Office of Research and Development

Homeland Security Research Program

Water Security Test Bed

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National Homeland Security Research Center

EPA's Homeland Security Responsibilities

Drivers

Bioterrorism Act

Presidential Directives

Executive Orders

National Response Framework

Elements of:

- Comprehensive Environmental Response, Compensation and Liability Act
- Emergency Planning and Community Right-to-Know Act
- Clean Water Act
- Safe Drinking Water Act
- Oil Pollution Act
- Clean Air Act
- Resource Conservation and Recovery Act

Responsibilities

- **Support water systems to prepare for and recover from attacks and other disasters**

  by leading efforts to provide States and water utilities guidance, tools and strategies. ***EPA is the federal government Sector Specific Agency (SSA) lead for water infrastructure***.

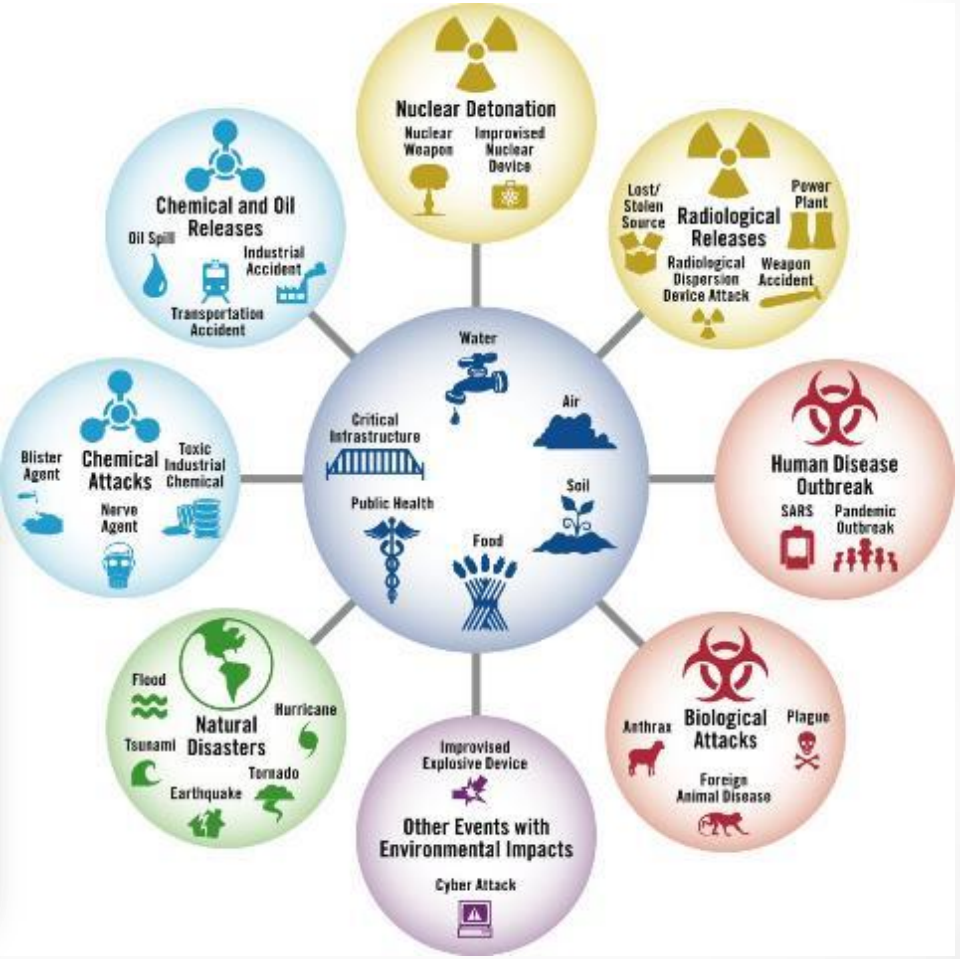
- **Clean up buildings and outdoor areas**

  impacted by a terrorist attack or other disaster by leading efforts to establish clearance goals and clean up.

