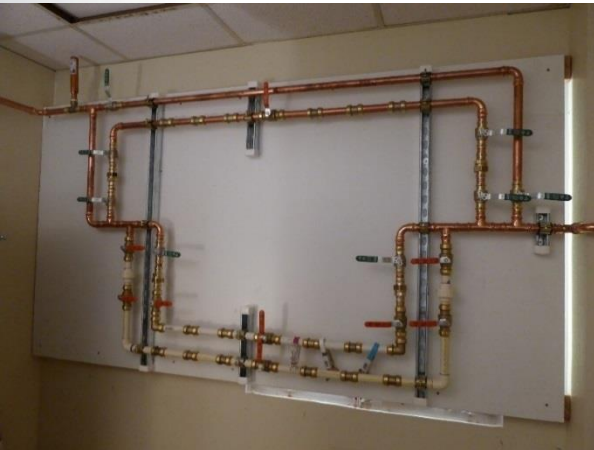




USEPA Office of Research and Development HOMELAND SECURITY RESEARCH PROGRAM



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

James A. Goodrich, Helen Y. Buse, and Jeff Szabo
Biofilm Technologies: Pathways to Product Development
February 4-5, 2020



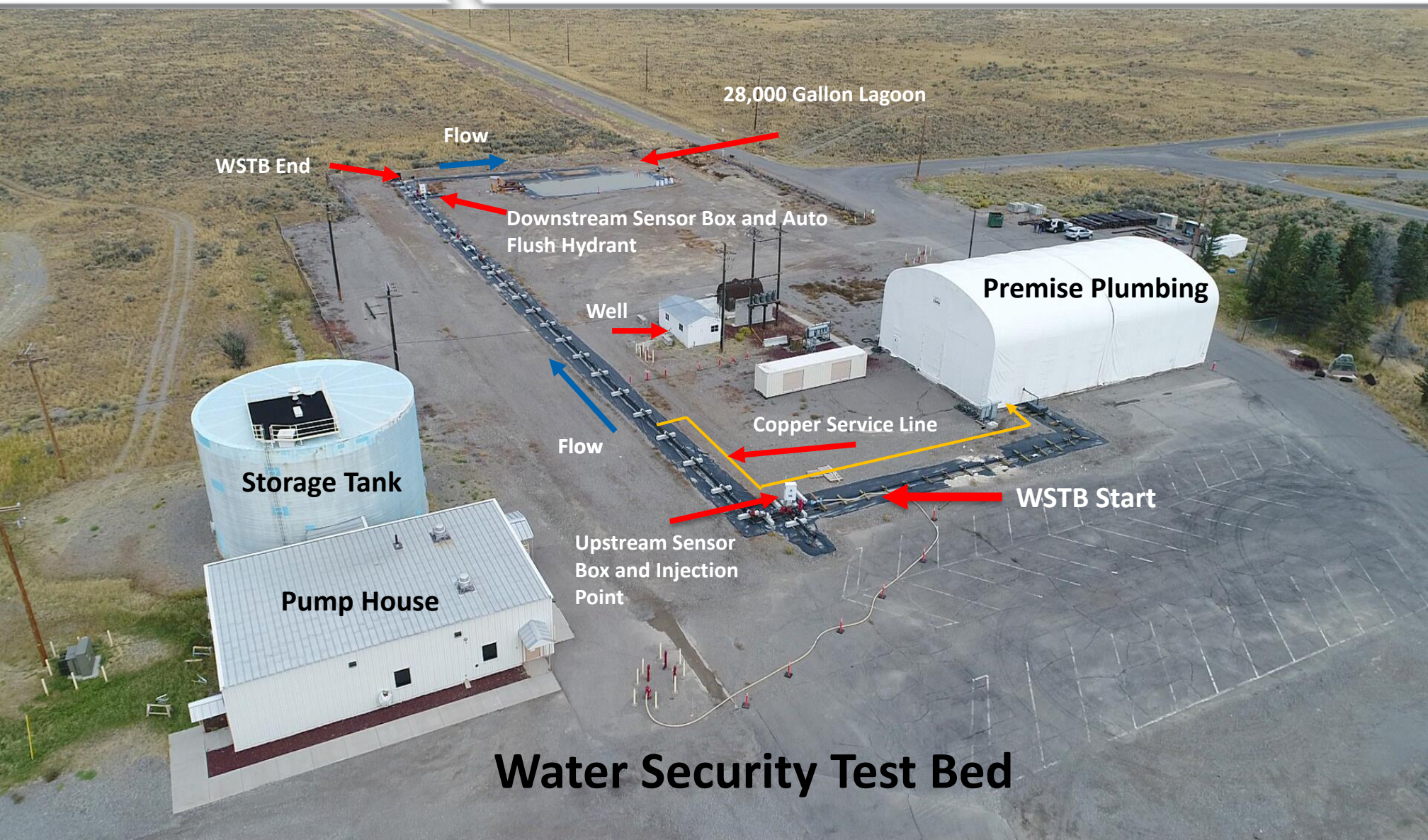
Presentation Outline

- **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

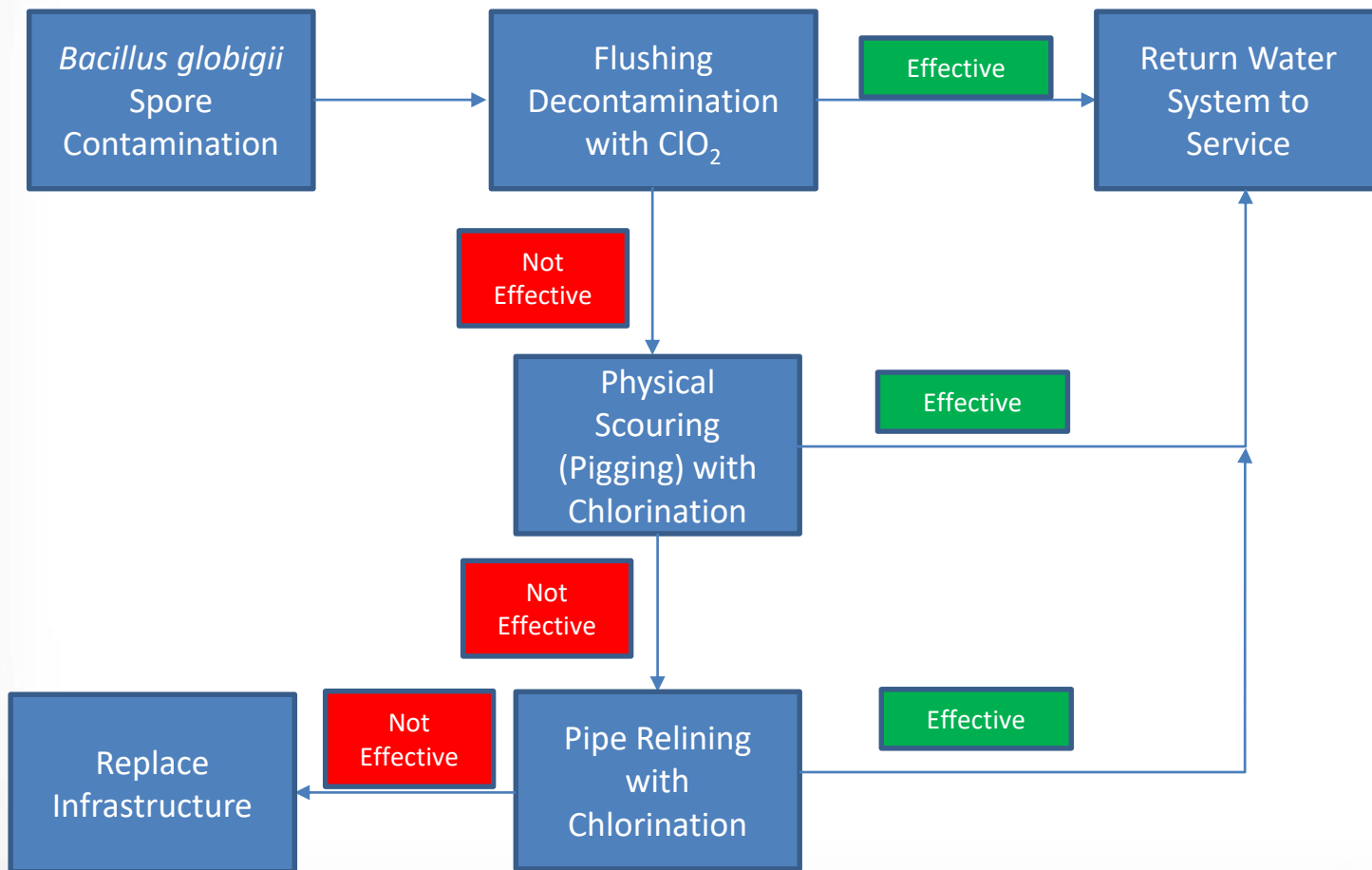
Water Security Test Bed Video: <https://www.youtube.com/watch?v=pQvsBC-U4a8>



