Building Water Safety: New Developments and Resources

Andrew J. Whelton, Ph.D.

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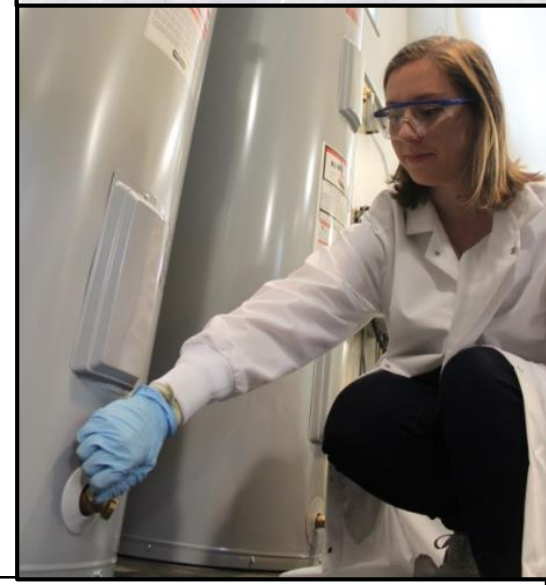
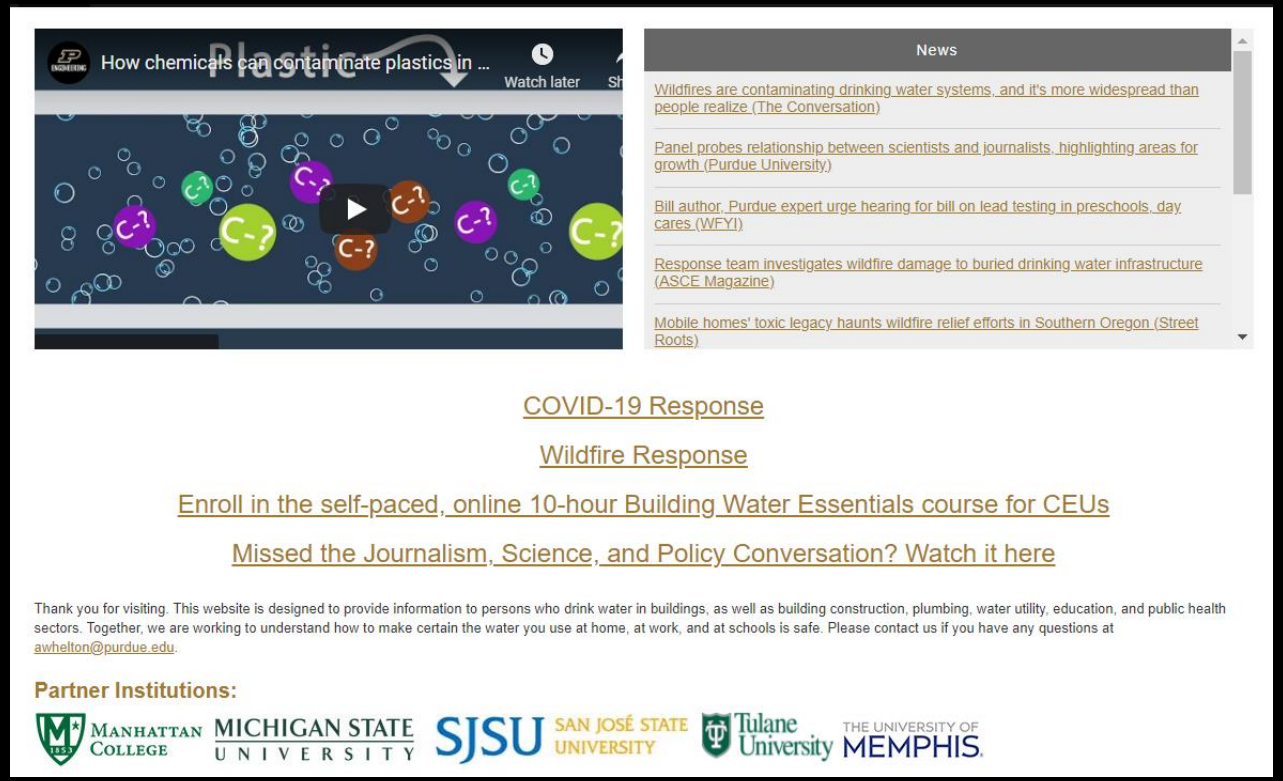
Thanks to NSF



Files will be posted at www.PlumbingSafety.org



- ✓ Online short-course
- ✓ Plumbing education videos
- ✓ Flushing plans
- ✓ Plumbing explainers
- ✓ 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

PURDUE UNIVERSITY

To Address the Public Health Knowledge Gap

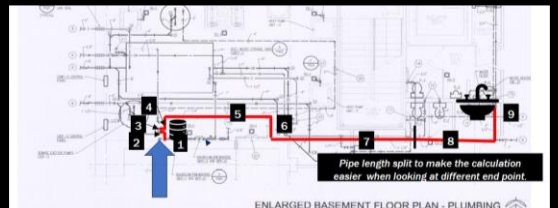
Building Water Essentials – Public Health

10 Hour, Online Self-paced 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 awhelton@purdue.edu

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

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

Commercial district

Street

Fire Hydrant

PROPERTY OWNER RESPONSIBILITY

Single vs. Multiple tenants

BUILDING PLUMBING

Water meter

Corporation Stop

Water Main (metal or plastic)

WATER UTILITY RESPONSIBILITY

Utility Service Line (metal or plastic)

Property Service Line (metal or plastic)

[sometimes other water sources]

Food Prep Facility

Industrial Facility

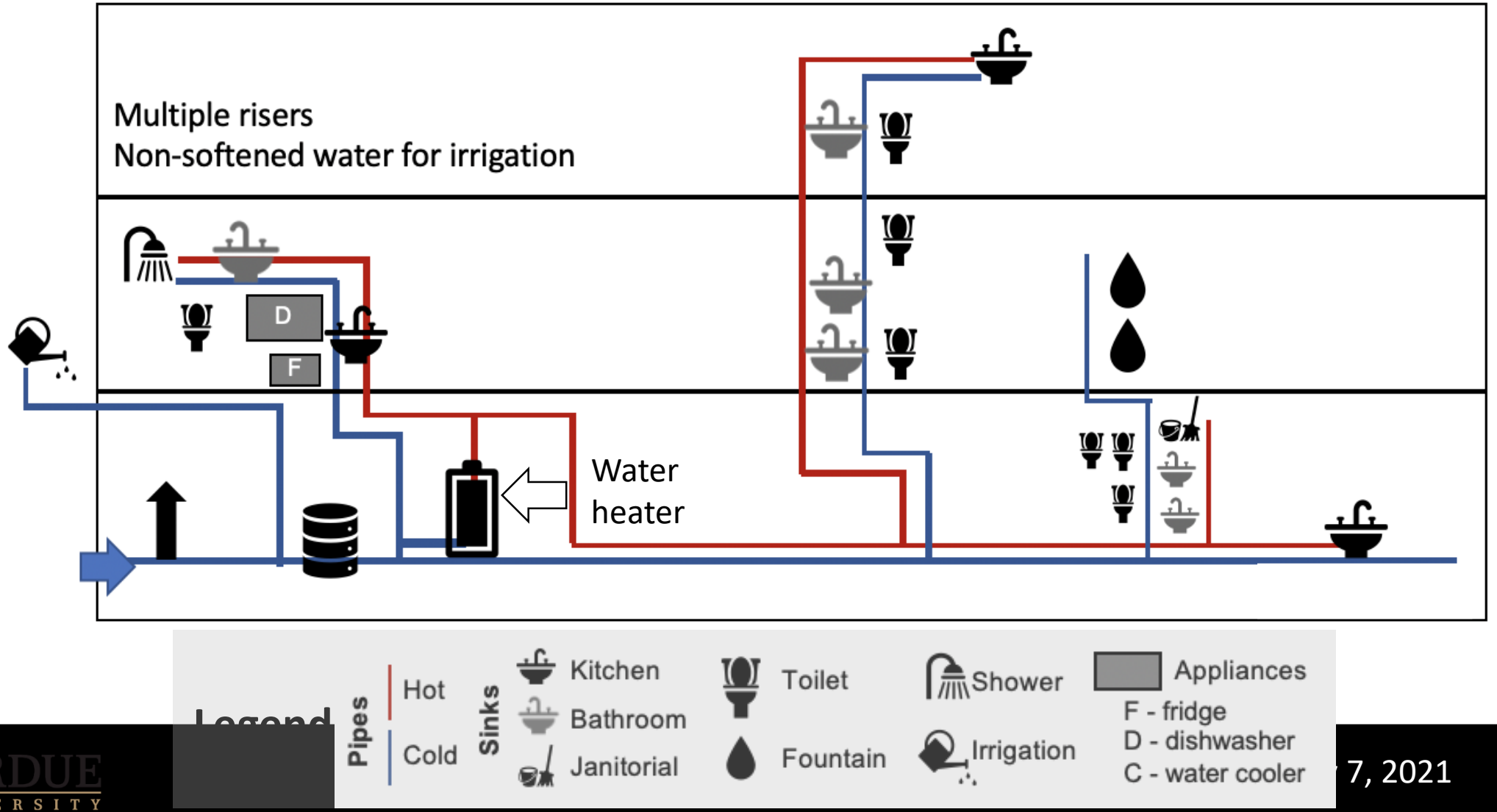
Gyms
Salons
Offices
Restaurants
Retail
Daycares
Schools
Government Buildings
Colleges & Universities
Hotels & Motels
Sports & Entertainment Venues
Casinos
and more…