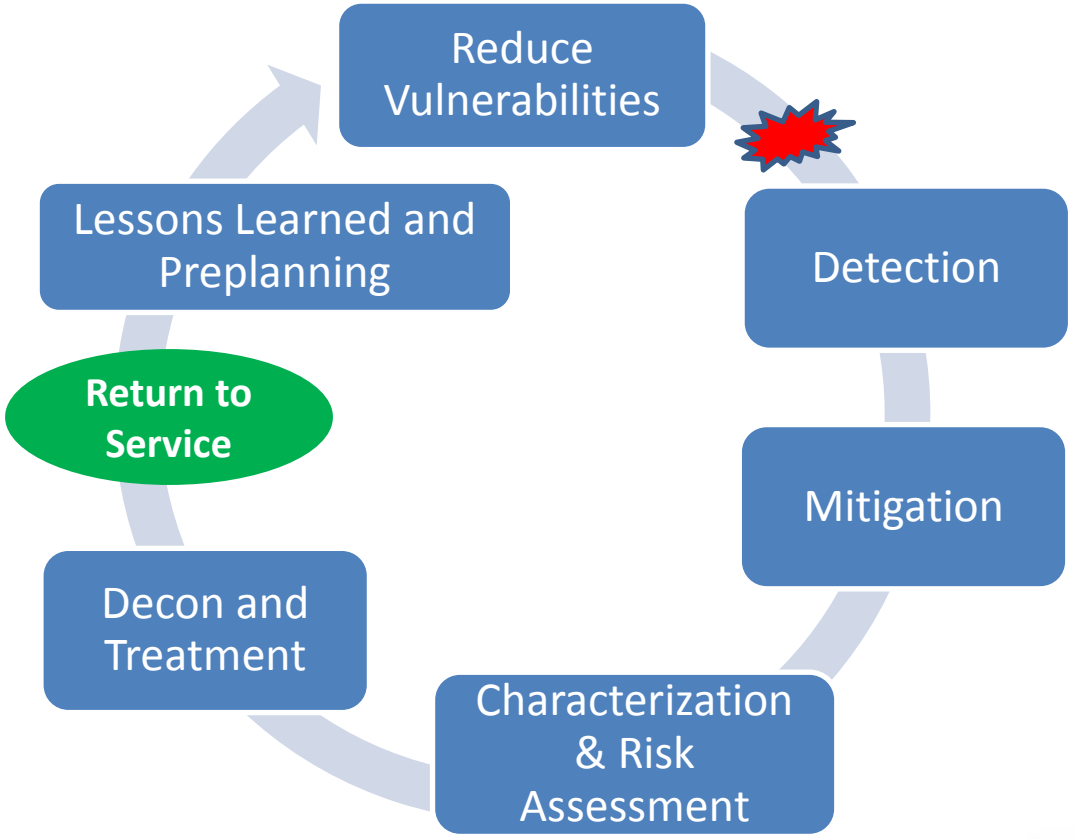
- **Develop a nationwide laboratory network**

  with the capability and capacity to analyze for chemical, biological and radiological (CBR) agents for routine monitoring and in response to a terrorist attacks.

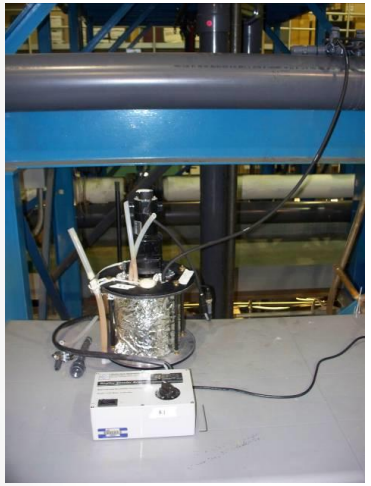
EPA's "All Hazards" Universe



Water System Security and Resilience Systems Approach



Applied Research Solutions Approach



Bench-Scale → Pilot-Scale → Full-Scale

Andrew W. Breidenbach Environmental Research Center

- Internationally recognized for water research
- Second largest research and development facility owned and operated by EPA
- Located on a 22-acre complex
- 429,646 GSF with approximately 710 personnel
- Multiple Labs/Centers
- 100 Years of Water Research History

Features:

- 7,000-square-foot Research Containment Facility
- Large-scale (6.4 L/min) pilot plant
- Advanced Materials and Solids Analysis Research Core

Test & Evaluation Facility –
Cincinnati, Ohio

- Located on the grounds of Cincinnati's Mill Creek wastewater treatment plant
- Studies on new treatment technologies for contaminants in water and wastewater
- 36,101 GSF with approximately 35 personnel

