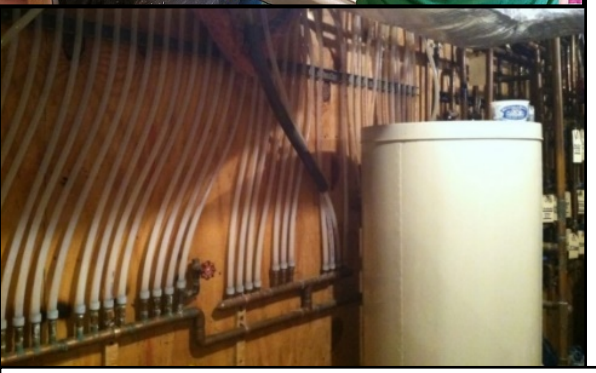


Lessons From the Pandemic: Building Water Safety in Schools, Offices, and Beyond

Andrew J. Whelton, Ph.D.

Caitlin Proctor, Ph.D., Christian Ley, Kyungyeon Ra, Danielle Angert, Elizabeth Montagnino, Yoorae Noh, Maria Palmegiani, Ryan Day, Andrew Golden

@TheWheltonGroup
www.PlumbingSafety.org

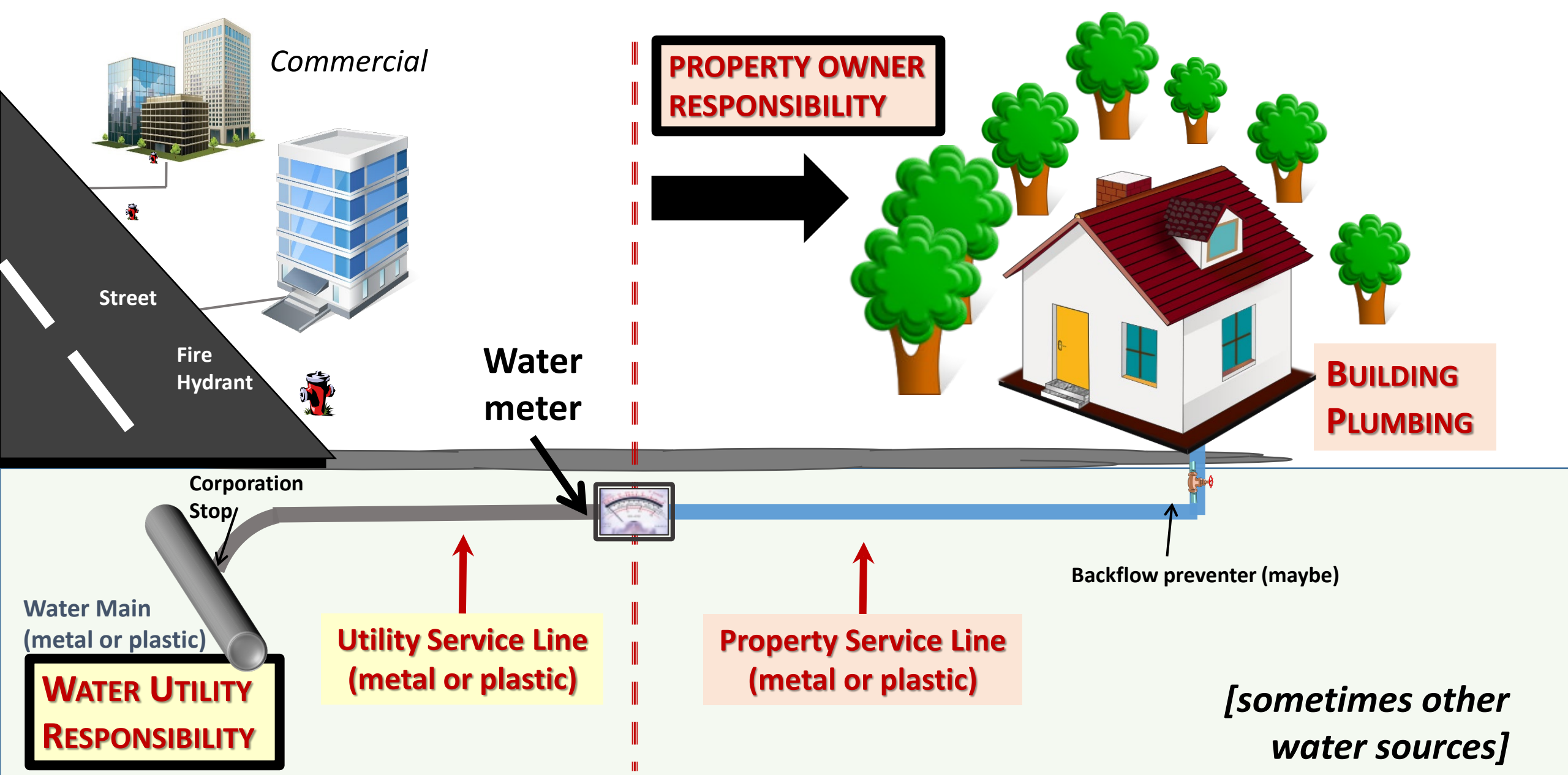
Thanks to NSF

Our Focus

Water Safety and Disasters

Infrastructure Construction and Repair Technologies

Waste Materials and Management Solutions


Commercial
PROPERTY OWNER RESPONSIBILITY
Street
Fire Hydrant
Water meter
BUILDING PLUMBING
Corporation Stop
Backflow preventer (maybe)
Water Main (metal or plastic)
WATER UTILITY RESPONSIBILITY
Utility Service Line (metal or plastic)
Property Service Line (metal or plastic)
[sometimes other water sources]

System Basics

Building water system public health **risks**

Exposure Routes of Concern: Ingestion, Dermal, Inhalation

Routine Operations

Disinfectant residual isn't replenished

Heavy metals can leach (Copper, lead, zinc, …)

Scale can destabilize and suspend

Harmful organisms can grow (e.g., *Legionella pneumophila* and other pathogens)

Post-Disaster or Accident

Pressure loss, backflow, chemical spill, hurricane, flooding, wildfire, intentional attack, and more

Plumbing component	Type of material
Service lines	Polyvinyl chloride (PVC), high-density polyethylene (HDPE), cross-linked …VC), copper, lead, multilayer pipes …arrier layers could be aluminum or
Piping and tubing	…temperature, copper, ductile iron, … steel, black steel, malleable iron, …stic layer–barrier layer–plastic layer; …ene vinyl alcohol)
Pipe and tank coatings	
Fixture fittings, valves, fittings	…ess steel
Gaskets	…and peroxide cross-linked], natural …eoprene
Water-heater specific	…nterior linings, magnesium, or
Domestic storage and cistern	…, HDPE
In-building treatment	…ers), plastic housing for sorbent or …ge resin, stainless steel
Small-diameter tubing for faucet conn… humidifiers, dishwasher supply, was… machine supply, in-building water treatment systems	…er, PVC, HDPE