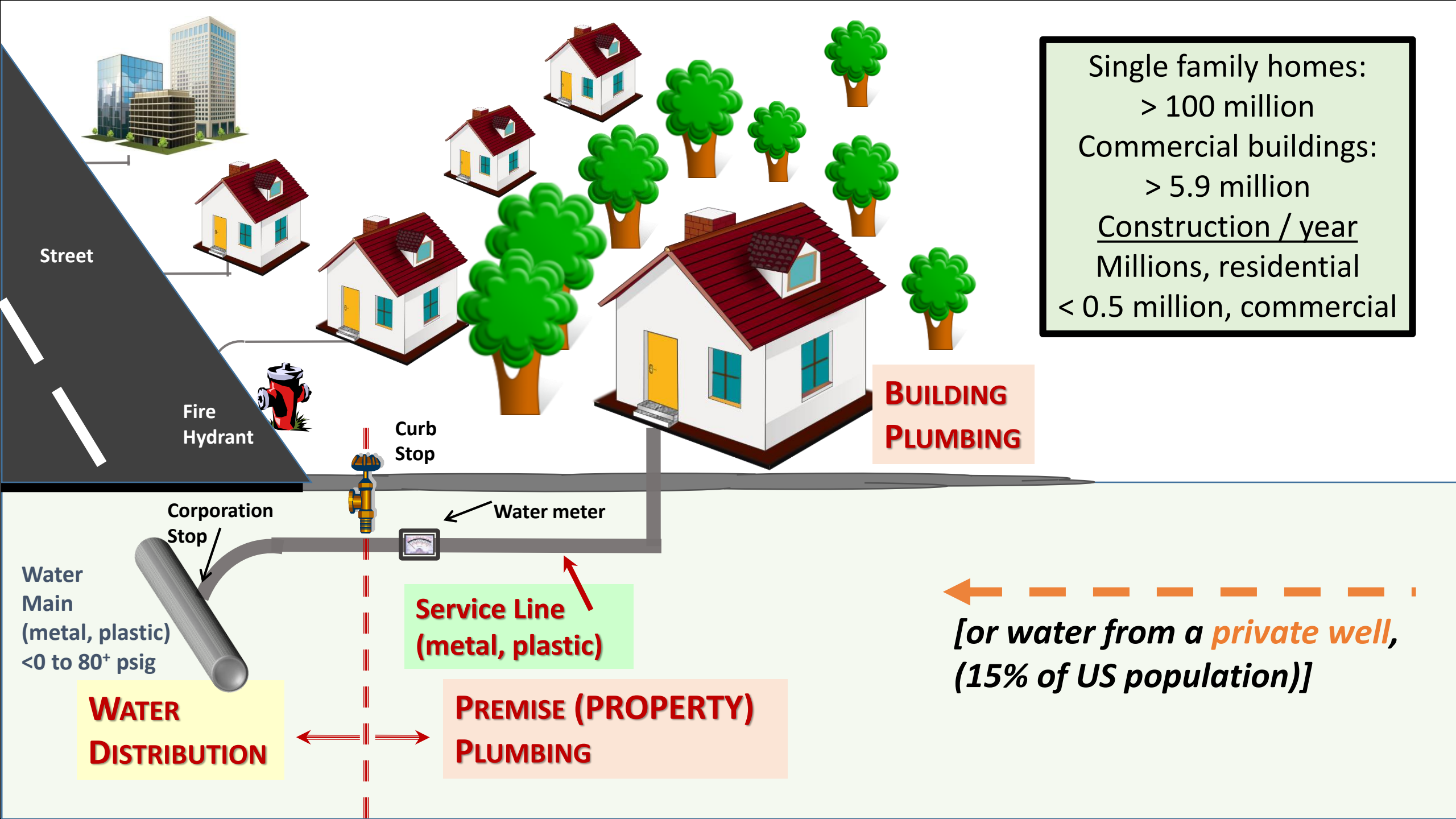
Domestic Hot Water

Cartridge Filters

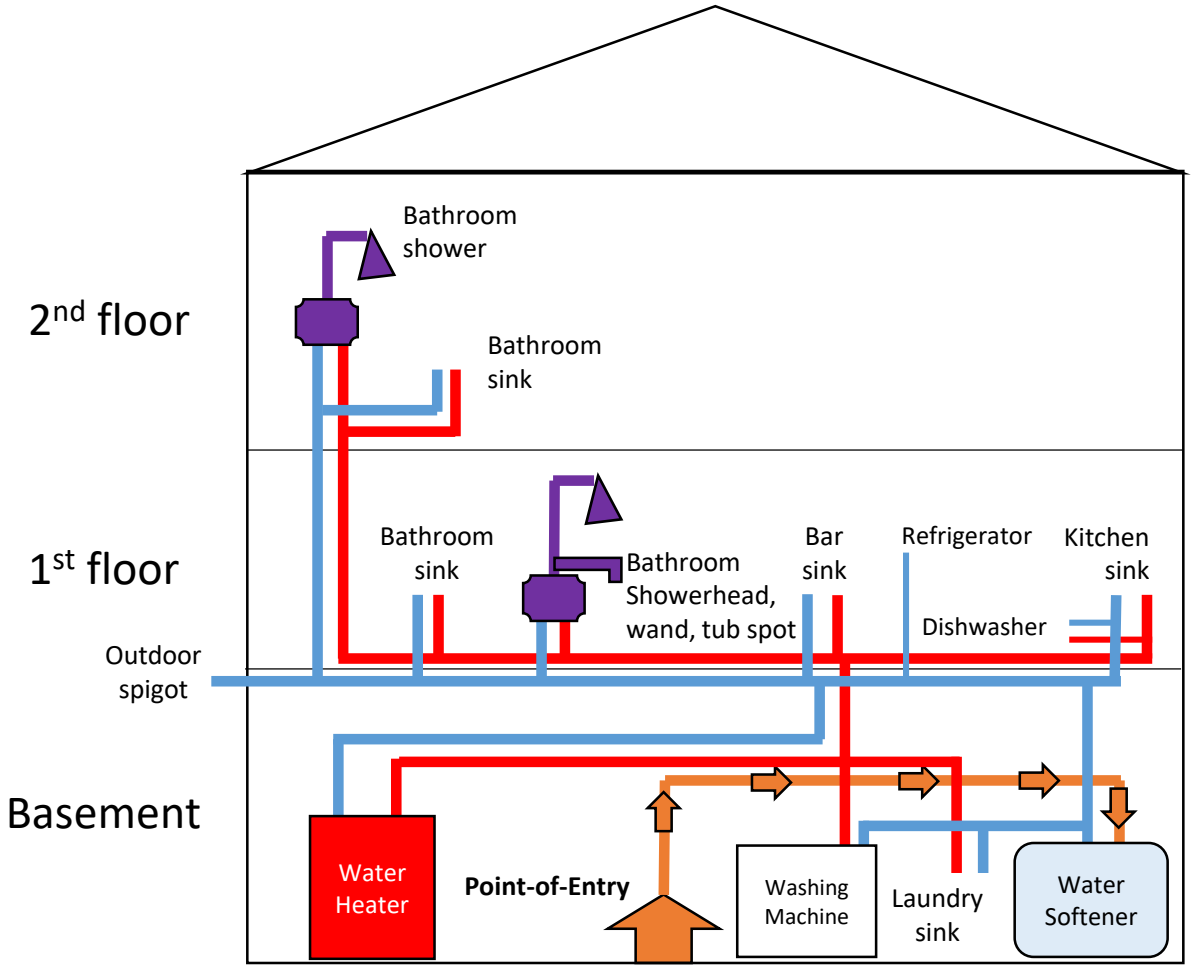
Courtesy of: Gordon & Rosenblatt, LLC

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

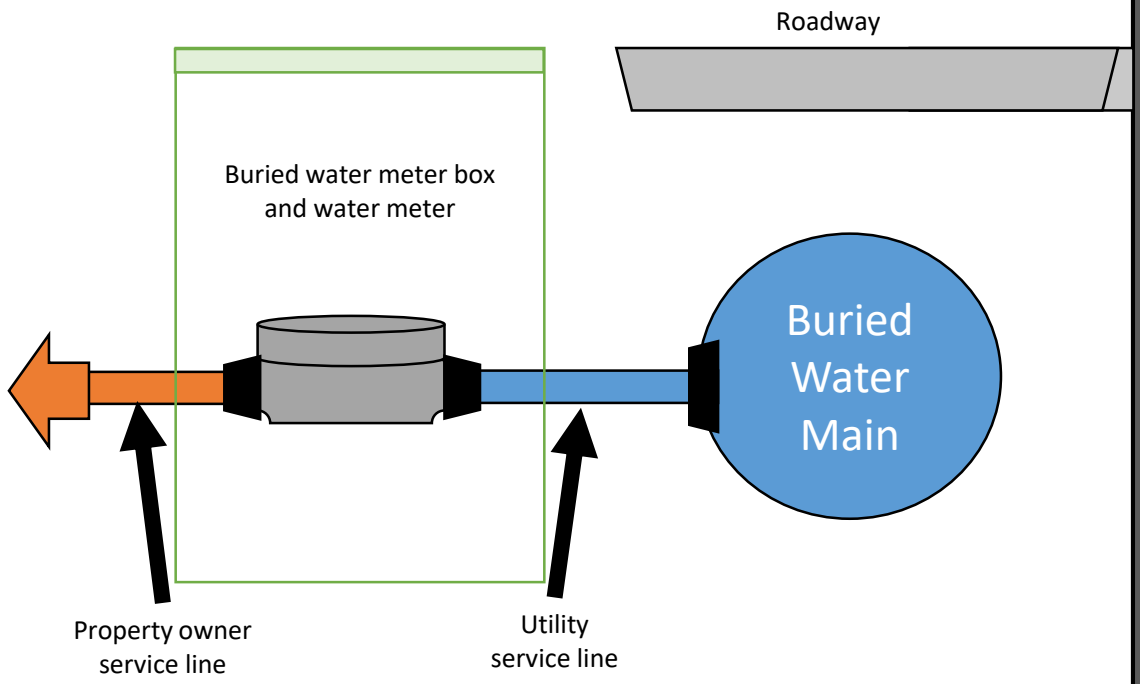



Single family homes:
> 100 million
Commercial buildings:
> 5.9 million
Construction / year
Millions, residential
< 0.5 million, commercial
Street
Fire Hydrant
Curb Stop
Corporation Stop
Water meter
Water Main (metal, plastic) <0 to 80+ psig
Service Line (metal, plastic)
BUILDING PLUMBING
WATER DISTRIBUTION