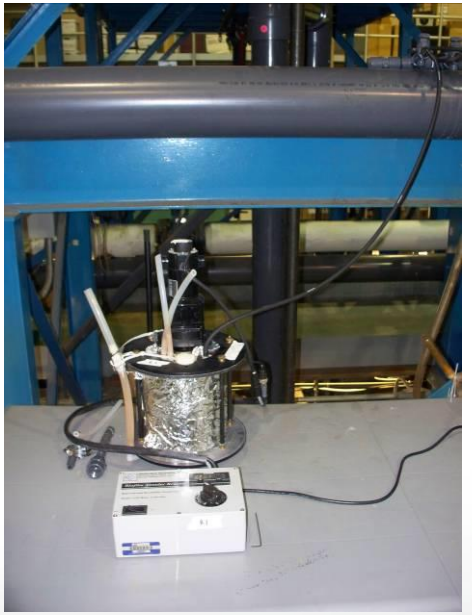
Features:

- Machine shop for fabricating specialty items & building or repairing experimental apparatus
- 16 experimental locations in the 24,000 ft^2 high-bay area

Bench-Scale Experiments

- Bench scale systems simulate a drinking water environment and allow small-scale decontamination experiments

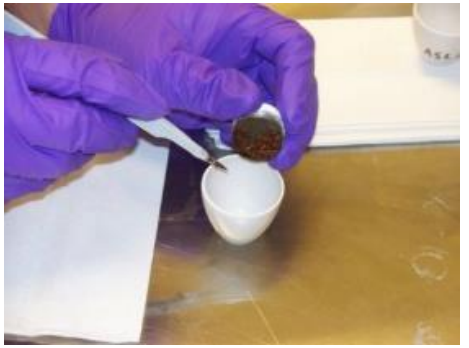
- Biofilm annular reactors
  - Allow for variation of shear forces independent of flow
  - 20 sampling slides available
  - Minimizes the mass of contaminant
  - Use less water
  - Easier to clean between experiments and can be sterilized
  - Good for initial experiments when data does not exist on a contaminant




Pilot-Scale
The Distribution System Simulator (DSS)
Located at the USEPA's Test and Evaluation facility

Example: Contaminant Persistence and Decontamination of Drinking Water Infrastructure

- Persistence studied - determine the need for decontamination
- ^{137}Cs, ^{85}Sr, ^{60}Co and spore form of *Bacillus* spp - all persistent
- Flushing alone not successful for decontaminating infrastructure
- Coupons made from commonly used water pipe materials inserted into a pipe loop to test decontamination methods
- *Field scale testing is required*



Wastewater Research

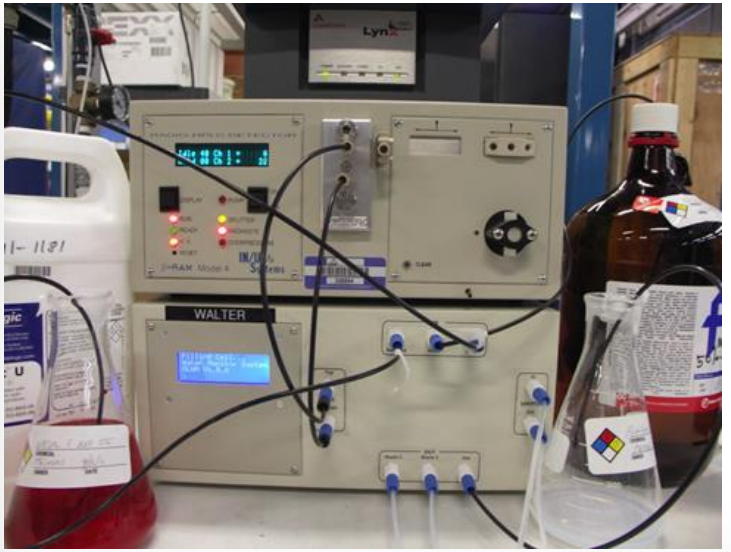
Activated sludge experimental set-up: assessing how contaminants travel through wastewater treatment systems

Wastewater test bed: assessing persistence of contaminants on sewer infrastructure →