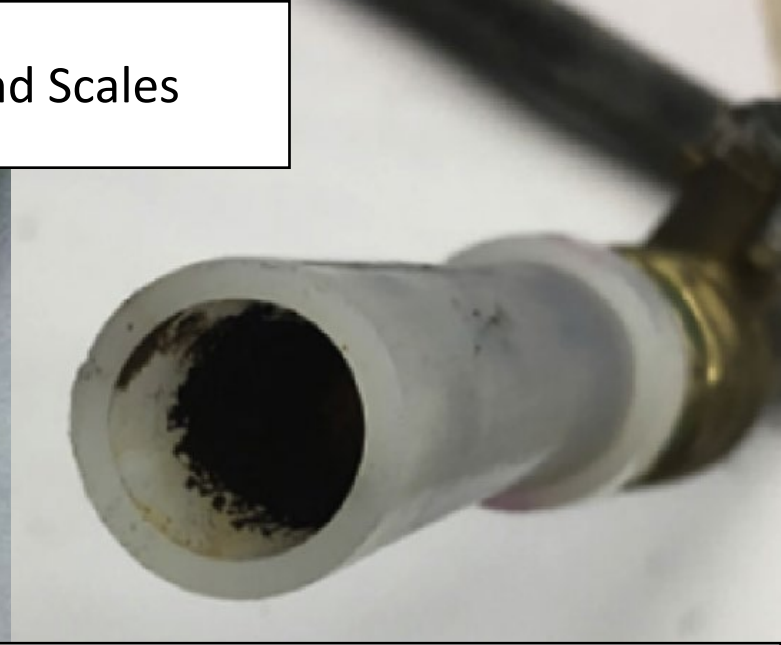
Residential Systems

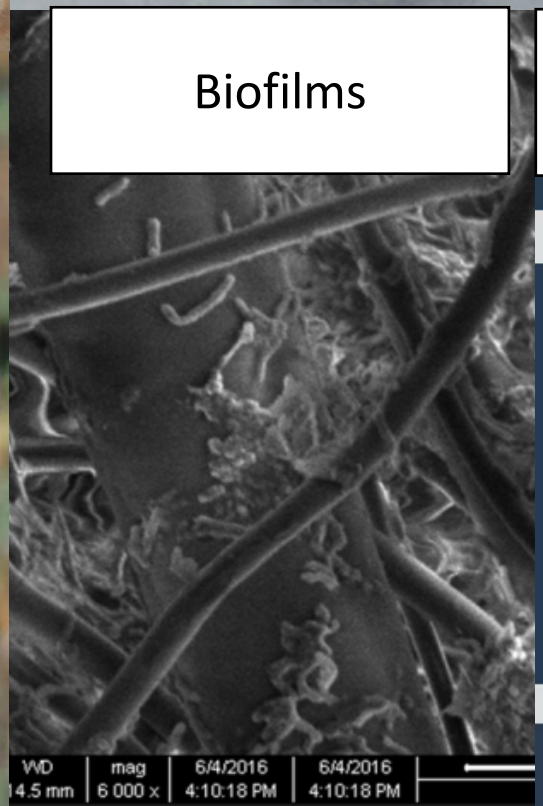
Service line (single vs. shared)
POE/POU devices
Central vs. on-demand water heaters
Recirculation loops
Irrigation
Mixing valves
Fixture types and internals
Faucet gaskets and aerators