PREMISE (PROPERTY) PLUMBING
[or water from a private well, (15% of US population)]

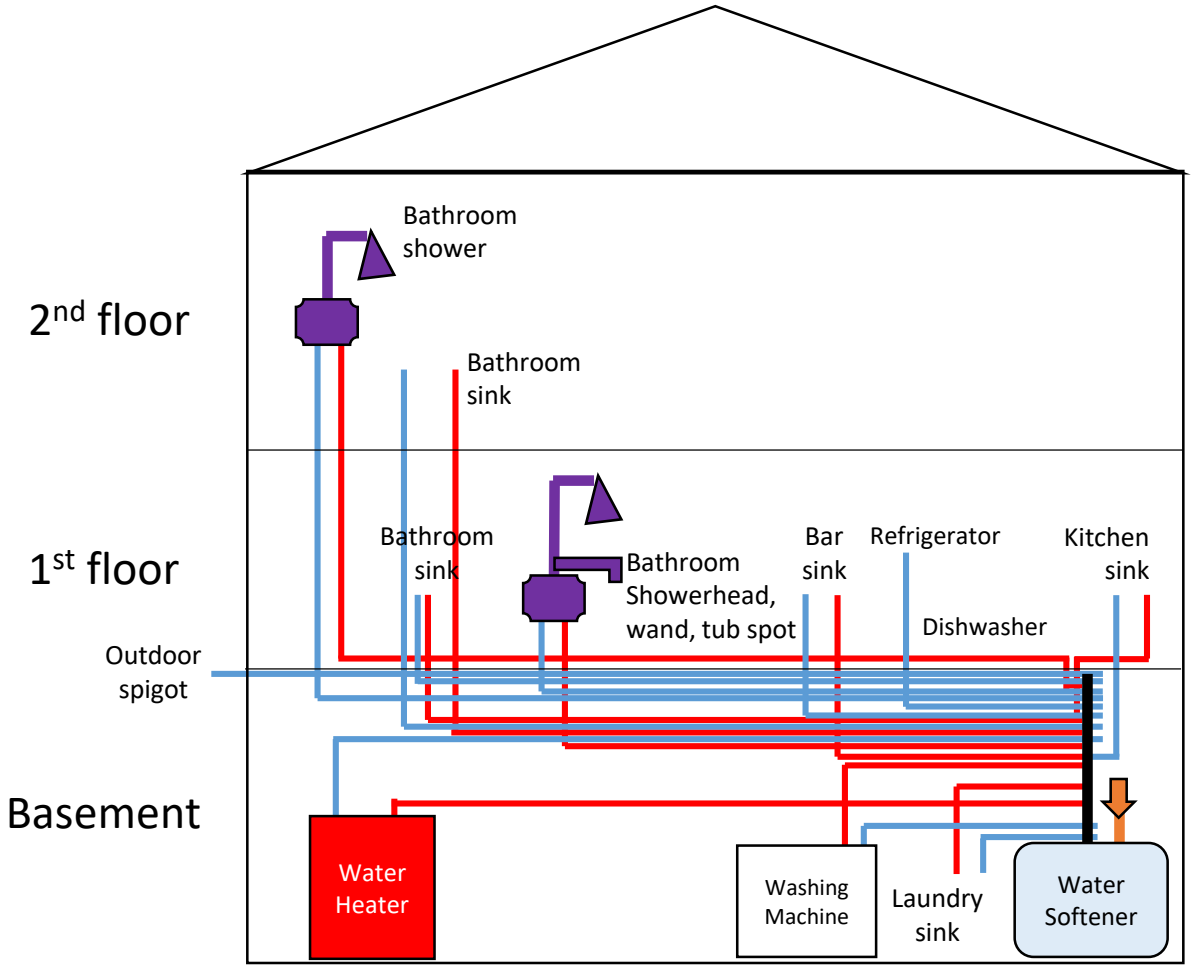
Single family home trunk and branch design with a centralized water heater (Manifold designs are much different)



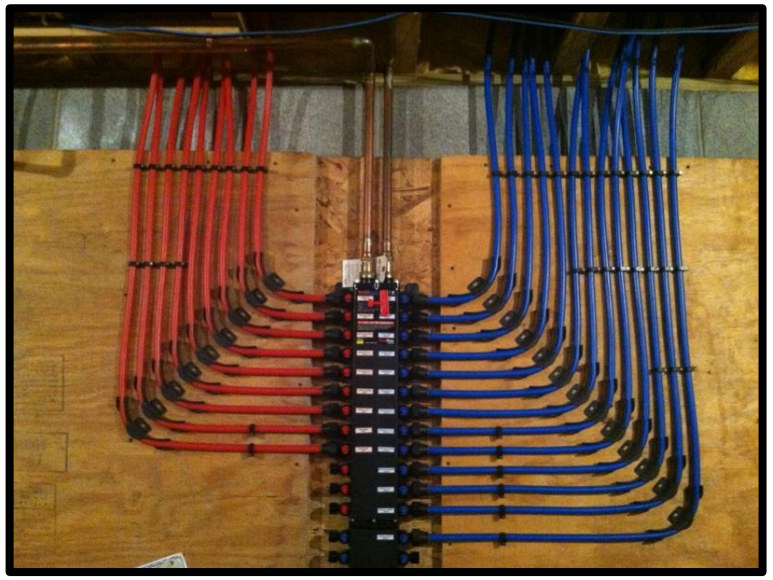
Cold and hot water flow through separate pipes
Some locations are downstream from others, but branch off into separate pipes
Trunk and branch vs. manifold designs



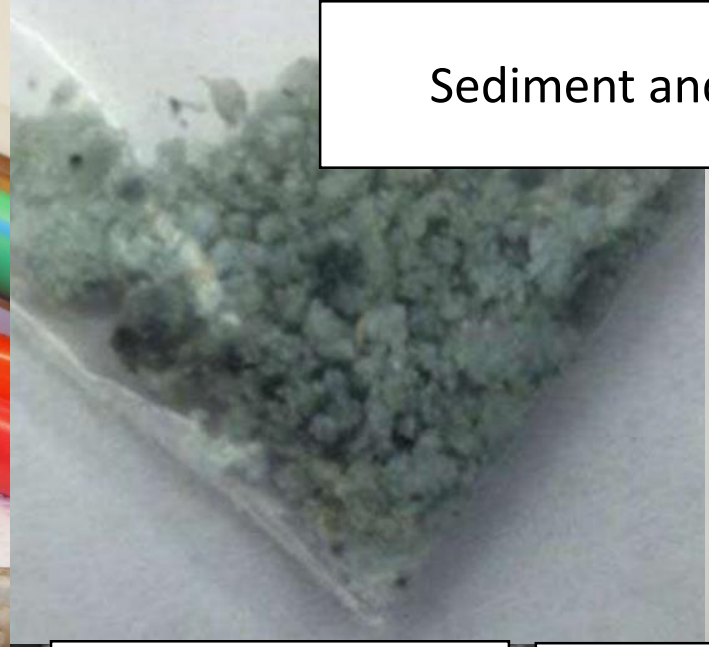
A home with PEX manifold plumbing and central water heater