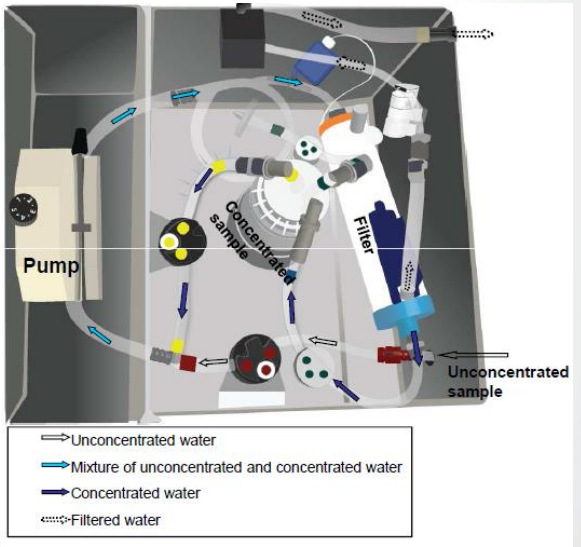
Real-Time Sensor Technologies

- Development, testing and evaluation of new sensing technologies
- Performance testing in operational settings

Sievers 900 Portable (UV Persulfate TOC)



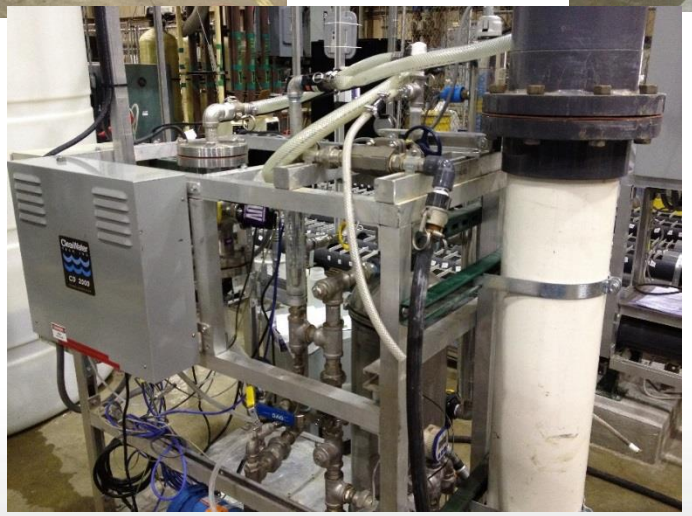
LabLogic Beta Ram on line water Quality monitoring system



Water Sample Concentrator

Field Deployed Sensor Station

Water and Washwater Treatment



Ozone/UV Mobile Trailer

Tools and Methods to Increase Security and Resilience – Software Development

Suite of modeling and simulation tools enable water utilities to

- Understand threats and consequences = Enhance water security
- Improve system awareness and control = Improve daily operations
- Prepare and respond to upset conditions = Improve community resiliency