Julien et al. 2020. https://doi.org/10.1002/aws2.1177

Piping and Tubing Types, and Coatings

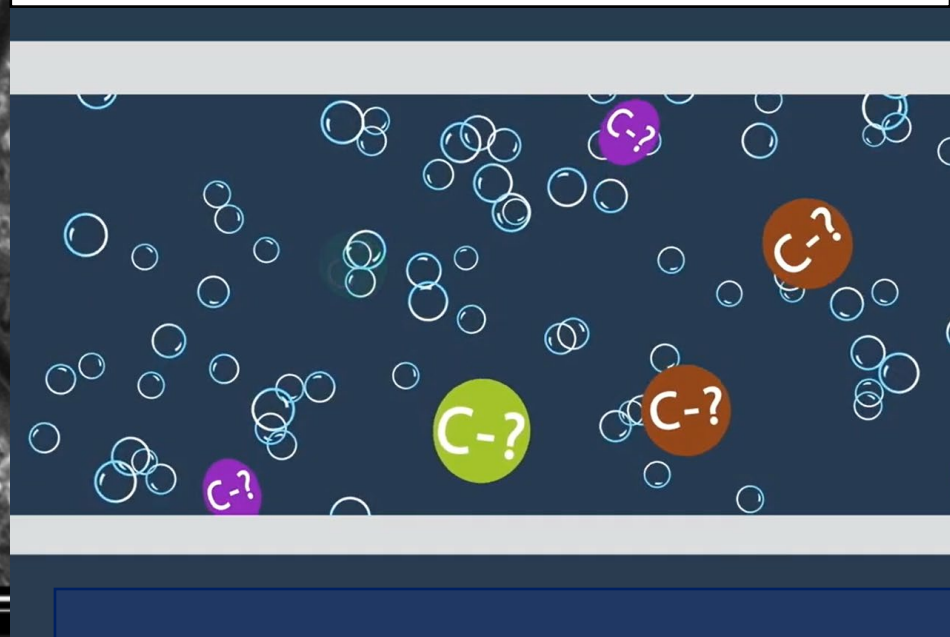
Sediment and Scales





Biofilms

Plastics can Uptake Organic Chemicals



Food Prep Facility

Domestic Hot Water

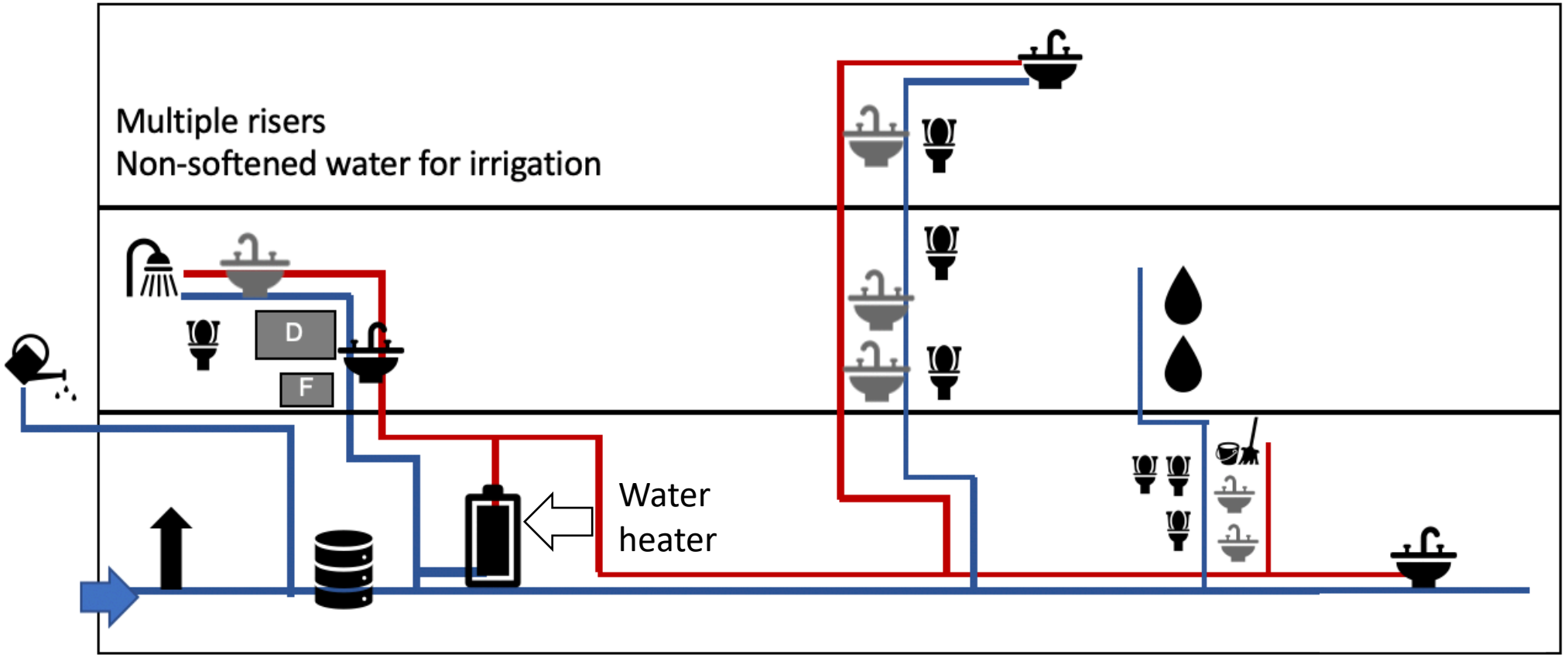
Industrial Facility

Cartridge Filters

Gyms
Salons
Offices
Restaurants
Retail
Daycares
Schools
Government Buildings
Colleges & Universities
Hotels & Motels
Sports & Entertainment
Venues
Casinos
and more…

Courtesy of: Gordon & Rosenblatt, LLC

Example: A 3 story office building with 3 risers and a centralized water heater



Legend

Pipes: Hot, Cold

Sinks: Kitchen, Bathroom, Janitorial

Toilet

Fountain

Shower

Irrigation

Appliances
F - fridge
D - dishwasher
C - water cooler

Some of our efforts involved testing building water systems in response to the pandemic