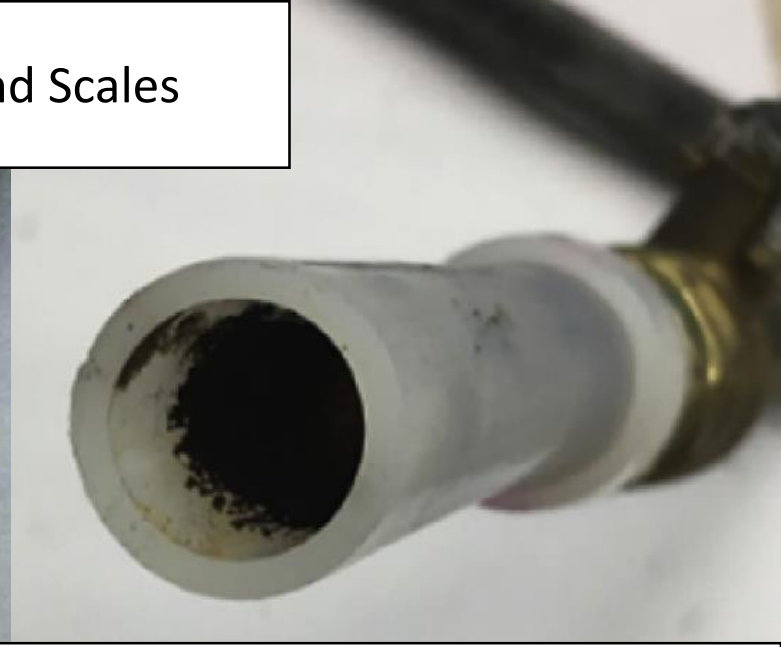
Cold and hot water flow through separate pipes
Each fixture has it's own isolated pipe
No 2 pipes convey the same water
Co-located shutoff location for all each fixture
Smaller diameter pipes compared to T/B design

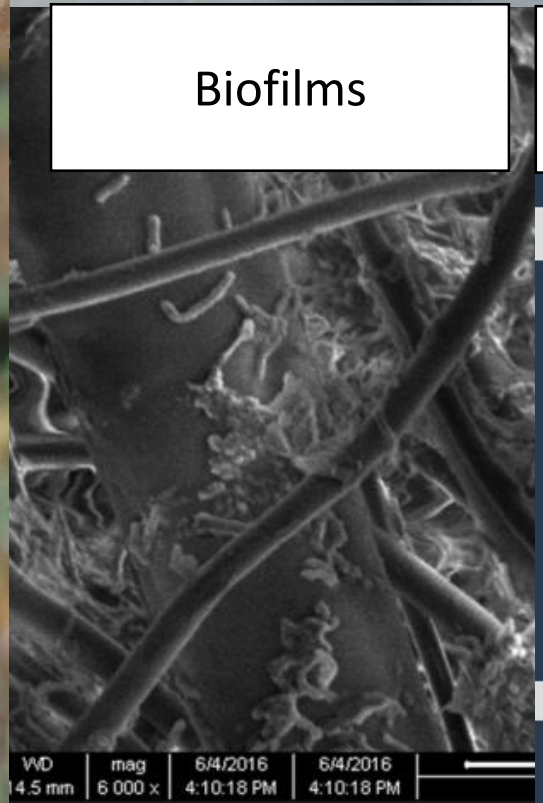


Piping and Tubing Types, and Coatings



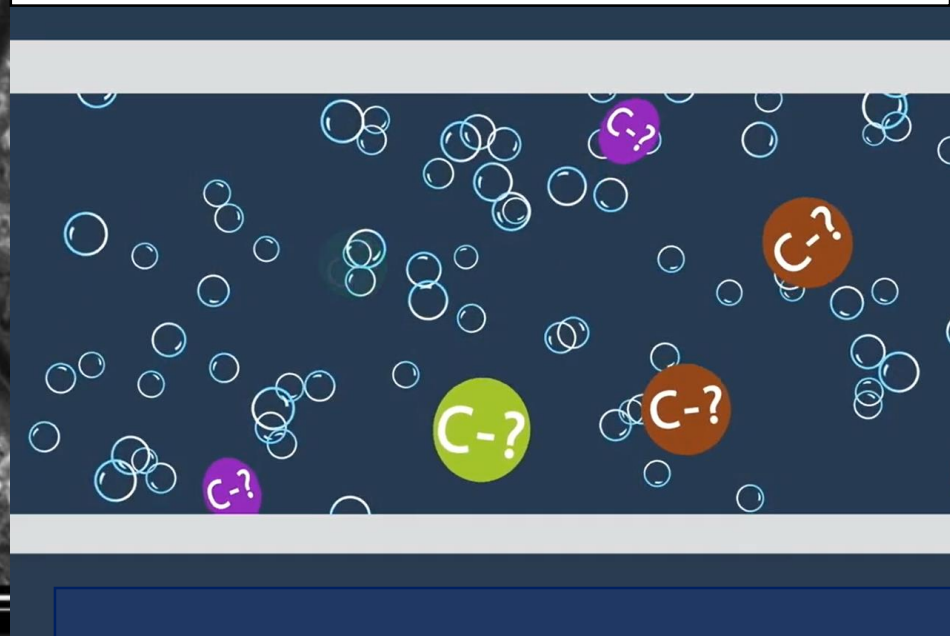
Sediment and Scales





Biofilms

Plastics can Uptake Organic Chemicals

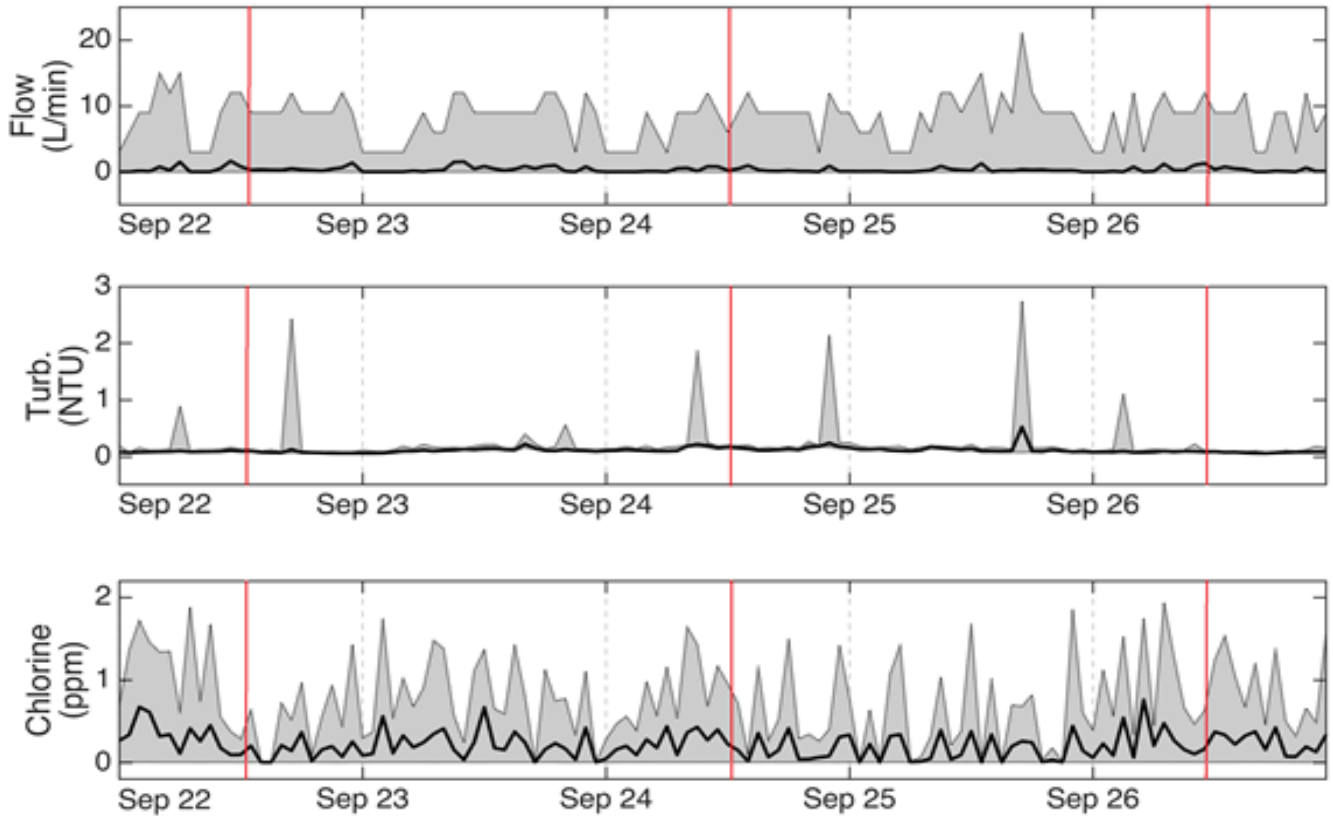


Water quality entering a single building - Different water is delivered to different parts of the plumbing