Water Security Test Bed



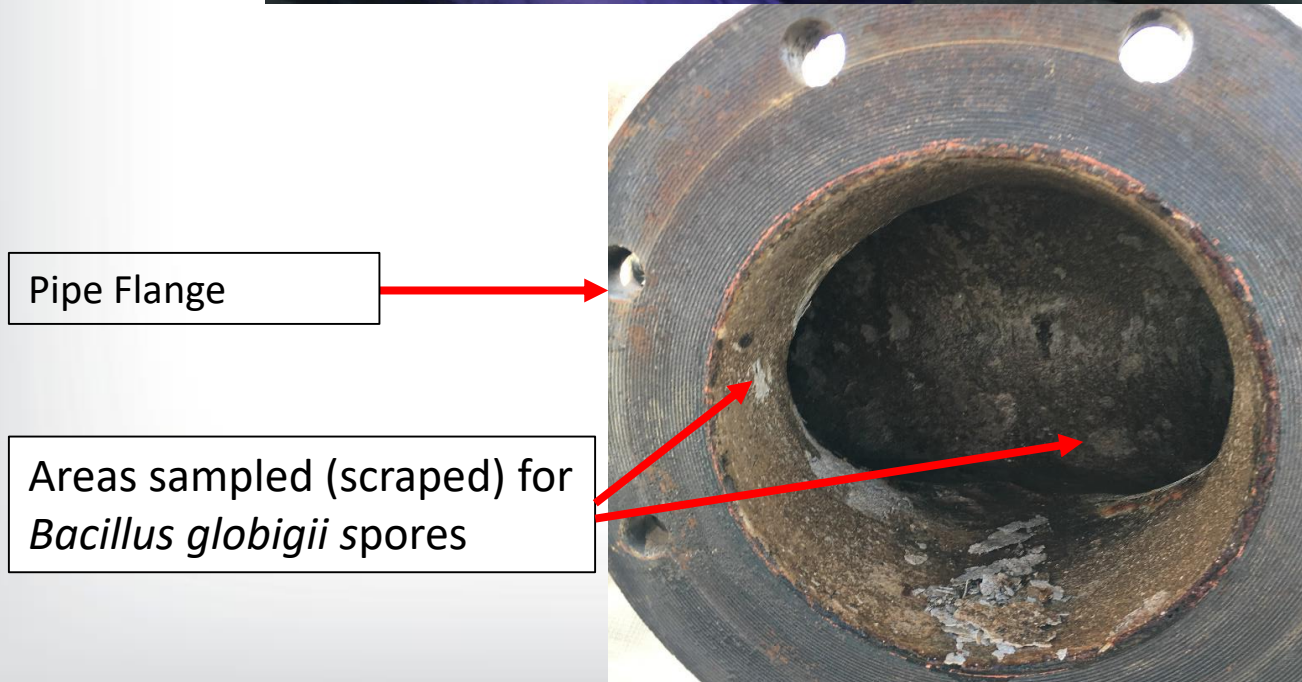
Microbial Pipe Decontamination Approach



- 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

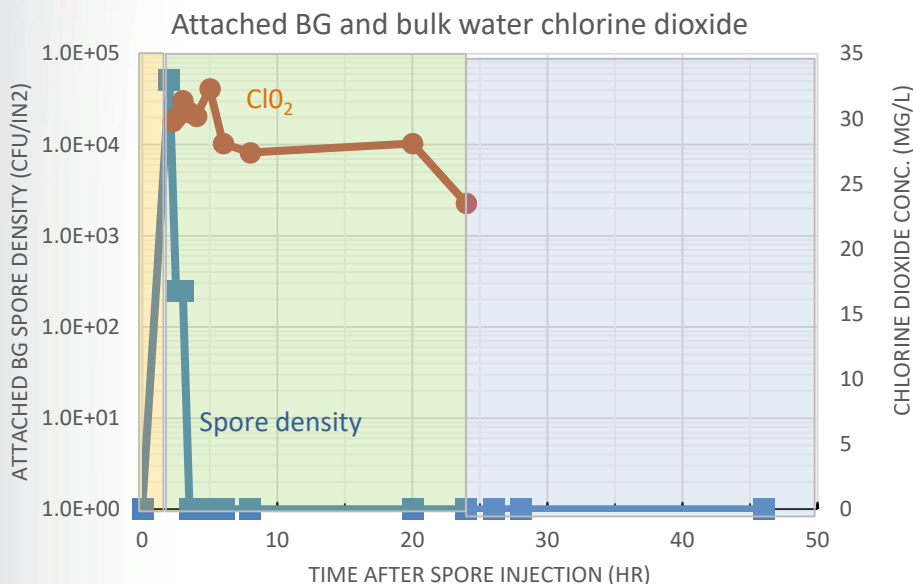


Microbial Sampling



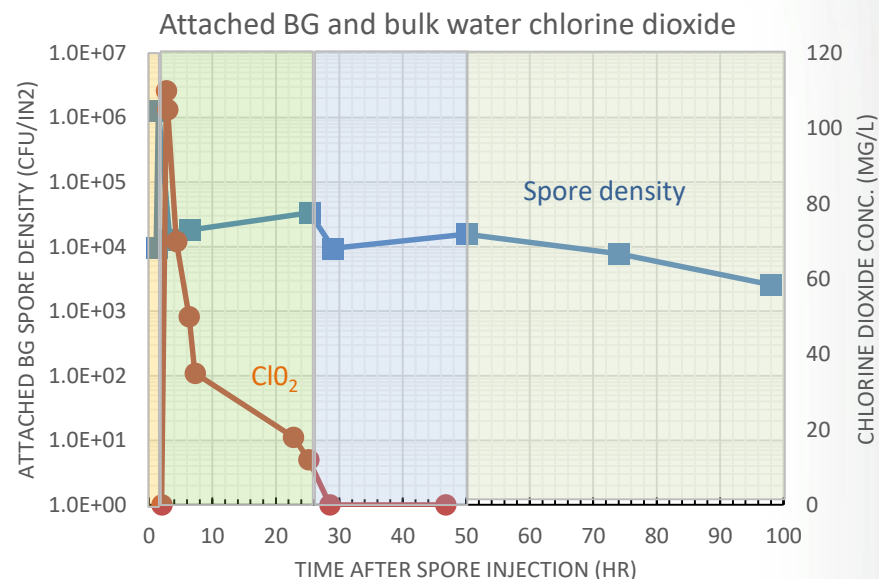


Bacillus globigii Experiments



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_2

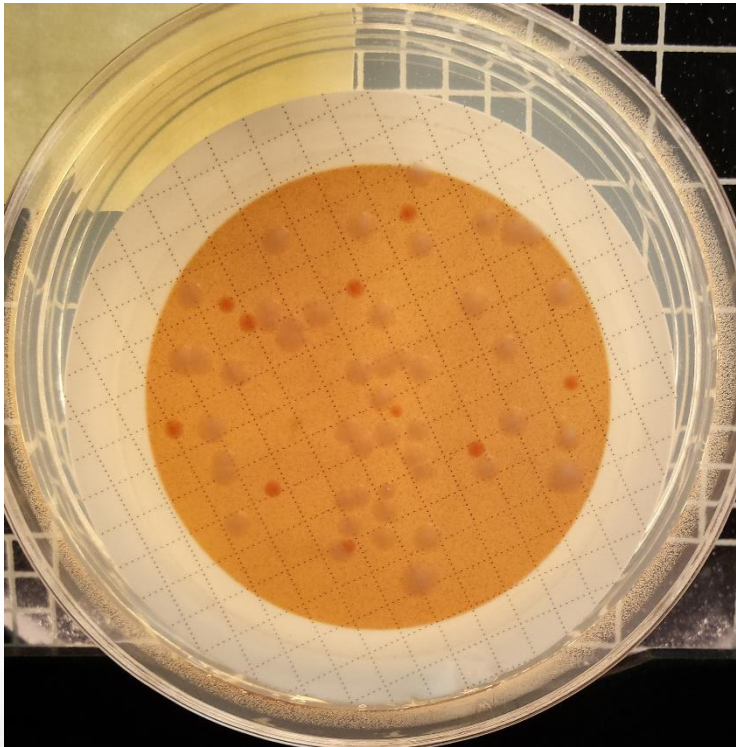


Data from Full Scale WSTB at INL

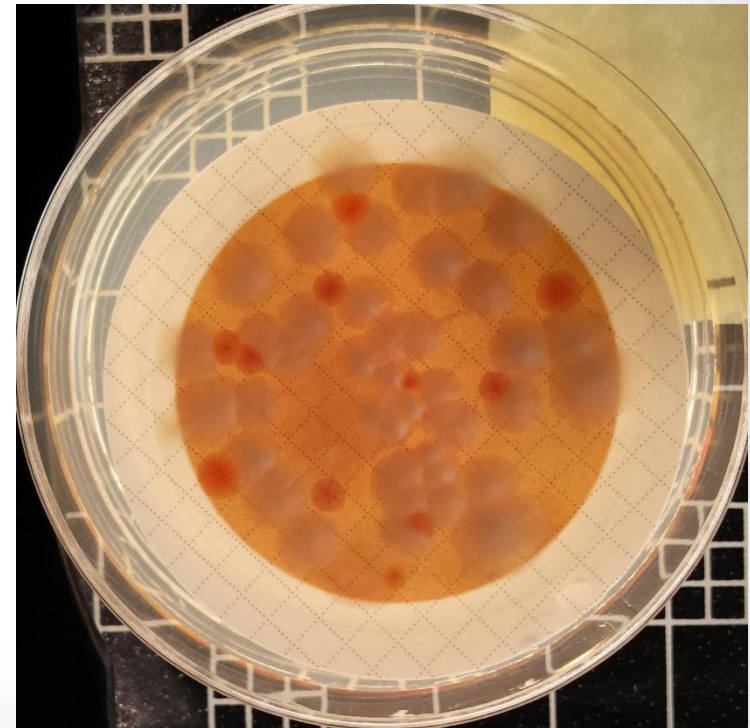
- Spores persisted on cement-mortar in the presence of up to 100 mg/L ClO_2
- Pipe demand, temperature fluctuation and dead end spaces impacted decontamination
- Spores found on surfaces even after WSTB was mothballed for winter