11 buildings across 4 studies

All free chlorine disinfectant

3-5 months of low/no water use

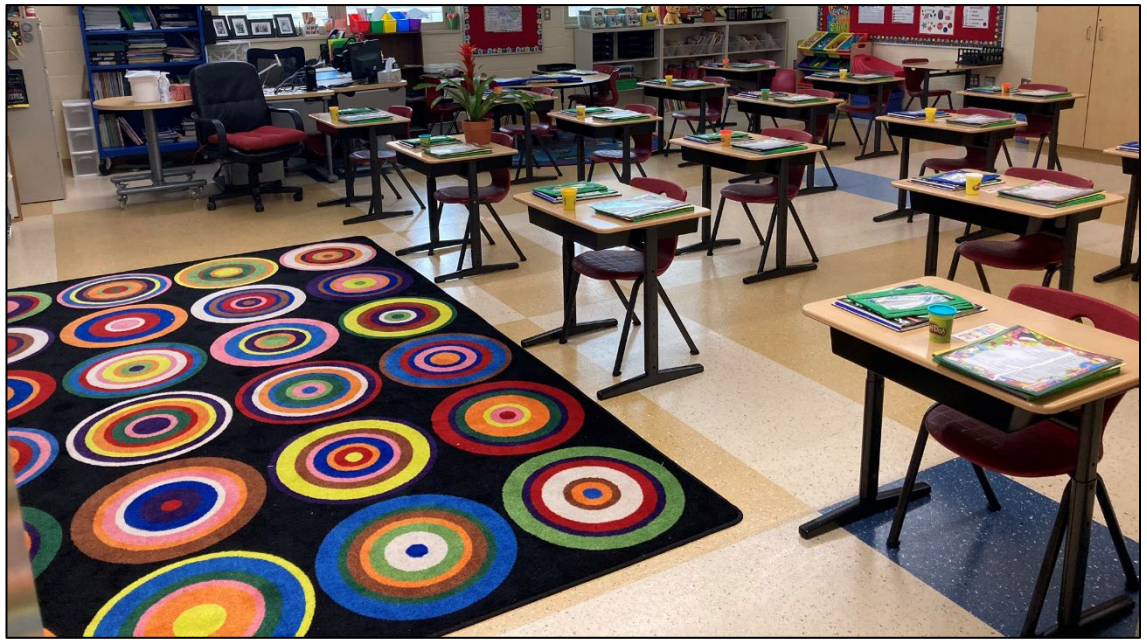
Some served by the same utility

Some have recirculation loops, in-building storage, showers

All had indoor copper pipe

Up to 400 water outlets/building

Not all had as-built drawings



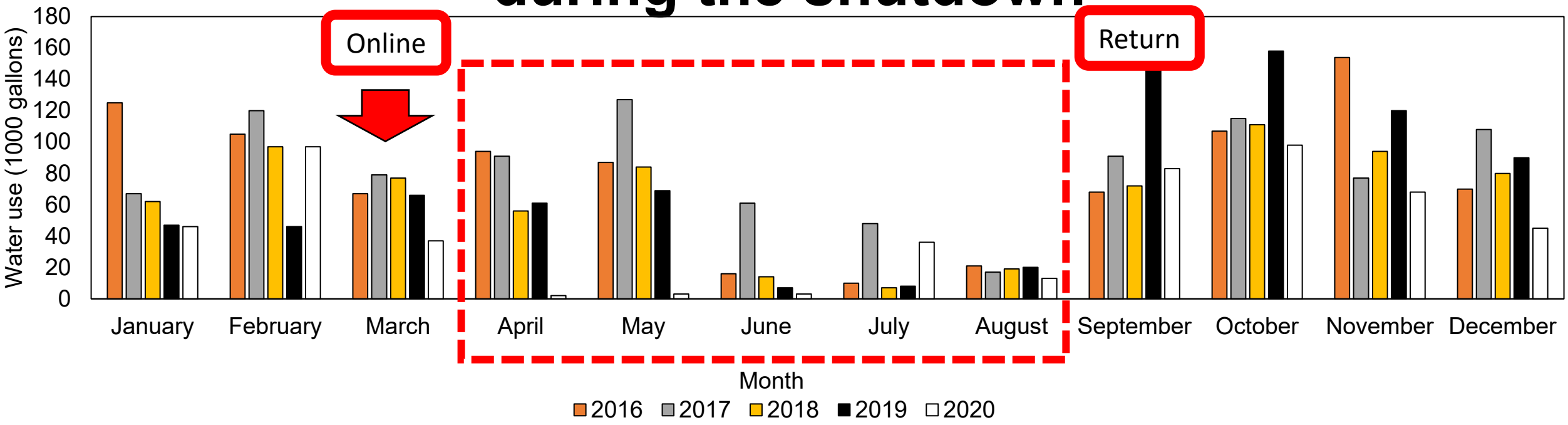
1. Elementary school, Indiana (Ra et al.)
2. Large residential building, Indiana (Angert et al., led by Proctor, Ph.D.)
3. Institutional buildings, Indiana (Ra et al.)
4. Elem/mid/high school, Ohio (Ley et al.)

In Ohio, a utility and an 8 year old LEED K-12 school reached out for assistance.

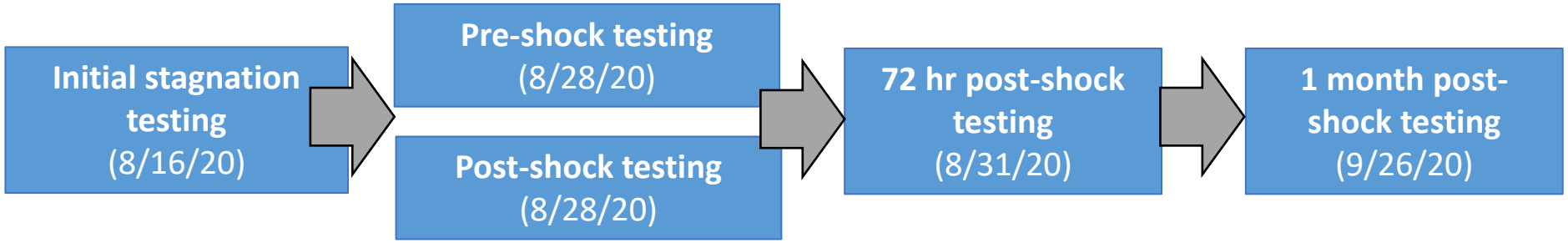
- Utilities across the U.S. saw increased residential demand (+43%) and reductions in commercial (-46%) and industrial (-21%) demands (Faust et al. 2021)
- 1 water utility found that after 6 months of low water use, free chlorine levels were not detectable after the school building had been flushed
- We setout to examine water quality in the 2 story building
  - No water management program or flushing plan
  - 220 sinks, 31 water fountains, 30 showers, and 1 hydrotherapy spa in the facility's athletic training room.
  - Water heating set at 140° F (60° C). 2 boilers with a 500 gallon hot water storage tank. No recirculation system.
  - Rainwater used for toilet flushing – NOT potable water –

Ley et al. (In preparation)

The school had a >95% reduction in water use during the shutdown



Approach



Ley et al. (In preparation)

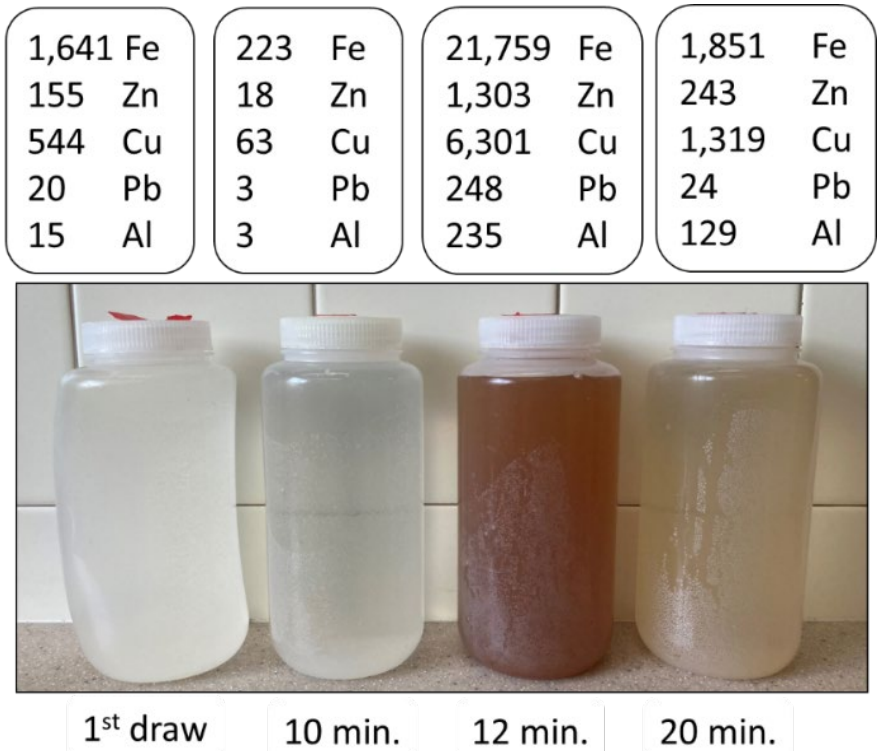
Metal levels were not consistent across the school, were impacted by flushing, and the 8 year old hot water system was excessively corroding

Some **Cu** levels exceeded the acute health-based limit of 1,300 µg/L, while others did not

Zn exceeded the USEPA health advisory level at 1 cafeteria soup filling station because of nonuse and stainless steel piping

Nonpotable fixtures used for potable purposes

Hot water system had excessive corrosion. Discolored water was observed



Ley et al. (In preparation)

Legionella was detected before and immediately after the shock disinfection + flushing intervention