Year-long study

Water quality at the service line varied by season, time of day, and day of week

No detectable disinfectant residual entered the building
…in summer 25% of the time
…in winter 6% of the time



Shown: 5 day period, 1x/min, 24 hr/day

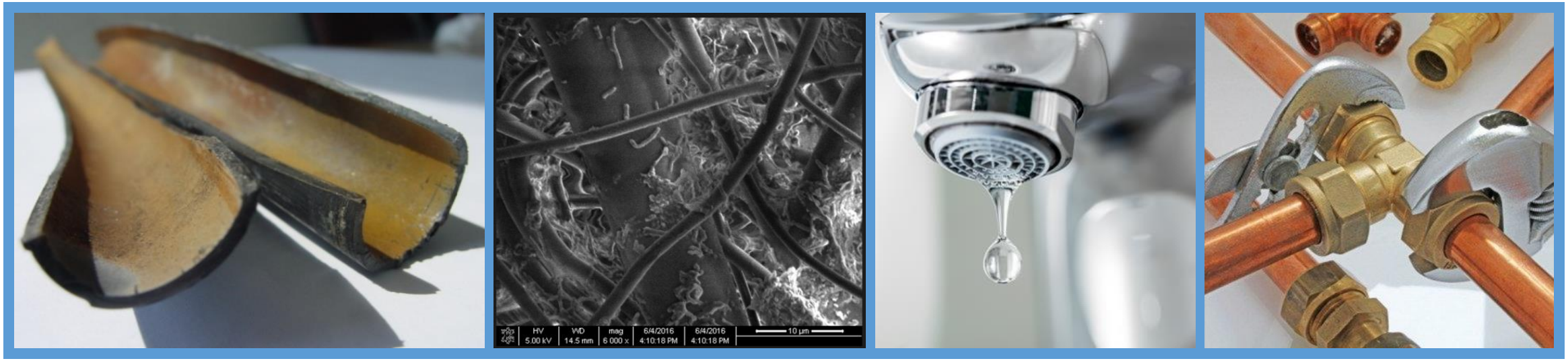
Salehi et al.
Published 2019
https://www.doi.org/10.1016/j.buildenv.2019.106566

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

COVID-19 Pandemic

Building water use *has* changed during the pandemic

Implications of Social Distancing Policies on Drinking Water Infrastructure: An Overview of the Challenges to and Responses of U.S. Utilities during the COVID-19 Pandemic

Lauryn A. Spearing, Nathalie Thelemaque, Jessica A. Kaminsky, Lynn E. Katz, Kerry A. Kinney, Mary Jo Kirisits, Lina Sela, and Kasey M. Faust*

- ✓ 28 water utilities contacted
- ✓ **43% increased RESIDENTIAL** demand
- ✓ **46% decreased COMMERCIAL** demand
- ✓ 21% decreased INDUSTRIAL demand

Sometimes the increase in RESIDENTIAL demand offset the decrease in COMMERCIAL demand

ACS ES&T Water

Published December 2020

https://doi.org/10.1021/acsestwater.0c00229

Some of our COVID-19 response efforts involved testing building water systems

11 buildings across 4 studies

All free chlorine disinfectant

3-5 months of low/no water use

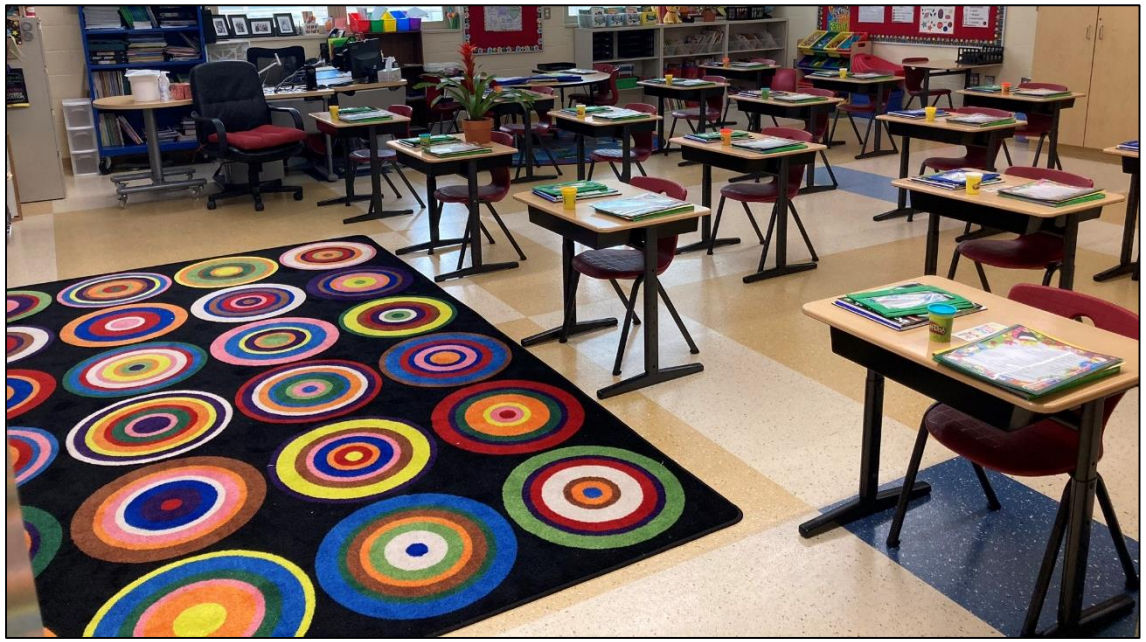
Some served by the same utility

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



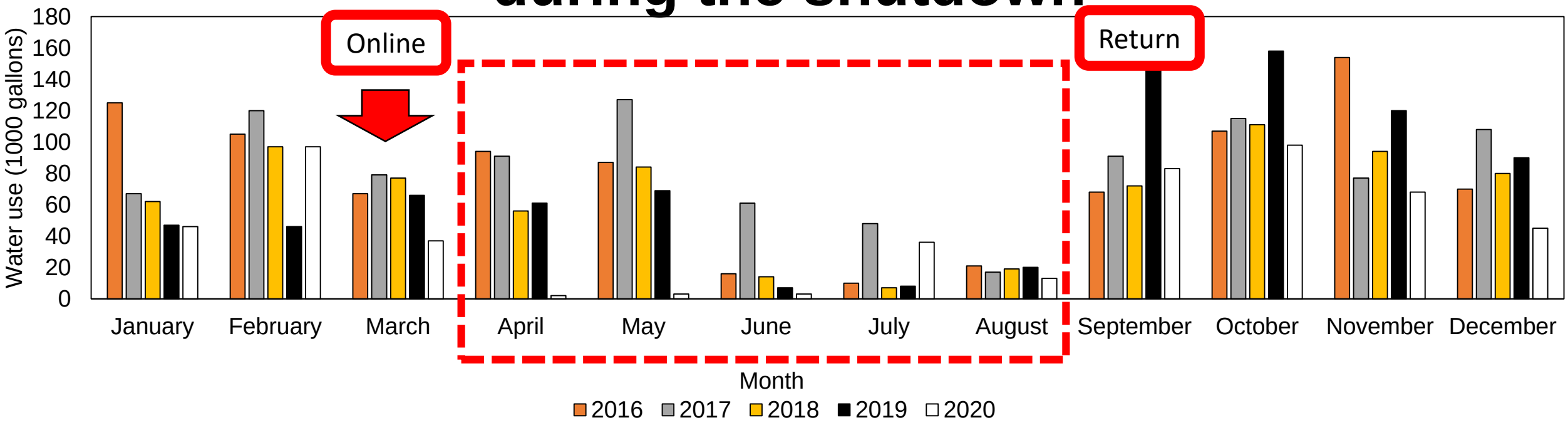
1. Elementary school, Indiana (Ra et al.)
2. Large residential building, Indiana (Angert et al., led by Proctor, Ph.D.)
3. Institutional buildings, Indiana (Ra et al.)
4. Elem/mid/high school, Ohio (Ley et al.)