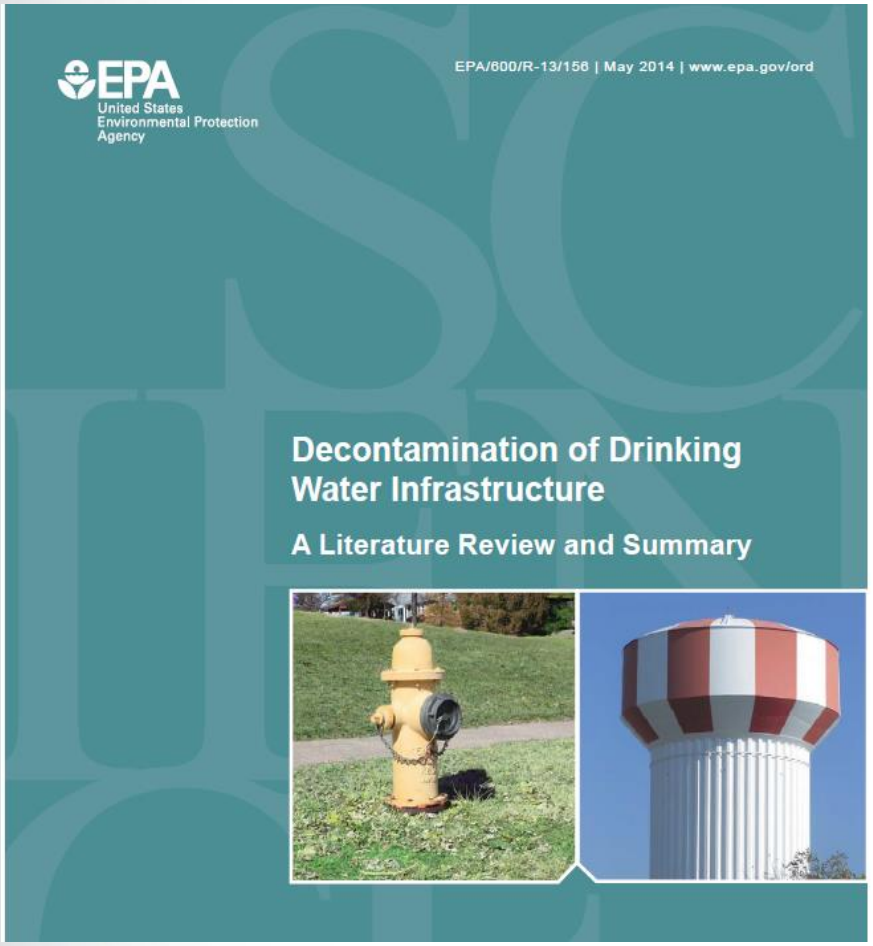
Publically available, free software

Designed, developed, and improved through water utility partners

CANARY

2010 R&D 100

Bench- to Pilot- to the Water Security Test Bed



EPA/600/R-13/156 May 2014 www.epa.gov/ord

EPA/600/R-08/016 January 2008 www.epa.gov/ord

Water Security Test Bed (WSTB)

U.S. Water Sector identified full-scale testing of water security tools, sensors, methods, with real contamination, a MAJOR gap

Our Response: build and operate a full-scale water system that:

- Simulates intentional and inadvertent distribution system contamination (chem, bio, rad) and disruptions (cyber-attacks)
- Supports diverse applied research
- Located at Idaho National Lab (near Idaho Falls, Idaho)

Phase I of the WSTB

Phase I of the test bed is a once through system:

- ~445’ of 8” cement mortar lined, ductile iron pipe (water main)
- 6 × 1” service connections/sample ports, 2 hydrants
- 15’ pipe material coupon section for sampling the interior of the pipe surface
- Above ground system, underlined by secondary containment
- 28,000 gallon lagoon/high rate groundwater pump/storage tank

Where Did the Pipe Come From?

- Drinking water pipe that was in service from the early 1970's until a few years ago
- The pipe was in good condition when it was excavated
- The pipe was partially filled with water, but no major leaks were found

- Cement-mortar lined ductile iron
- Some pipes are corroded where the lining was worn or broken
- Four and eight-inch diameter pipes were excavated.