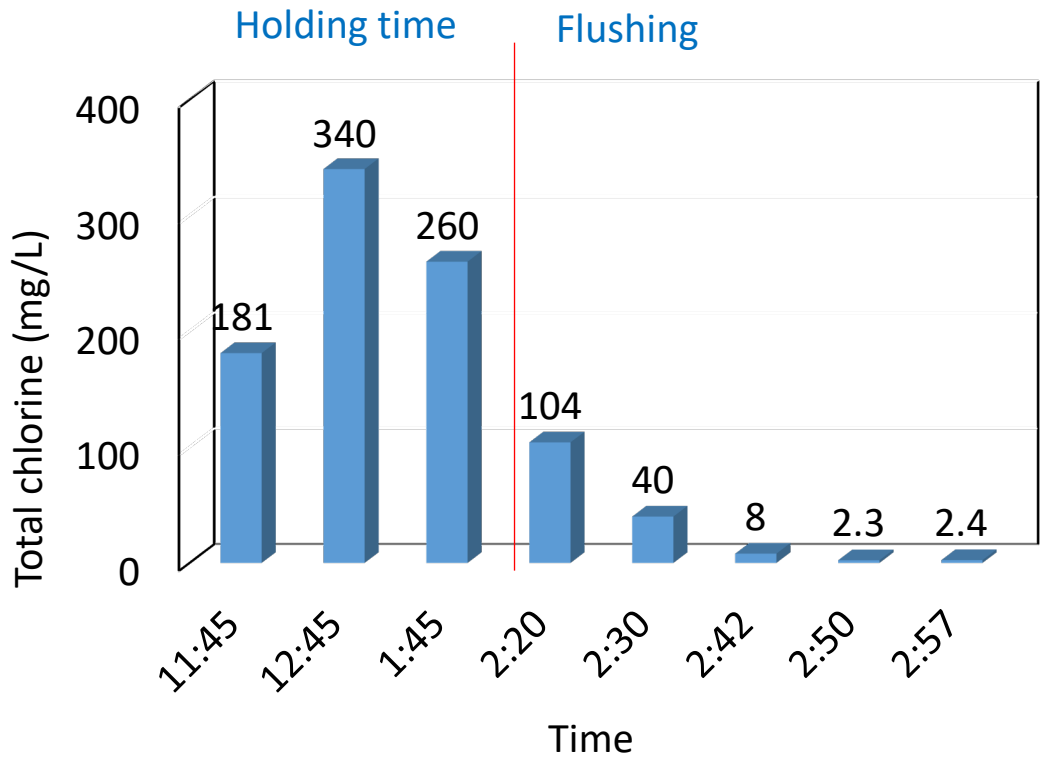
Sample type	Fixture type	*L. Pneumophila* conc., MPN/100 mL	Exceeded suggested *L. pneumophila* Limit, 106 CFU/mL
Initial stagnation	Water fountain	239.6	Yes
	Staff sink (cold)	1,289.6	Yes
	Cafeteria sink (cold)	3.5	No
	Cold faucet (distal end)	1	No
	Cold faucet (central)	1.1	No
Pre-shock chlorination	Various	0	No
Immediately after shock	Various	0	No
	Fountain	3.9	No
	Bathroom sink	7.9	No
72 hr post-shock	Various	0	-
1 mo. post-shock	Various	0	-

Stagnation:
5.3% (n=5 of 94 total) of sampled fixtures tested positive for *L. pneumophila*.

After shock:
L. pneumophila was detected in 2 fixtures (drinking water fountain, sink thermostatic mixed valve)

One month after shock:
L. pneumophila not detected 1 month after the shock disinfection

There are NO standards for disinfecting building plumbing or determining it was “disinfected enough” post-shutdown



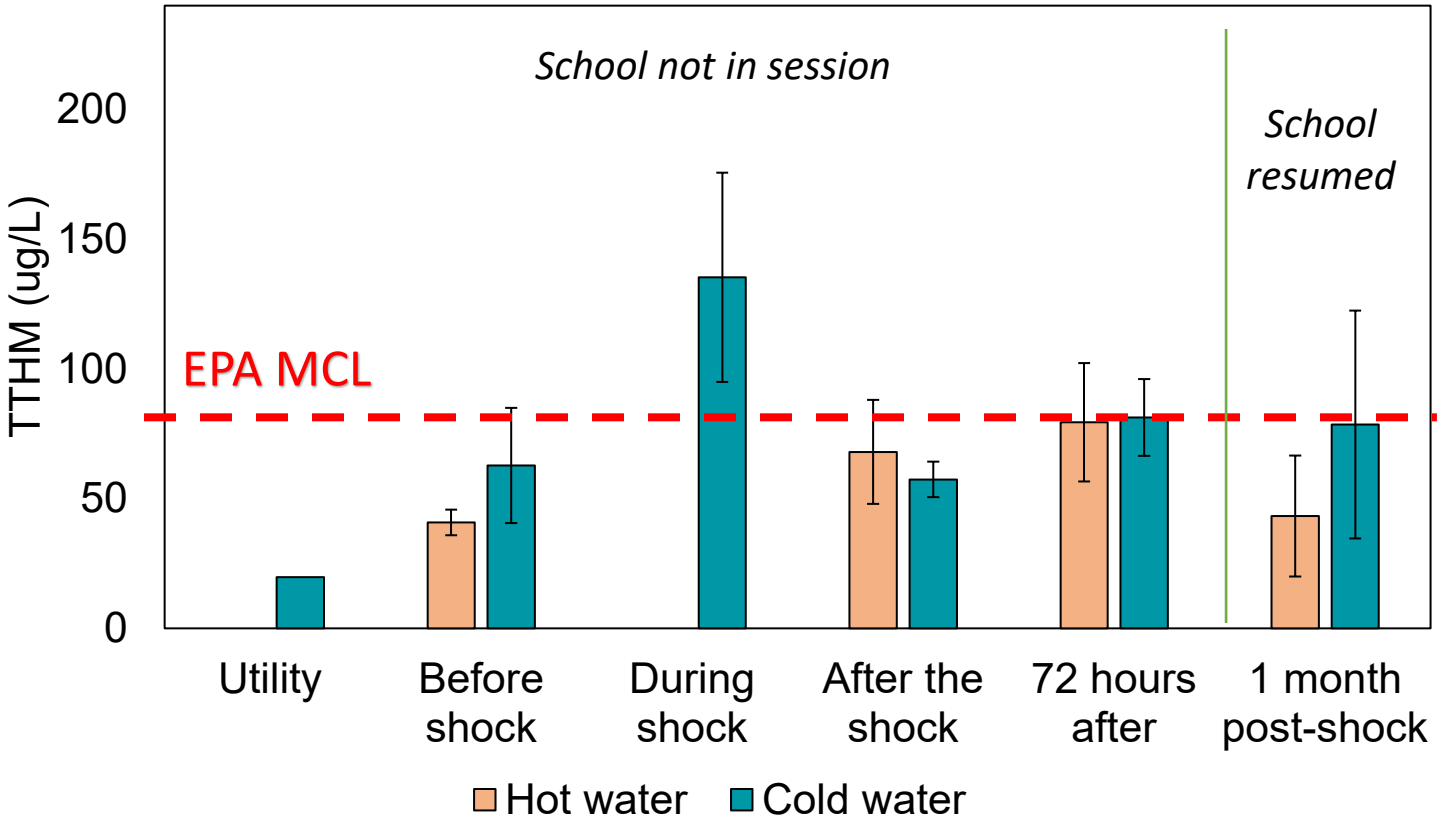
The company pumped in 12.5% hypochlorite solution