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

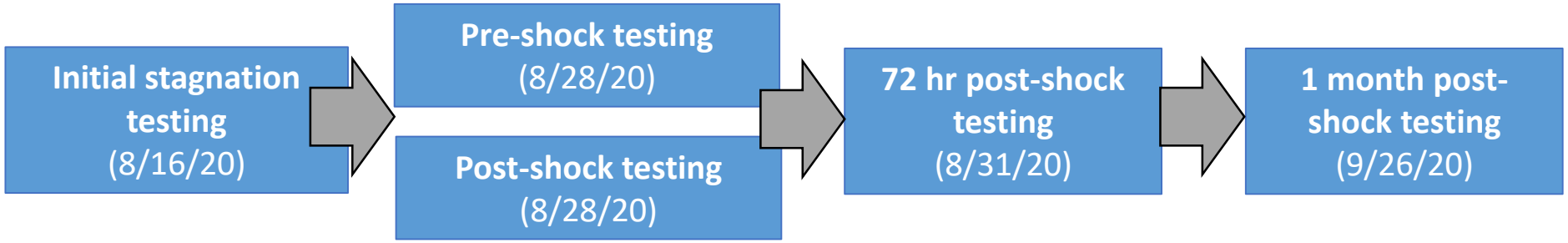
- Utilities across the U.S. saw increased residential demand (+43%) and reductions in commercial (-46%) and industrial (-21%) demands (Faust et al. 2021)
- 1 water utility found that after 6 months of low water use, free chlorine levels were not detectable after the school building had been flushed
- 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)

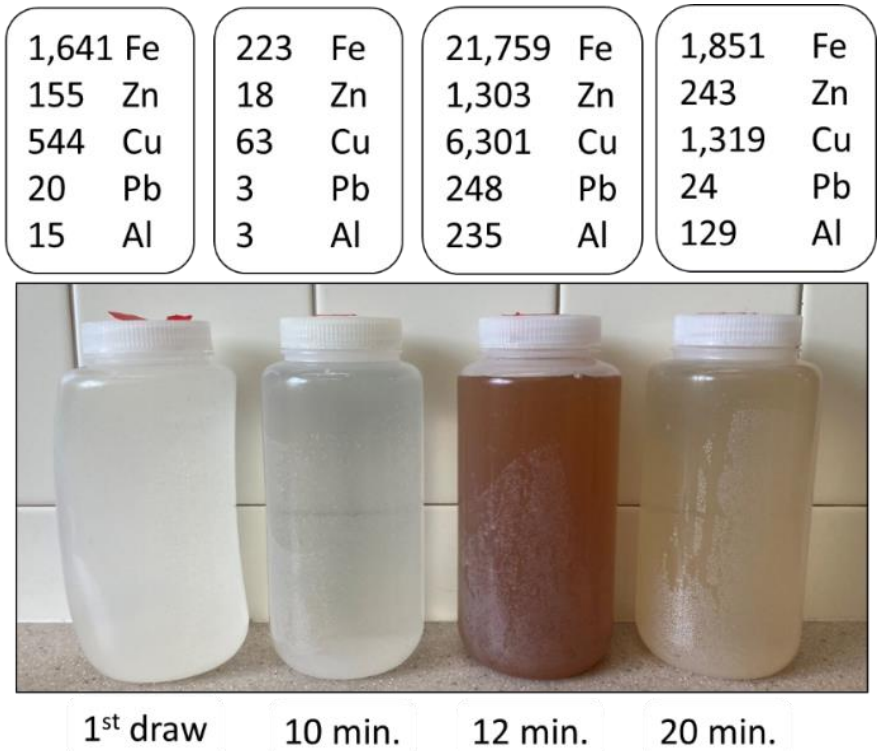
Metal levels were not consistent across the school, were impacted by flushing, and the 8 year old hot water system was excessively corroding

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

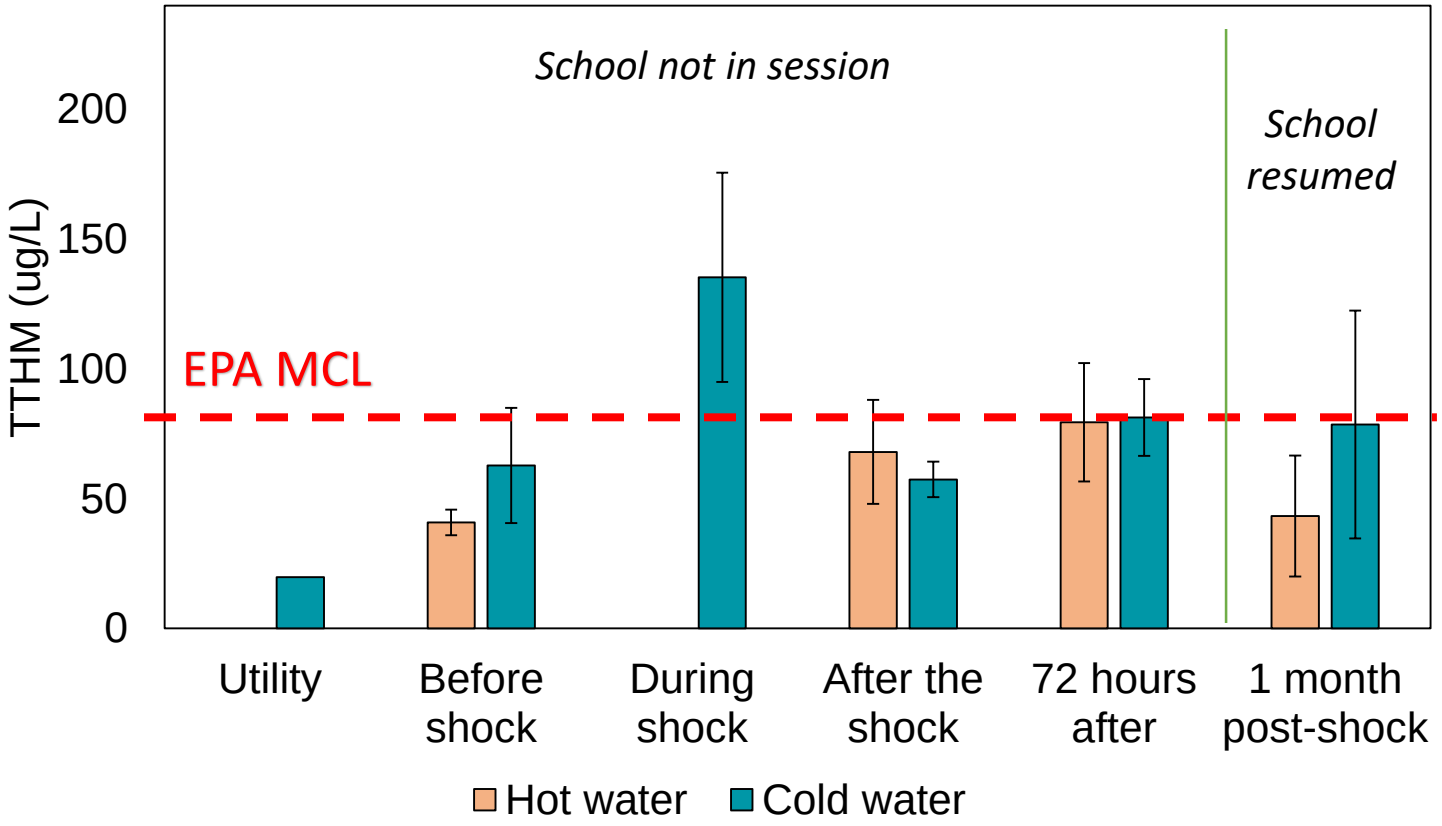
Sample type	Fixture type	*L. Pneumophila* conc., MPN/100 mL	Exceeded suggested *L. pneumophila* Limit, 106 CFU/mL
Initial stagnation	Water fountain	239.6	Yes
	Staff sink (cold)	1,289.6	Yes
	Cafeteria sink (cold)	3.5	No
	Cold faucet (distal end)	1	No
	Cold faucet (central)	1.1	No
Pre-shock chlorination	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

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).