- 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

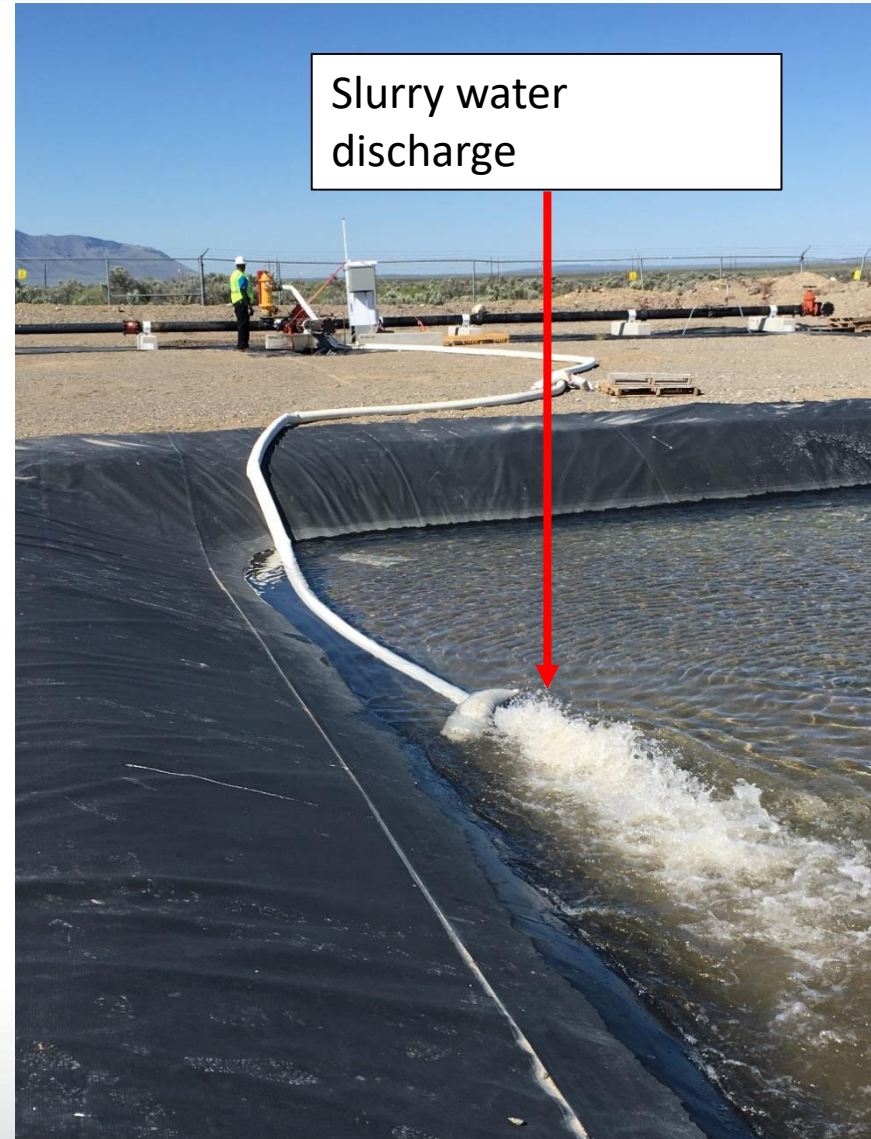


Ice slurry mix connection to upstream fire hydrant

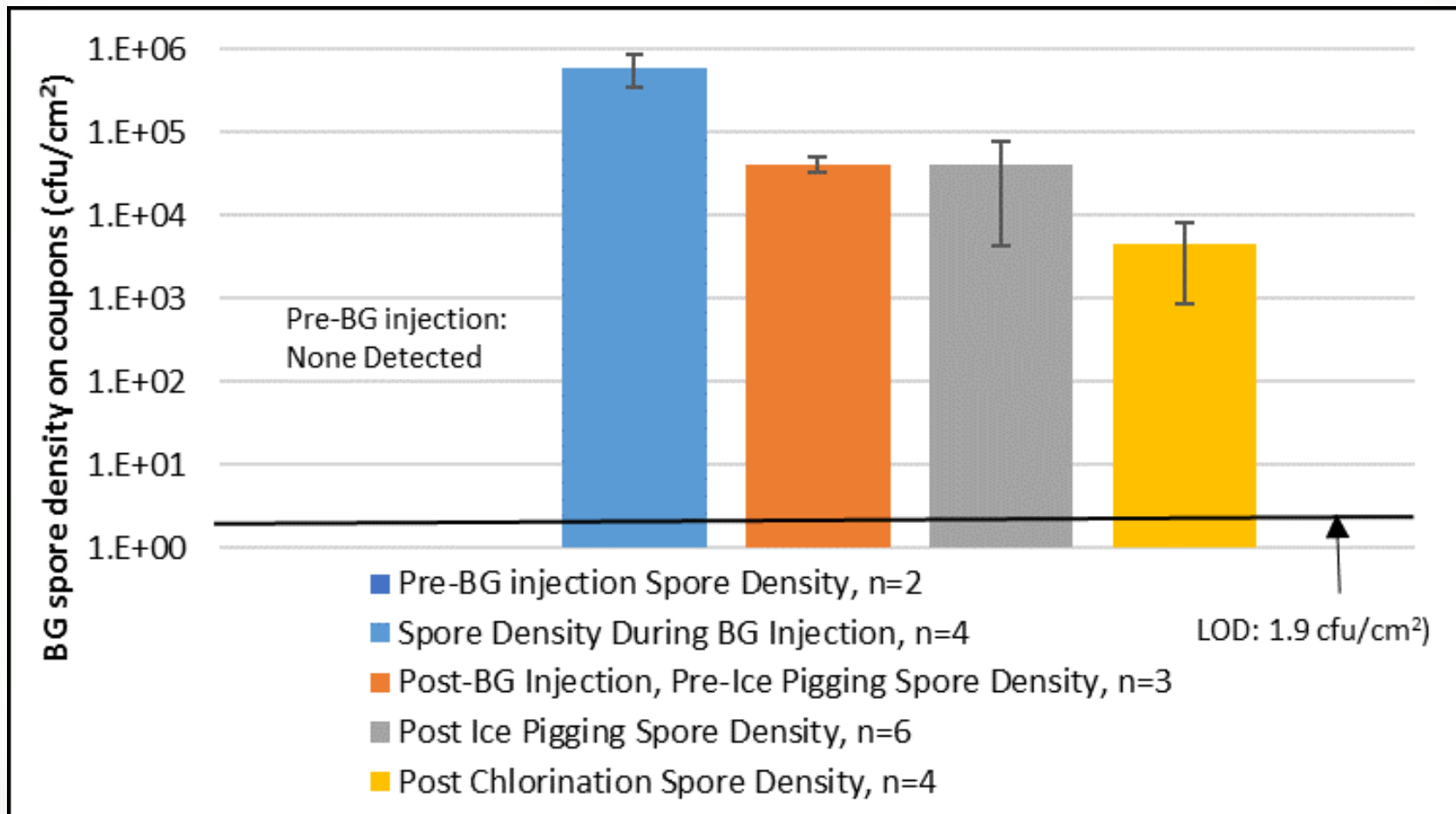




Decontamination Using Ice Pigging



Ice Pigging Decontamination Data



Chain Cutter

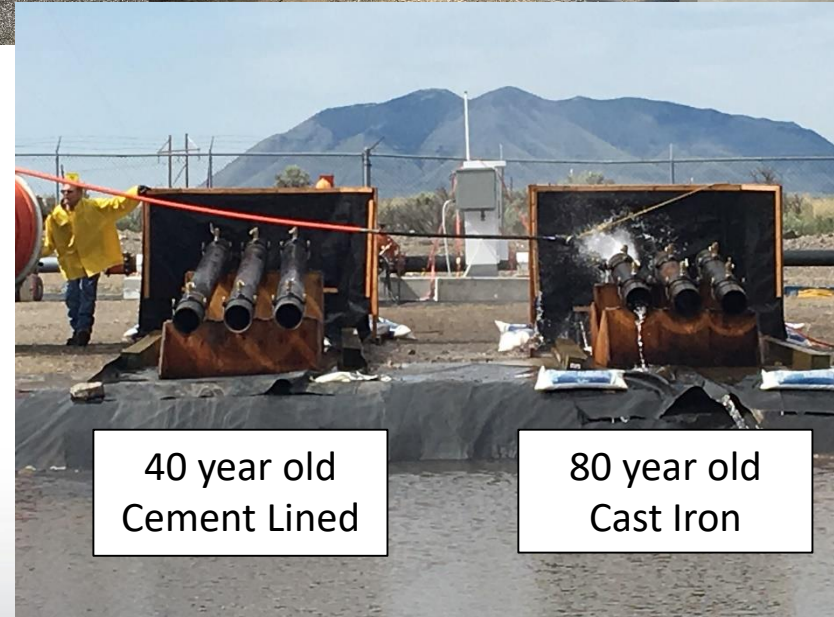




Decontamination with Chain Cutter



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:

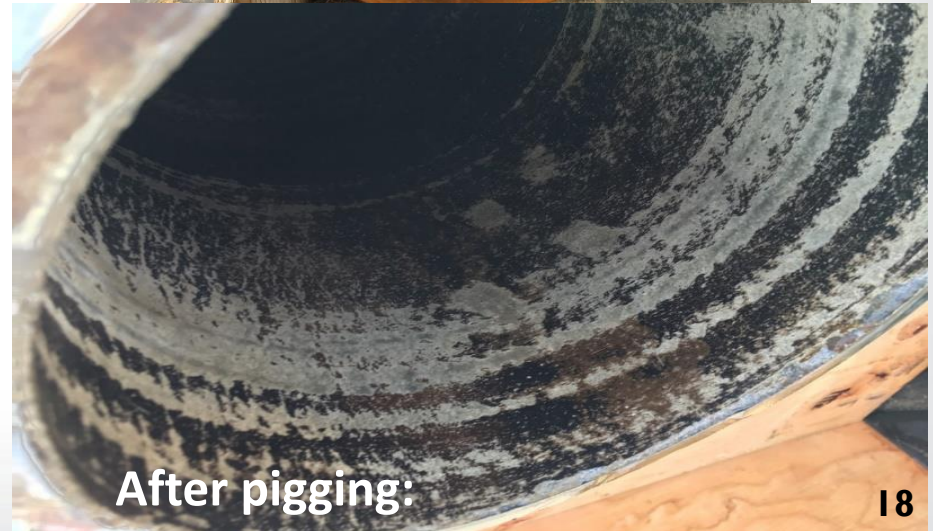


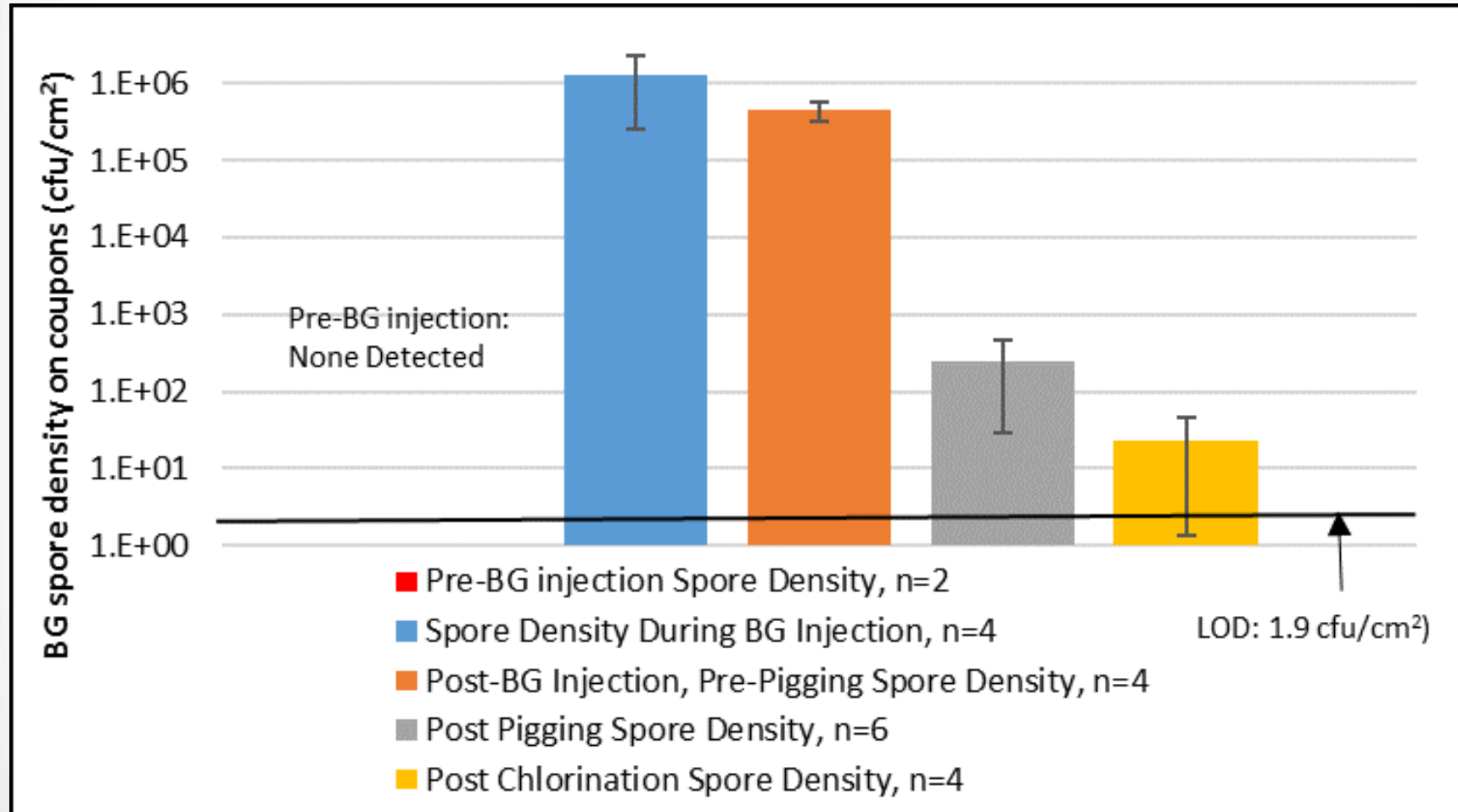
Cement Lined

After pigging:



After pigging:







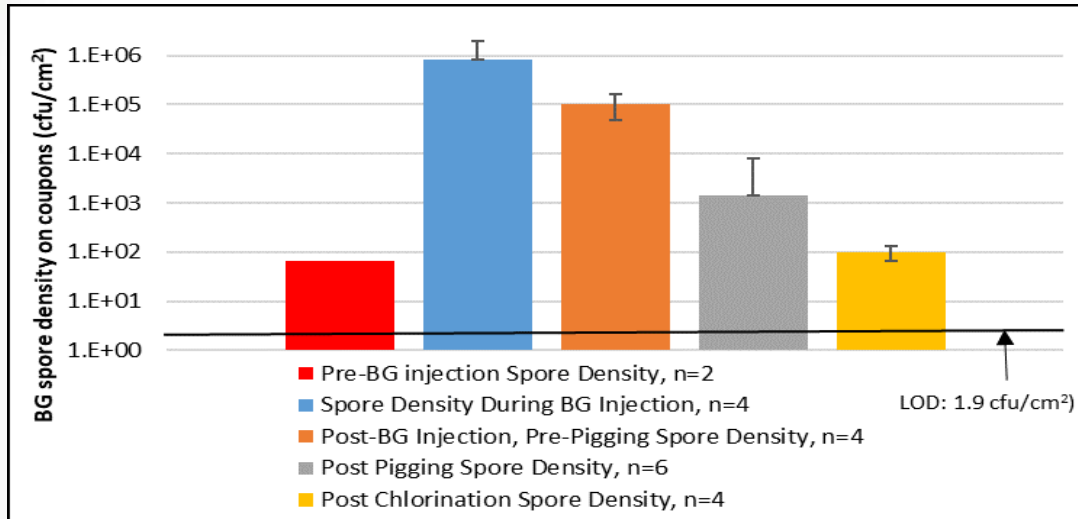
Decontamination with Jet Sprayer



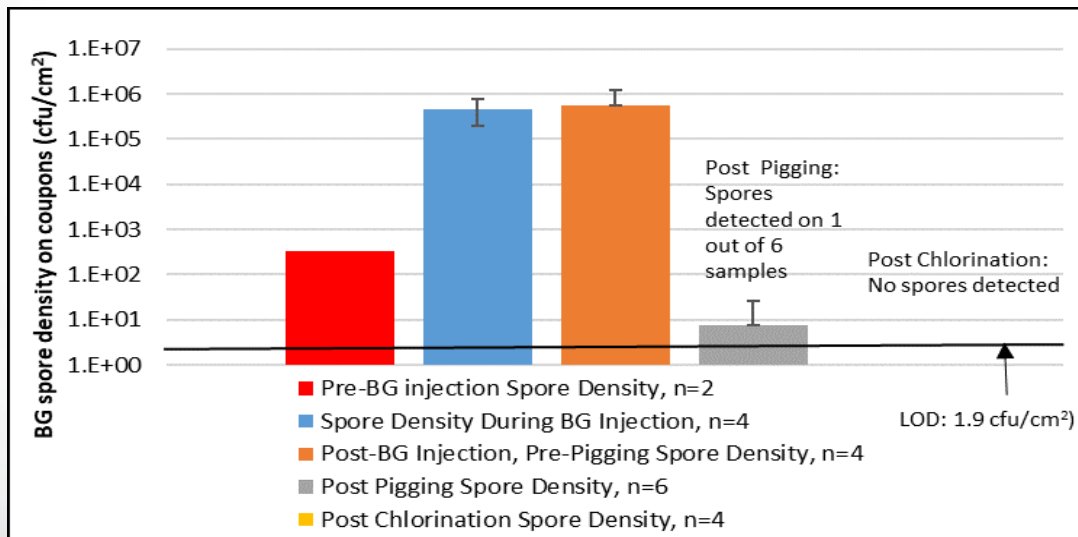
Jet Sprayer Video



BG Decon with Jet Sprayer



Bg decon from cement mortar-lined pipe section



Bg decon from DC Water corroded cast iron pipe

Cast Iron Pipe



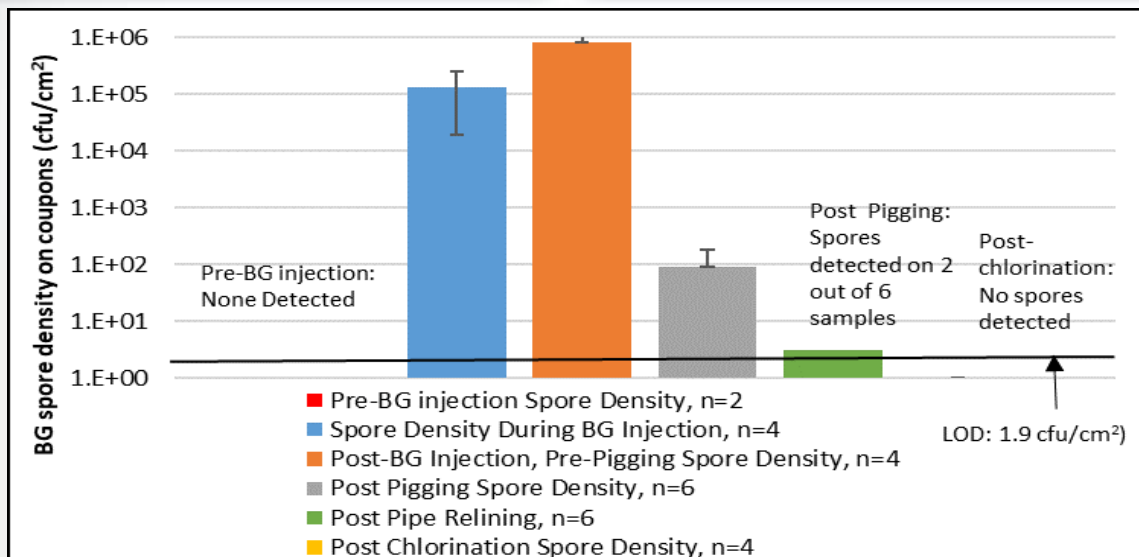
Chemical Pipe Re-lining



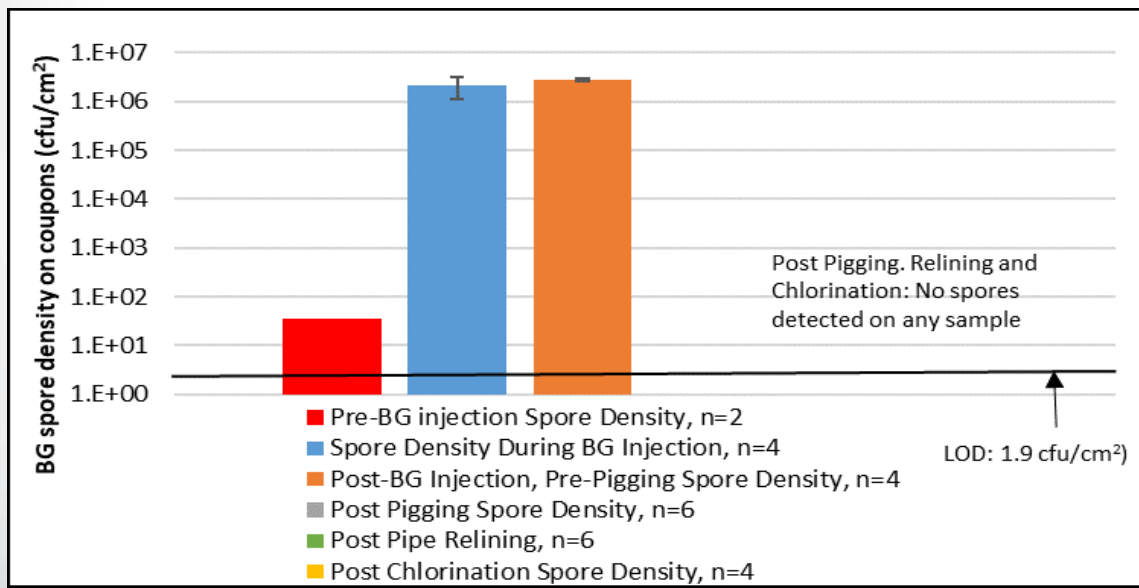
- *BG* spore scrapings and swabs being analyzed
- Pipes lined with chemical mixture
- Post pigging chlorine residuals ranged from 60 to 120 ppm
- Post lining chlorine residuals nearly doubled in pipe
- No need to open service connections