Their ***target*** was 200 mg/L to be reached at the furthest point

Water remained in hot and cold plumbing system for 3 hours (11am-2pm)

The company then flushed fixtures and **targeted** levels below 4.0 mg/L. Some were ~ 9 mg/L when they left.

TTHM and copper levels were affected by the shock disinfection and flushing procedure



TTHM levels in plumbing >> water utility's distribution system

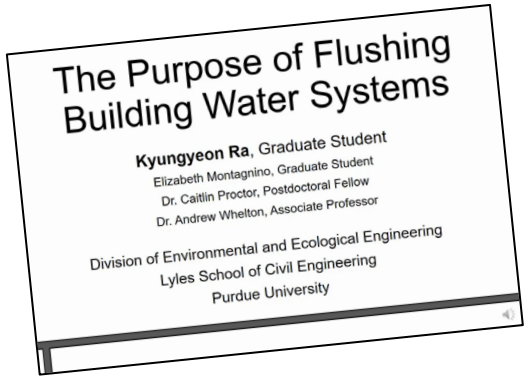
Highest TTHM levels: Shock chlorination (mean: 135.3 µg/L).

Highest number of exceedances: 72 hours after the shock + flushing, 7 / 15 samples

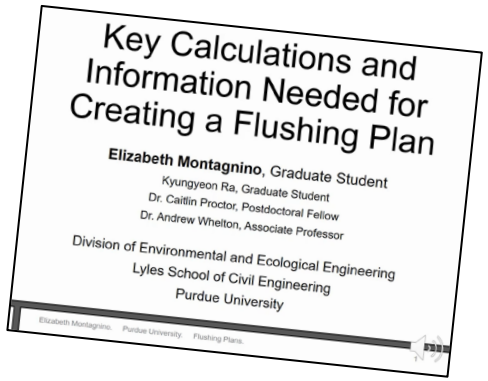
Some samples had copper levels exceed 1.3 mg/L post-shock, while lead was unaffected.

Ley et al. (In preparation)

An Indiana Elementary School: 3 buildings and a 3 month shutdown



YouTube



- Little to no chlorine found at stagnant fixtures
- Ni exceeded the health based limit in 3 month stagnant water before flushing, but other metals were okay. Cu did not exceed safe limits. Pb found at a maximum of 3.5 ug/L.
- *L. pneumophila* detected in all buildings, but not at all locations (1.1 to 188 MPN/100mL): bathroom sinks, class sinks, water fountains.
- After complete building flushing and 2 weeks later, the pathogen was not detected.

Ra et al. (In preparation)

Institutional Buildings: March 2020 still 100% use, then buildings went to reduced occupancy until July 2020

4 buildings sampled and were constructed in 1952 – 2007

Monthly building water use for 4 buildings tested was -93% compared to 2020.

Total water usage/building during the 5 month low occupancy period (March to July) was -57 to -93% lower than the previous year.

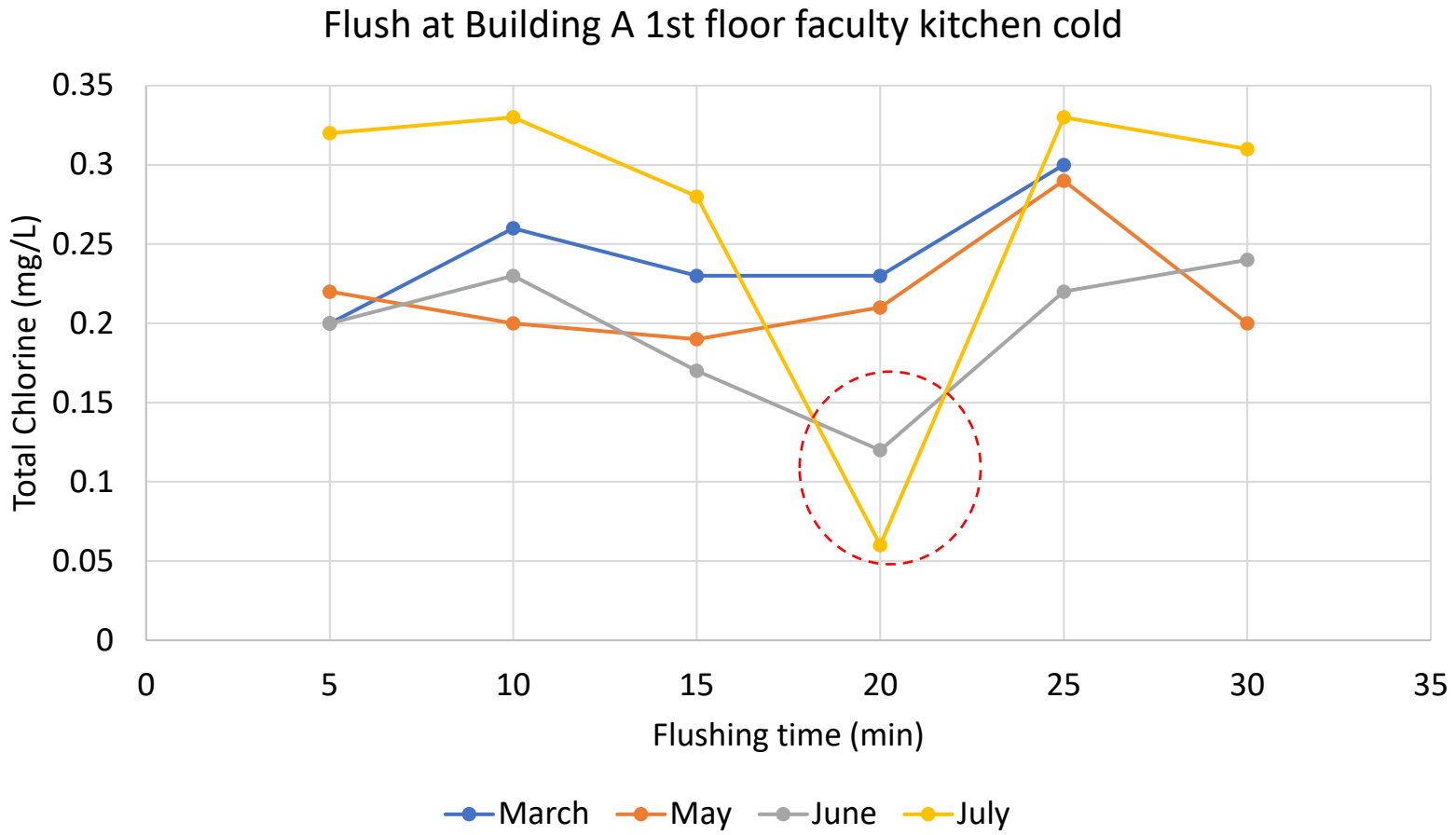
For all 4 buildings…of 180 first draw drinking water samples