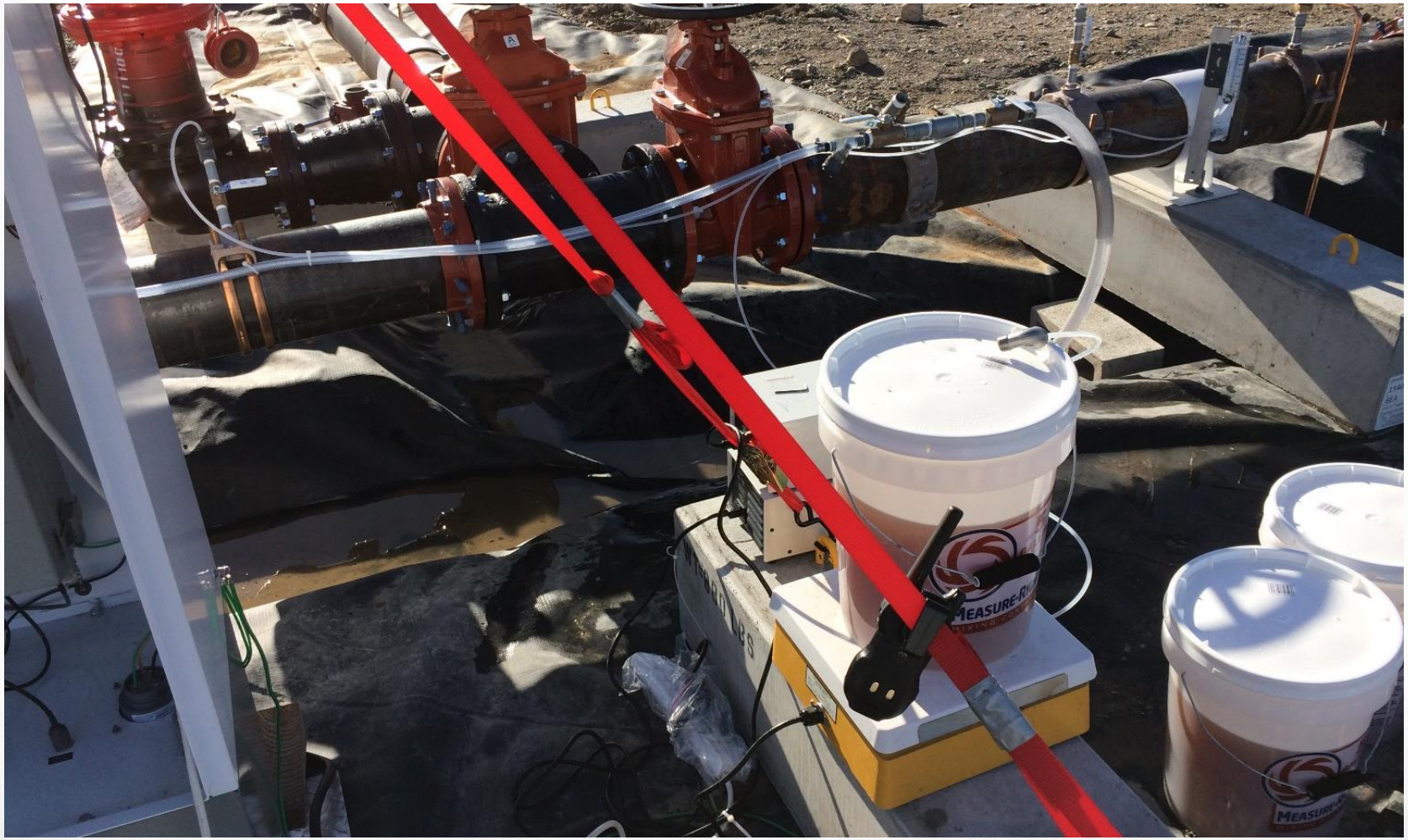
Aerial View – Phase I

Water Security Test Bed as of November 12, 2014

Injection Point and Sensor Boxes

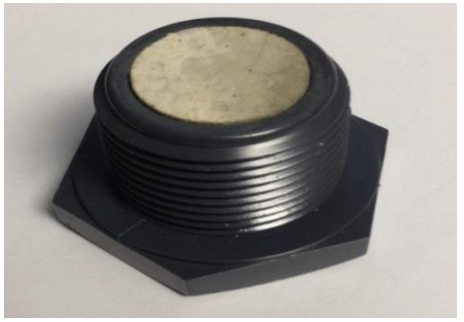
Chlorine and UV Sensors with Cellular Modem