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

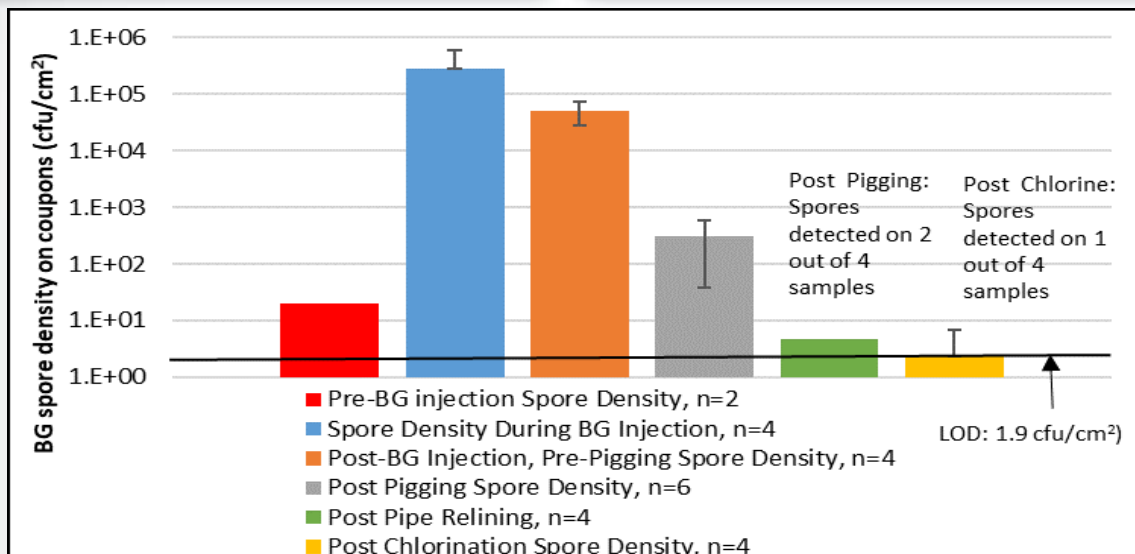


Cured-In-Place Pipe Re-lining

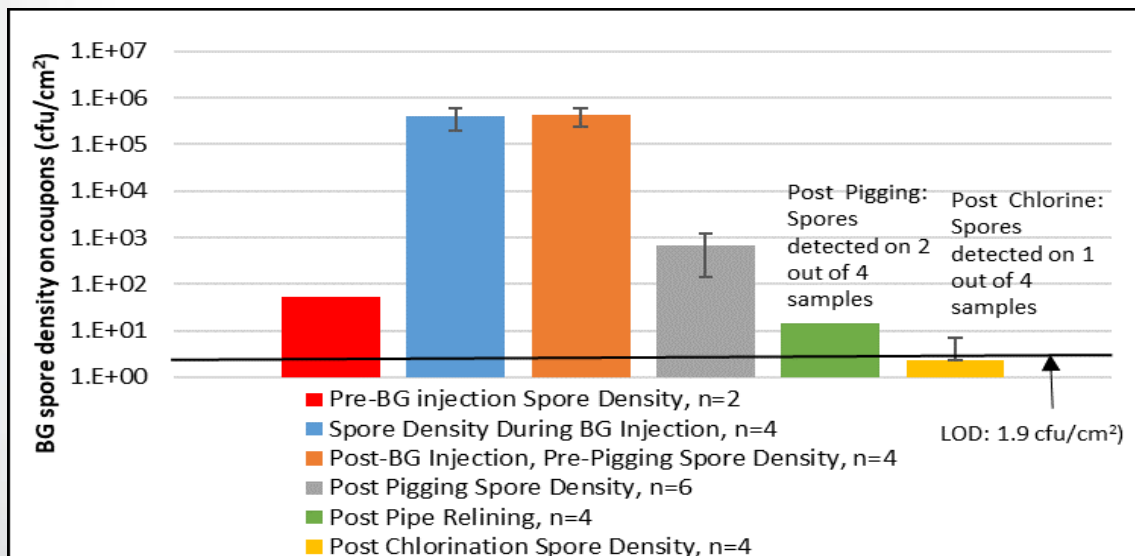




BG Decon with CIPP Re-lining



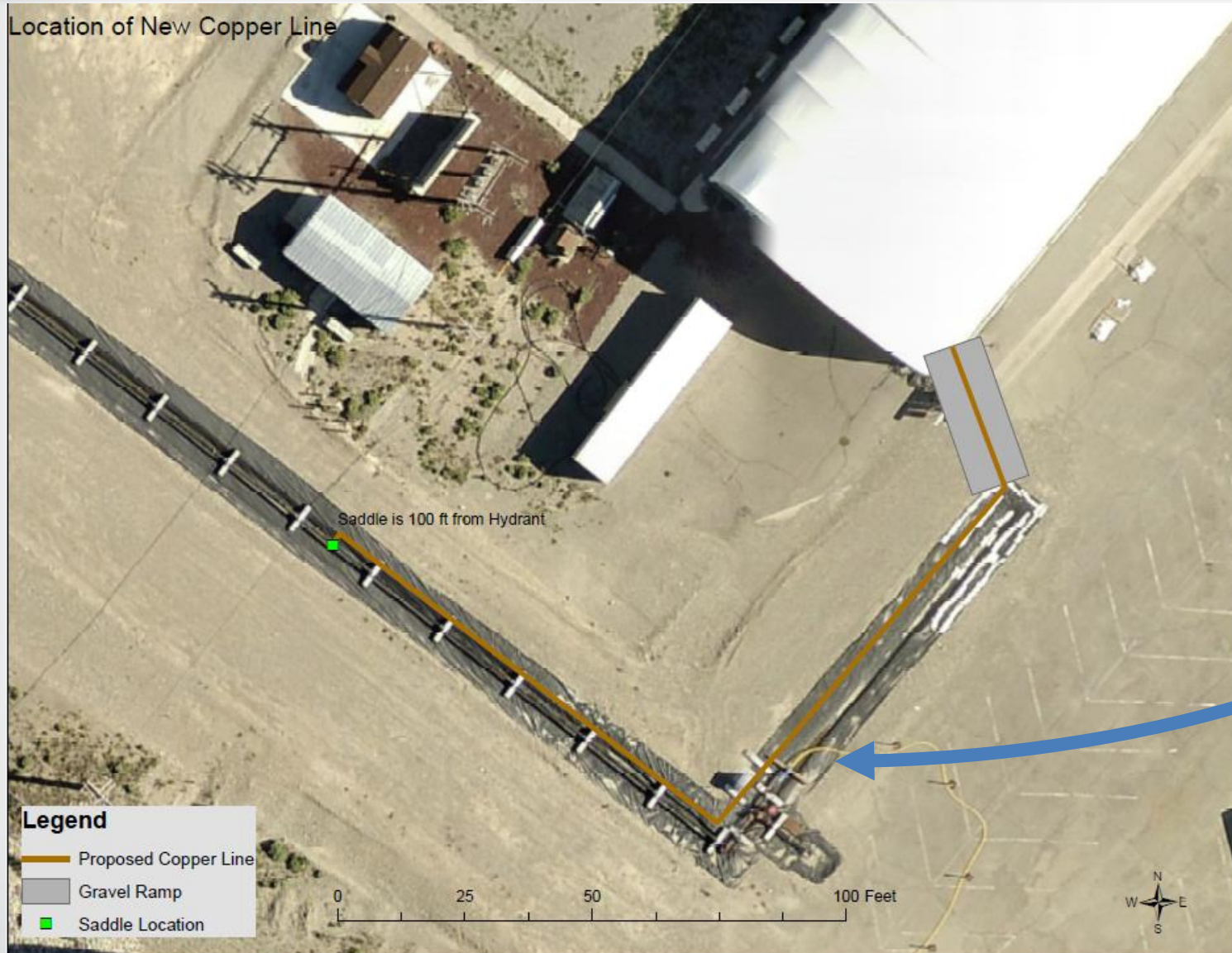
Bg decon from cement mortar-lined pipe section