- Chlorine disinfectant sometimes, not always, found at faucets
- 3 samples exceeded the Cu limit and 2 were from the same water fountain just in different months. 2.87 mg/L Cu max
- 2 samples exceeded the 5 ppb Pb level and this was from the same drinking water fountain in different months. 45 ug/L max.
- 8 samples exceeded the 100 ppb Mn health advisory level, but were all in the same building.

The building owner sometimes flushed some faucets in the buildings before we arrived which is likely why we found fresh water.

Ra et al. (In preparation)

Water delivered to buildings on the same water distribution system is not always the same quality. When you test more you can see this.



Chlorine levels reported by the water system owner in 2019 ranged from 0.8 – 1.2 mg/L

Ra et al. (In preparation)

Chlorine disinfectant: Most locations was non detectable (<0.2 mg/L). Flushing can bring detectable chlorine in, but flushing time varies depending on location

Heavy Metals: Cu, Pb, Mn, Zn exceeded levels of concern at several location in several buildings

TTHMs: Concentrations were higher during shock chlorination, and changed throughout process

Legionella pneumophila: *Legionella pneumophila* was detected sporadically across buildings (including cold water), even after system shocking.

Deeper thoughts…

- Water testing of new or existing buildings isn't required (except healthcare buildings).

- The following assumptions are sometimes false:
  1. Plumbing to Code = Safe drinking water at the faucet
  2. Public Water System delivers safe drinking water to the building = Safe drinking water at the faucet

- Absence of standards and best practices: People do what they think is best, which may or may not work.

- Building owners should test their water and institute water management programs.

The pandemic put a spotlight on plumbing safety...

health officials, industry, governments, institutions, and more responded.

To Address the Public Health Knowledge Gaps

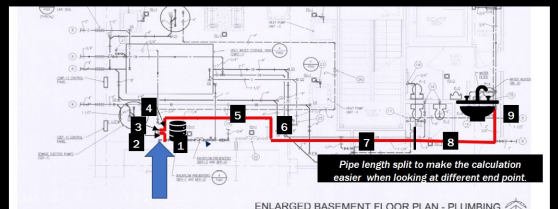
Building Water Essentials – Public Health

10 Hour, Online Short-Course

Input from practicing engineers, scientists, utilities and public health officials.

A training tool, an encyclopedia, and an extensive FAQ, designed to be immediately applicable in the field.

Modules do not have to be taken in sequence.



If interested e-mail EngrOnline@purdue.edu

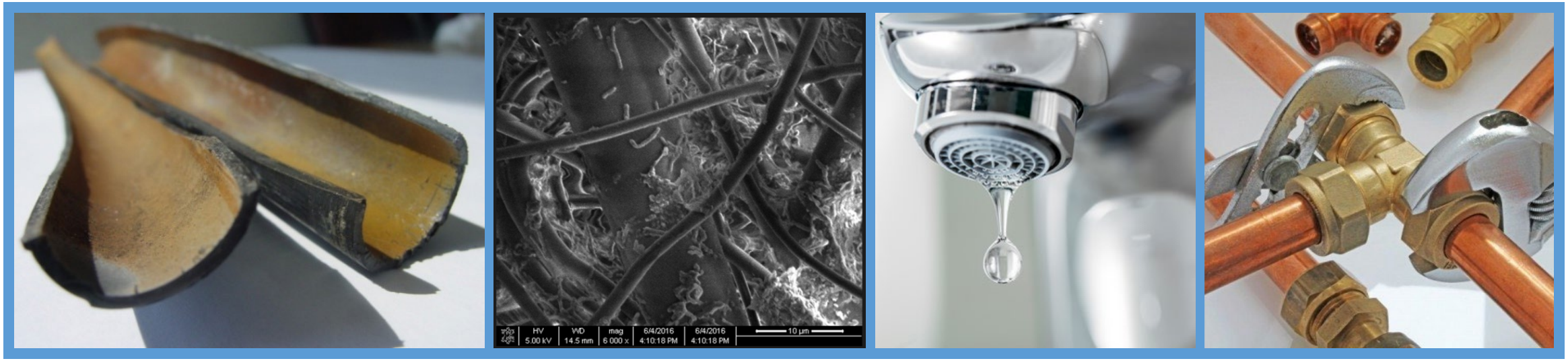
Info and registration: https://cutt.ly/Sg4RXJv

Plumbing Safety Decision Support Tool Coming Soon:

Right Sizing Tomorrow's Water Systems for Efficiency, Sustainability, and Public Health, 2016-2021

Supported by a grant from:

EPA



Andrew Whelton, Jade Mitchell, Joan Rose, Juneseok Lee, Pouyan Nejadhashemi, Erin Dreelin, Tiong Gim Aw, Amisha Shah, Matt Syal, Maryam Salehi

Manhattan College

Michigan State University

Purdue University

Tulane University

The University of Memphis

Right Sizing Tomorrow's Water Systems for Efficiency, Sustainability, & Public Health, 2017 through 2021

1. Improve the public's understanding of decreased flow and establish a range of plumbing flow demands
2. Elucidate the factors and their interactions that affect drinking water quality through simulation models
3. Create a risk-based decision support tool (DST) to help guide decision makers to identify plumbing characteristics, operations and maintenance practices that minimize health risks