Contaminant Injection



Looking Downstream

Removable Coupons for Decontamination Experiments



Coupon Sampling

Triggered Flushing

Lagoon, Tanker Truck, & Mobile Chlorine Water Treatment System

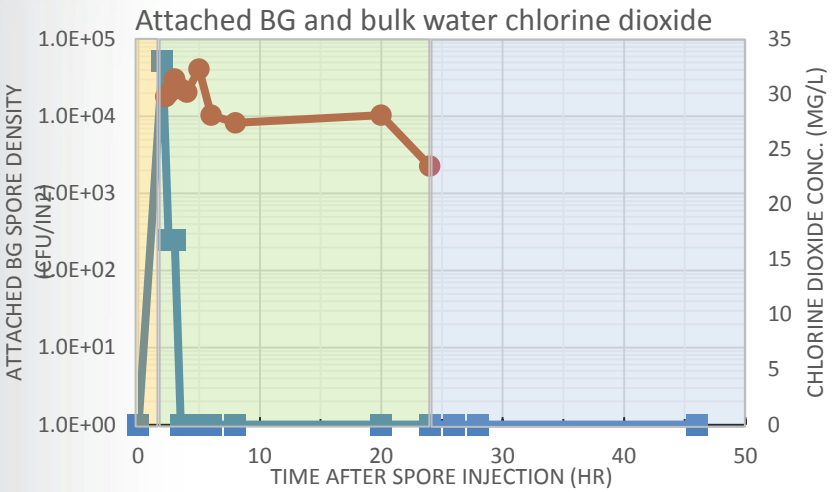
2014 Experiments

- A dye test (tracer) to evaluate travel times and system flows
- Sodium thiosulfate ($Na_2S_2O_3$) injection to remove free chlorine from the pipe – successfully triggered an automated fire hydrant flushing device
  - Residual sodium thiosulfate in pipe dead legs was released with subsequent hydraulic changes.
- Biological agent contamination
  - Spores of *Bacillus atrophaeus* subsp. *globigii*
  - Non-pathogenic surrogate for *Bacillus anthracis* (causes anthrax)
  - Injected 40 L of a ~10^8 cfu/ml over 1 hour
  - Achieved 10^6 cfu/ml in the water inside the pipe (a 1 hour long slug or bolus)
  - The contaminant traveled down the pipe emptied into the lagoon

Anthrax Surrogate Experiment

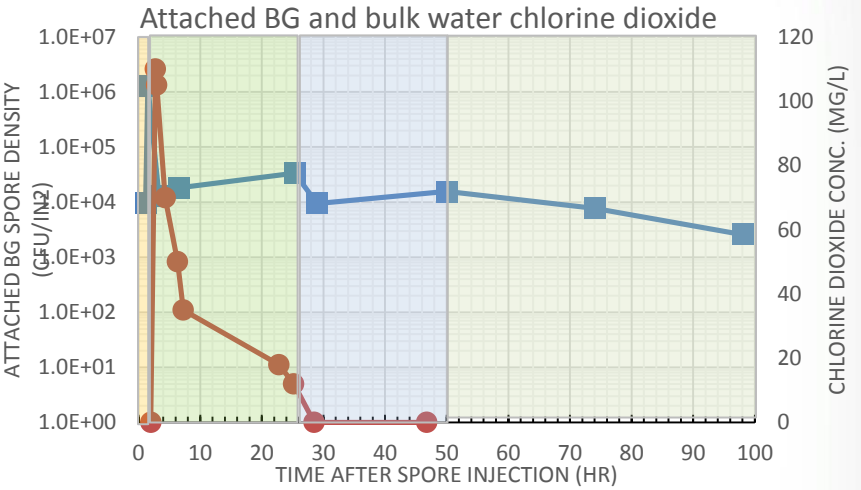
- Biological agent decontamination
  - Chlorine dioxide was used as the decontaminating agent (performed well in pilot studies)
  - Go2 chlorine dioxide was diluted in tap water (24 L of a 4000 mg/L stock solution)
  - One hour after the contaminant injection, chlorine dioxide was injected and allowed to travel down the length of the pipe until the pipe was full of chlorine dioxide
  - The chlorine dioxide was allowed to contact the pipe under stagnant conditions for 24 hrs
  - Target concentration was 25 mg/L, but over 100 mg/L was detected due to a stronger than expected stock solution (however the concentration degraded quickly)
  - After one day of contact, the pipe was flushed and returned to baseline flow
- Contamination and decontamination sampling
  - Bulk water and pipe coupons sample were removed before contamination
  - Two Bulk water and coupons samples were removed during contamination
  - Seven coupon samples and numerous water samples were removed during decontamination and flushing.
  - 20 L water samples were removed 1 and 2 weeks after contaminated and concentrated

Pipe Decontamination Data



- Data from the pilot scale decontamination loop at EPA's T&E facility
- No spores detected on cement-mortar after treatment with 25-30 mg/L $CL0_2$

Orange = Contamination with BG spores, Green = Decontamination with ClO2,
Blue = Flushing (high flow velocity), Grey=Baseline flow (normal flow velocity)



- Data from the WSTB at INL
- Spores persisted on cement-mortar in the presence of up to 100 mg/L $Cl0_2$
- Pipe demand, temperature fluctuation and dead end spaces impacted decontamination
- Decontamination will be repeated this year