Bg decon from DC Water corroded cast iron pipe



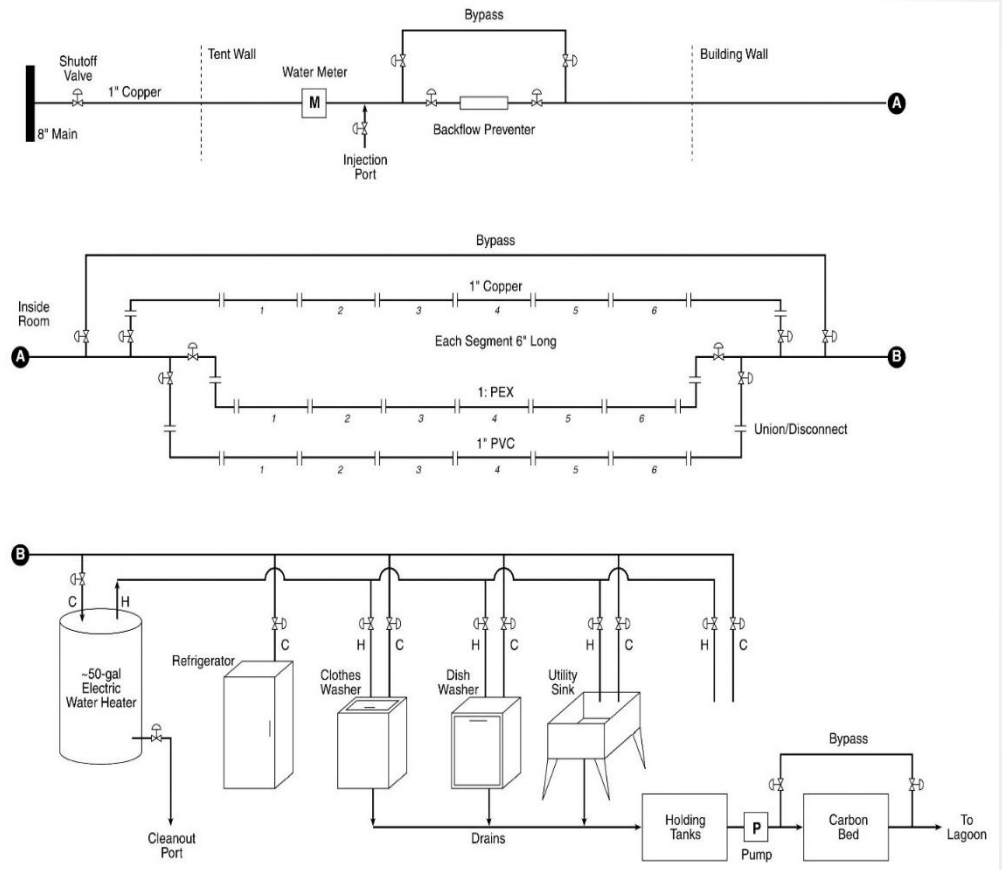
Premise Plumbing Decontamination



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



Premise Plumbing Decontamination



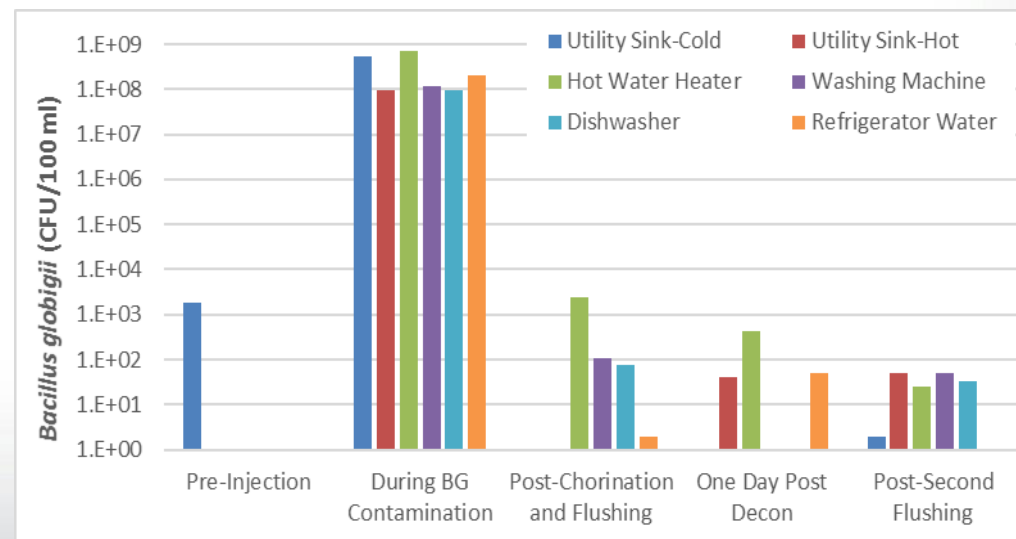
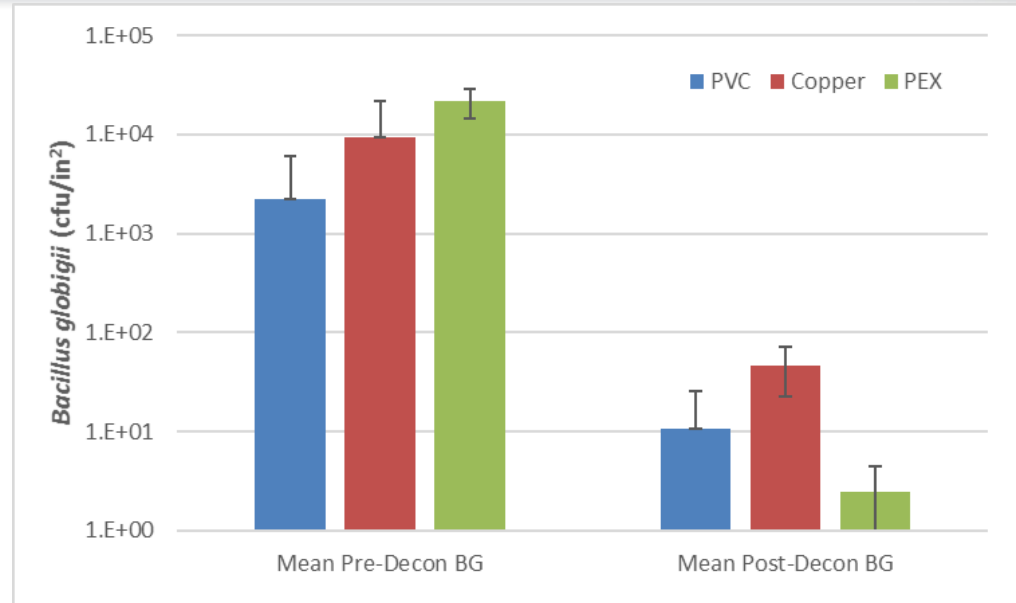
Premise Plumbing Setup





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.</i> <i>intracellularae</i> <i>/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®, respectively)



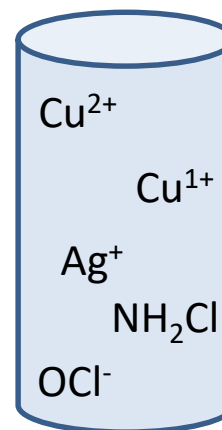
WSTB Decon Key findings (so far)

- 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)



- 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

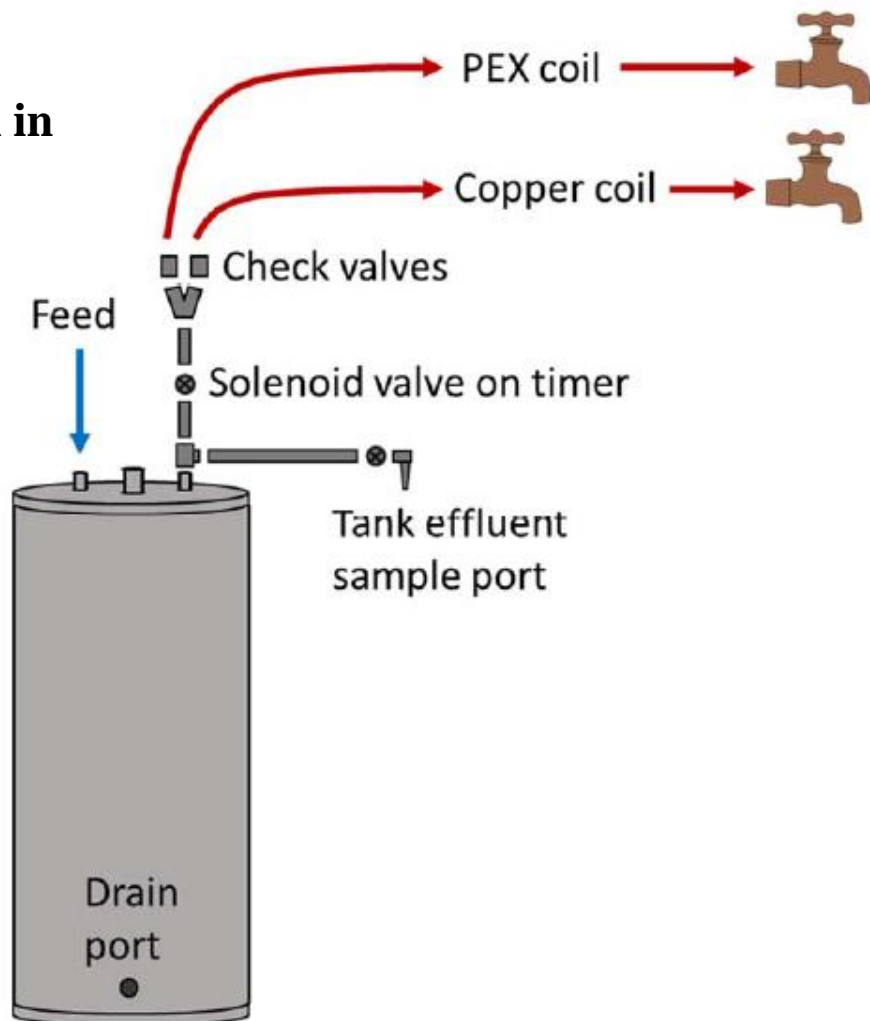


Figure 4. Hot Water Experiment Plumbing



Thank you

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Disclaimer: The U.S. EPA through its Office of Research and Development funded the research described in this presentation. It has been reviewed by the Agency but does not necessarily reflect the Agency's views. No official endorsement should be inferred. EPA does not endorse the purchase or sale of any commercial products or services. This project was supported by the U.S. Environmental Protection Agency, Center for Environmental Solutions and Emergency Response, Homeland Security and Materials Management Division and through an interagency agreement between the U.S. Department of Energy and EPA.