Education	~100 presentations Materials publicly available, 100,000(s)+ ppl reached Assisted all major sectors
Engagement	LCR Federal Register comment Scientific opinions Direct building owner and building designer support Manufacturer technical assistance
Discovery	Peer-review: >20 Published + 5 in Review + >10 in Development [DST coming and more]

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October 2017-October 2018

30,000+ individual water quality measurements completed - does not include flow monitoring, pressure monitoring, or qPCR

2.64 billion online plumbing related measurements

Results Coming Soon:

EPANET Model for Predicting Water Quality at the Faucet

4 Seasons (Summer, Fall, Winter, Spring)	2 Systems (Hot, Cold)
4 Service Line Length (1' (As is), 25', 50', 100')	2 Free Chlorine at service line (As is, 2x)
2 Pressure boundary conditions (35/40psig (As is cold/hot), 80psig)	4 Conservation Scenarios (25%, 50%, 100%(As Is), 200%)

Manhattan College

Purdue University

Michigan State University

We need to be able to predict water quality at the fixture

Courtesy of Prof. Juneseok Lee, Maria Palmegiani, and others ….

PurdueX: Massive Open Online Course (MOOC)

Plastics in Infrastructure and the Environment

May 17, 2021 to July 11, 2021
Online 8 week course
6-8 hours/week
FREE

Learning Objectives

- Explain the properties of polymer materials.
- Recognize the performance differences between polymeric materials.
- Describe the advantages and disadvantages of polymers for engineering applications.

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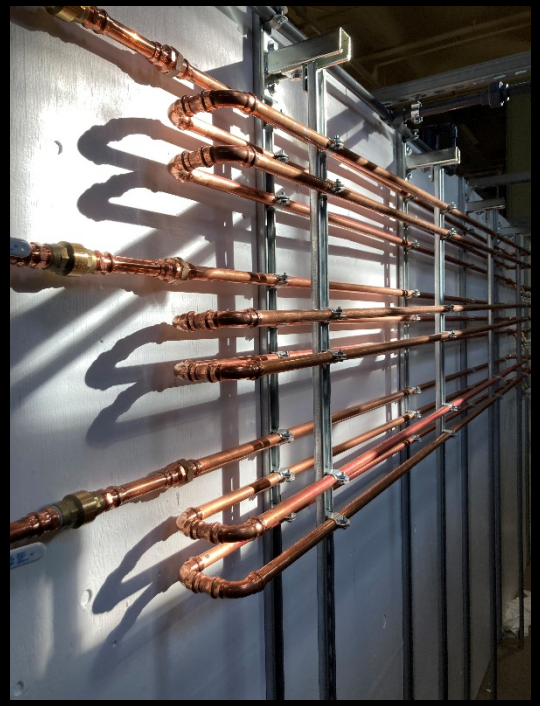
Healthy Plumbing Consortium, ca. 2021

DELTA FAUCET COMPANY

Intellihot

Cu Copper Development Association Inc.
Copper Alliance



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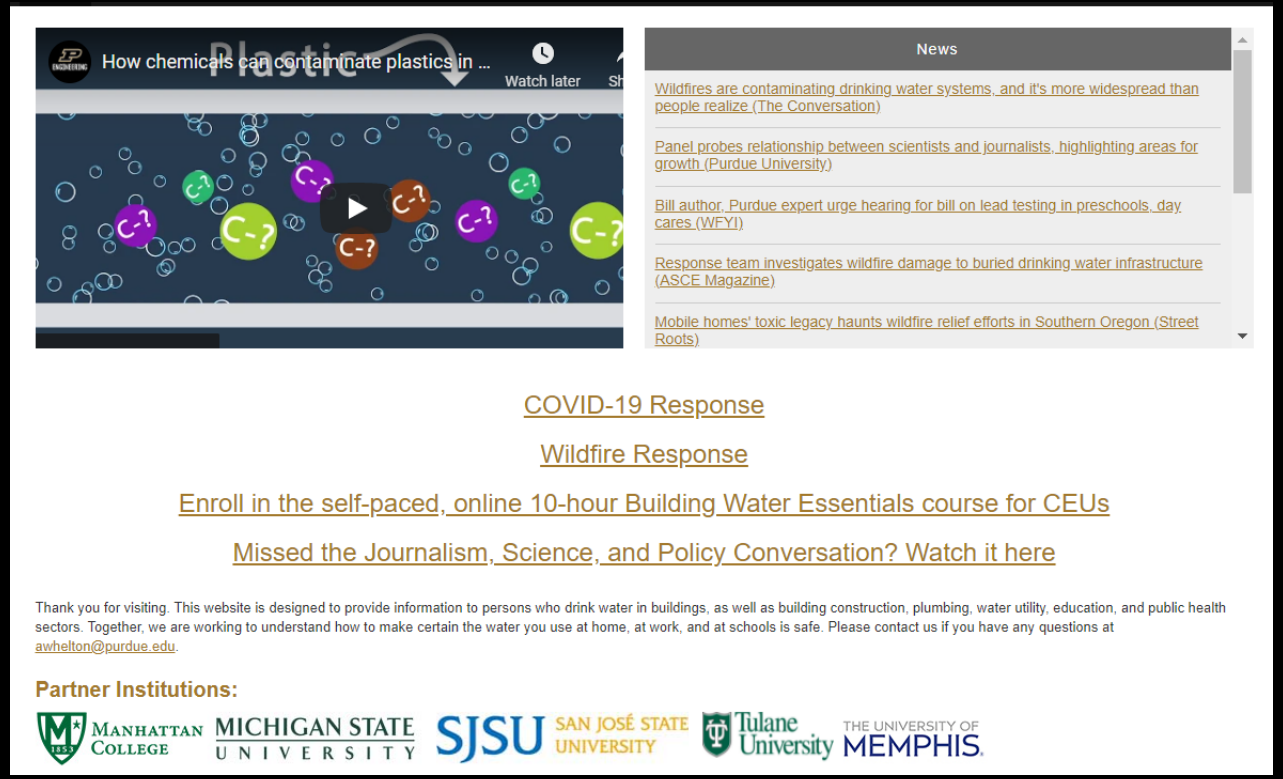
Education
&
Innovation

Thank you.

Andrew Whelton, Ph.D. awhelton@purdue.edu @TheWheltonGroup



- ✓ Online short-course
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- ✓ List of projects
- ✓ Scientific opinions
- ✓ Resources ➔ presentations
- ✓ Scientific reports
- ✓ External plumbing docs
- ✓ YouTube Channel

10 hr, 1 CEU, Self-paced, Online
Building Water Essentials Short-Course:
https://engineering.purdue.edu/online/certifications/building-water-essentials

www.PlumbingSafety.org

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