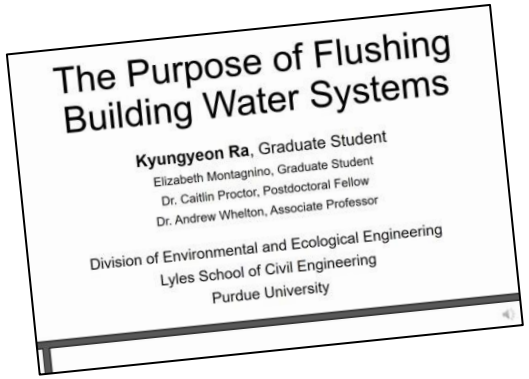
Highest number of exceedances: 72 hours after the shock + flushing, 7 / 15 samples

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

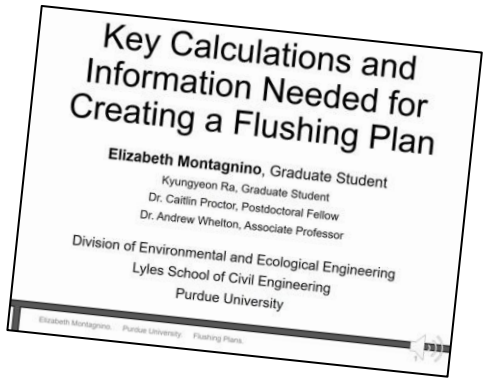
Hypochlorite shock disinfection levels varied 160-340 mg/L+

Ley et al. (In preparation)

An Indiana 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)

State-of-the-knowledge review about water safety impacts of prolonged stagnation

Collaborative effort

Caitlin R. Proctor, Ph.D., Purdue University
William Rhoads, Ph.D., Virginia Tech
Tim Keane, Legionella Risk Management, Inc.
Maryam Salehi, Ph.D., University of Memphis
Kerry Hamilton, Ph.D., Arizona State University
Kelsey J. Pieper, Ph.D., Northeastern University
David R. Cwiertny, Ph.D., University of Iowa
Michele Prévost, Ph.D., Polytechnique Montreal
Andrew J. Whelton, Ph.D., Purdue University

AWWA WATER SCIENCE

Considerations for Large Building Water Quality after Extended Stagnation

Download FREE here:

https://doi.org/10.1002/aws2.1186

PURDUE UNIVERSITY VIRGINIA TECH

LEGIONELLA RISK MANAGEMENT

THE UNIVERSITY OF MEMPHIS

Arizona State University

Northeastern University

THE UNIVERSITY OF IOWA

POLYTECHNIQUE MONTRÉAL

Disasters

Public health support due to plumbing contamination is important

Maximum Benzene Level	Event/Location	Population Affected	System Name	Year
6	Echo Mountain Fire/Oregon	120	Whispering Pines Mobile Home Park	2020
11	Echo Mountain Fire/Oregon	362	Hiland WC - Echo Mountain	2020
1	Echo Mountain Fire/Oregon	760	Panther Creek Water District	2020
76	Almeda Fire/Oregon	6,850	City of Talent	2020
45	Lionshead Fire/Oregon	205	Detroit Water System	2020
2	CZU Lightning Complex Fire/California	1,650	Big Basin Water Company	2020
42	CZU Lightning Complex Fire/California	21,145	San Lorenzo Water District	2020
2,217	Camp Fire/California	26,032	Paradise Irrigation District	2018
38	Camp Fire/California	924	Del Oro Water Co.-Magalia	2018
8	Camp Fire/California	1,106	Del Oro Water Co.-Lime Saddle	2018
530	Camp Fire/California	11,324	Del Oro Water Co.-Paradise Pines	2018
40,000	Tubbs Fire/California	175,000	City of Santa Rosa	2017

Hazardous waste levels of benzene. More VOCs and SVOCs above safe limits.

Sources: Smoke and plastics thermal degradation

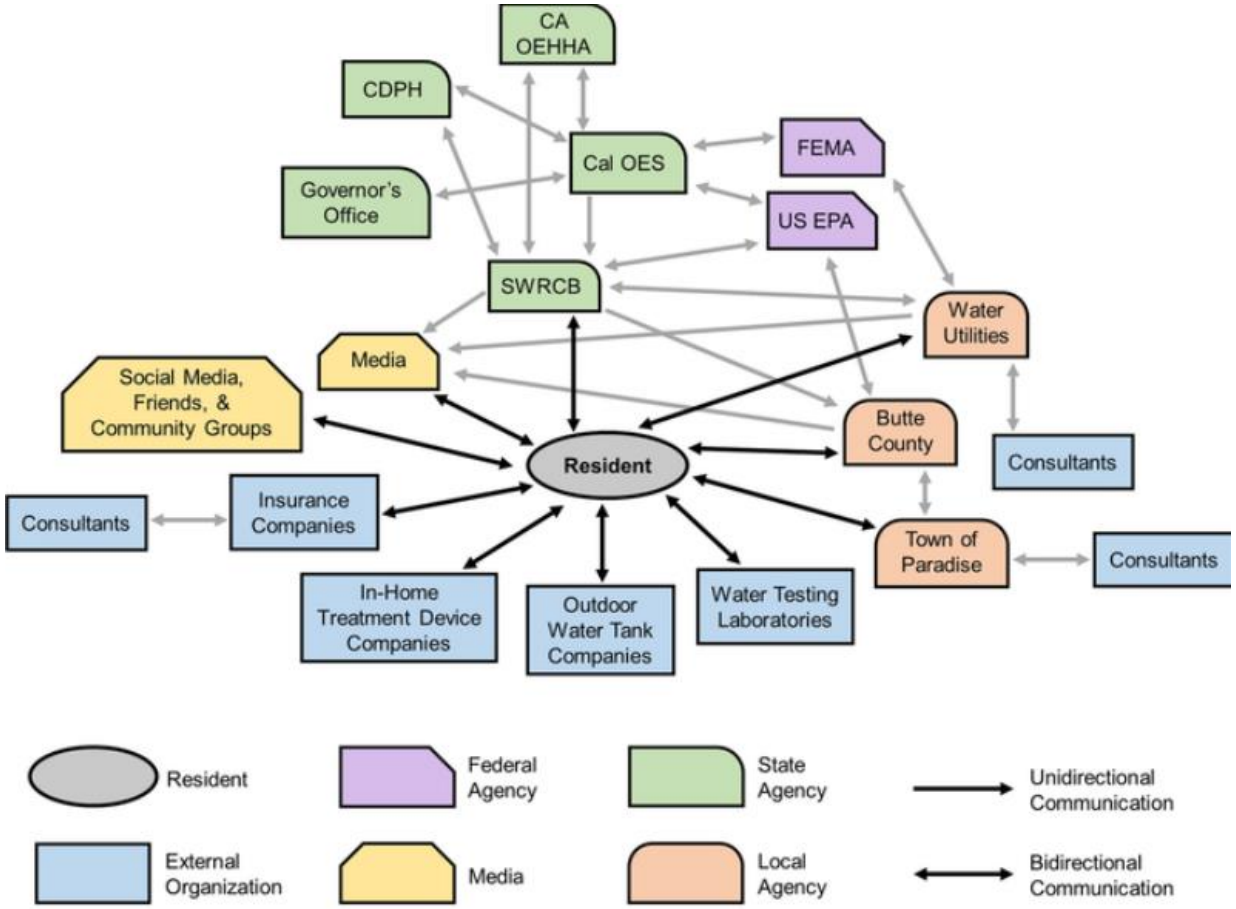
Some plastics uptake chemicals and leach them back out making clean water unsafe

Water safety attitudes, risk perception, experiences, and education for households impacted by the 2018 Camp Fire

Natural Hazards, Published May 2021 https://doi.org/10.1007/s11069-021-04714-9

Critical Public Health Issues

1) Water use restrictions,
2) **Plumbing** sampling and testing,
3) **Plumbing** decontamination methods and validation,
4) Water tank selection and maintenance,
5) In-home treatment device selection and maintenance, and
6) **Plumbing** design and material selection for property repairs and new construction.