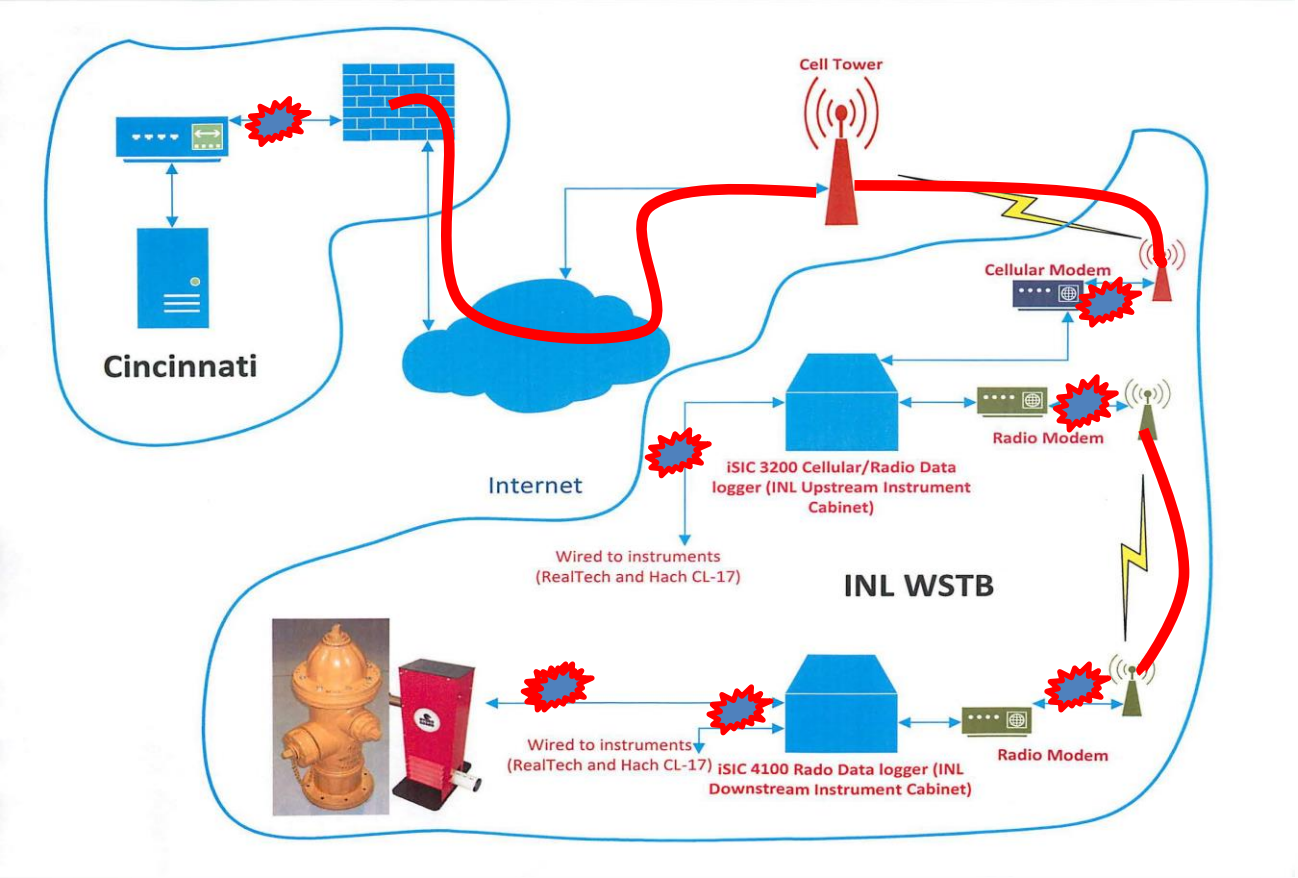
Wash Water Evaluation

- WaterStep Portable Water Treatment System treated effluent lagoon water to disinfect spores that were flushed from the WSTB pipe.
  - System is designed to disinfect water (by on-site chlorine generation) for human consumption or discharge.
  - Chlorine generation and disinfection efficacy was evaluated

2015 Experiments

- Additional ClO_2 decontamination and flushing of system
- Biofilm growth in the water main
- Effluent lagoon treatment using Cl_2, UV, and/or UV+O_3
- Crude oil contamination and decontamination - simulating a refinery/rail transport accident
- Cyber attack on system instrumentation and communications

Vulnerability/Consequence Cyber Security Assessment for Water Security Test Bed



Consequence

Potential veiled vulnerability exploitation

Experimental Concepts For 2015 and Beyond

Future studies may focus on:

- Connect to adjacent building and simulate home plumbing and appliances inside building or within construction trailers. Simulate homeowner decontamination.
  - Aerosolization of biological agents via a shower head
  - Testing and validation of water system components and household appliance decontamination
- SCADA vulnerabilities in water infrastructure
- Chem/rad/bio contamination due to natural, accidental, or intentional acts
- First responder training exercises

Disclaimer

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