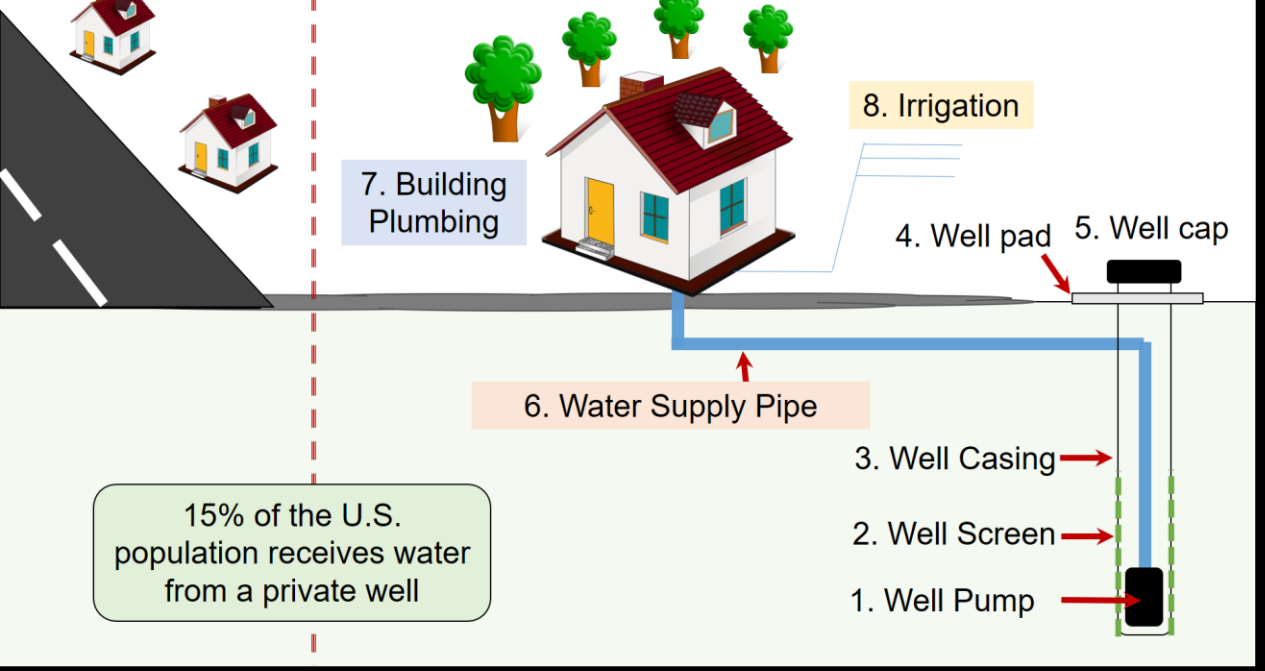


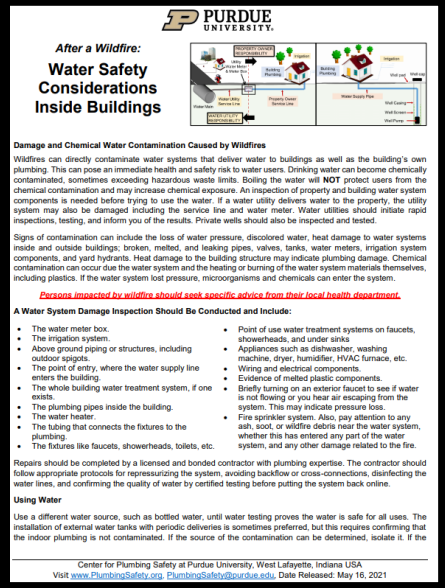
Q: Should in-home POU water filtration devices be used to treat wildfire contaminated drinking water?

Water Collected and Analyze	Preliminary Results, ppb			
	Benzene	Toluene	Ethyl Benzene	Xylene
Entering the filter	713	911	87	212
Exiting the filter				
1 L	20	15	3	4
1.5 L	33	30	5	9
2 L	47	46	6	11
3 L	64	75	10	21
3.5 L	62	75	10	20
4 L	24	22	4	5
4.5 L	87	98	11	21
5 L	37	37	5	8

The devices are NOT designed for this. The range of contamination must be known + testing.

In 2019, CA OEHHA concluded that short-term 26 ppb benzene exposure would prompt an increased risk of blood effects in children such as a decrease in lymphocytes and white blood cells; Benzene has a 5 ppb Federal MCL, 1 ppb CA MCL





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After a Wildfire:

Water Safety Considerations Inside Buildings

Damage and Chemical Water Contamination Caused by Wildfires

Wildfires can directly contaminate water systems that deliver water to buildings as well as the building's own plumbing. This can pose an immediate health and safety risk to water users. Drinking water can become chemically contaminated, sometimes exceeding hazardous waste limits. Boiling the water will **NOT** protect users from the chemical contamination and may increase chemical exposure. An inspection of property and building water system components is needed before trying to use the water. If a water utility delivers water to the property, the utility system may also be damaged including the service line and water meter. Water utilities should initiate rapid inspections, testing, and inform you of the results. Private wells should also be inspected and tested.

Signs of contamination can include the loss of water pressure, discolored water, heat damage to water systems inside and outside buildings; broken, melted, and leaking pipes, valves, tanks, water meters, irrigation system components, and yard hydrants. Heat damage to the building structure may indicate plumbing damage. Chemical contamination can occur due the water system and the heating or burning of the water system materials themselves, including plastics. If the water system lost pressure, microorganisms and chemicals can enter the system.

Persons impacted by wildfire should seek specific advice from their local health department.

A Water System Damage Inspection Should Be Conducted and Include:

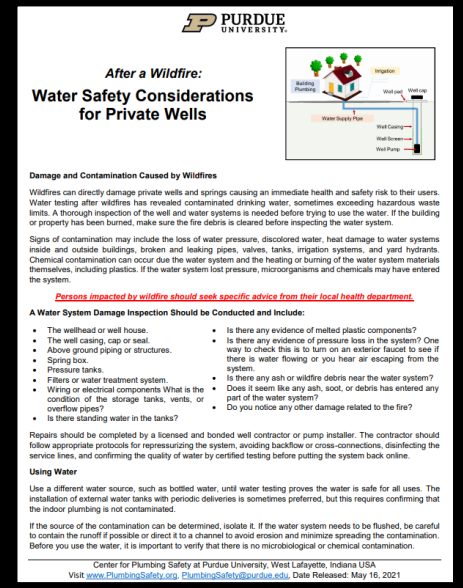
- The water meter box.
- The irrigation system.
- Above ground piping or structures, including outdoor spigots.
- The point of entry, where the water supply line enters the building.
- The whole building water treatment system, if one exists.
- The plumbing pipes inside the building.
- The water heater.
- The tubing that connects the fixtures to the plumbing.
- The fixtures like faucets, showerheads, toilets, etc.
- Point of use water treatment systems on faucets, showerheads, and under sinks
- Appliances such as dishwasher, washing machine, dryer, humidifier, HVAC furnace, etc.
- Wiring and electrical components.
- Evidence of melted plastic components.
- Briefly turning on an exterior faucet to see if water is not flowing or you hear air escaping from the system. This may indicate pressure loss.
- Fire sprinkler system. Also, pay attention to any ash, soot, or wildfire debris near the water system, whether this has entered any part of the water system, and any other damage related to the fire.

Repairs should be completed by a licensed and bonded contractor with plumbing expertise. The contractor should follow appropriate protocols for repressurizing the system, avoiding backflow or cross-connections, disinfecting the water lines, and confirming the quality of water by certified testing before putting the system back online.

Using Water

Use a different water source, such as bottled water, until water testing proves the water is safe for all uses. The installation of external water tanks with periodic deliveries is sometimes preferred, but this requires confirming that the indoor plumbing is not contaminated. If the source of the contamination can be determined, isolate it. If the

Center for Plumbing Safety at Purdue University, West Lafayette, Indiana USA
Visit www.PlumbingSafety.org, PlumbingSafety@purdue.edu, Date Released: May 16, 2021



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After a Wildfire:

Water Safety Considerations for Private Wells

Damage and Contamination Caused by Wildfires

Wildfires can directly damage private wells and springs causing an immediate health and safety risk to their users. Water testing after wildfires has revealed contaminated drinking water, sometimes exceeding hazardous waste limits. A thorough inspection of the well and water systems is needed before trying to use the water. If the building or property has been burned, make sure the fire debris is cleared before inspecting the water system.

Signs of contamination may include the loss of water pressure, discolored water, heat damage to water systems inside and outside buildings, broken and leaking pipes, valves, tanks, irrigation systems, and yard hydrants. Chemical contamination can occur due the water system and the heating or burning of the water system materials themselves, including plastics. If the water system lost pressure, microorganisms and chemicals may have entered the system.

Persons impacted by wildfire should seek specific advice from their local health department.

A Water System Damage Inspection Should be Conducted and Include:

- The wellhead or well house.
- The well casing, cap or seal.
- Above ground piping or structures.
- Spring box.
- Pressure tanks.
- Filters or water treatment system.
- Wiring or electrical components What is the condition of the storage tanks, vents, or overflow pipes?
- Is there standing water in the tanks?
- Is there any evidence of melted plastic components?
- Is there any evidence of pressure loss in the system? One way to check this is to turn on an exterior faucet to see if there is water flowing or you hear air escaping from the system.
- Is there any ash or wildfire debris near the water system?
- Does it seem like any ash, soot, or debris has entered any part of the water system?
- Do you notice any other damage related to the fire?

Repairs should be completed by a licensed and bonded well contractor or pump installer. The contractor should follow appropriate protocols for repressurizing the system, avoiding backflow or cross-connections, disinfecting the service lines, and confirming the quality of water by certified testing before putting the system back online.

Using Water

Use a different water source, such as bottled water, until water testing proves the water is safe for all uses. The installation of external water tanks with periodic deliveries is sometimes preferred, but this requires confirming that the indoor plumbing is not contaminated.

If the source of the contamination can be determined, isolate it. If the water system needs to be flushed, be careful to contain the runoff if possible or direct it to a channel to avoid erosion and minimize spreading the contamination. Before you use the water, it is important to verify that there is no microbiological or chemical contamination.

Center for Plumbing Safety at Purdue University, West Lafayette, Indiana USA
Visit www.PlumbingSafety.org, PlumbingSafety@purdue.edu, Date Released: May 16, 2021

Download this 2 page inspection and water testing guidance for private wells and building water systems affected by wildfires

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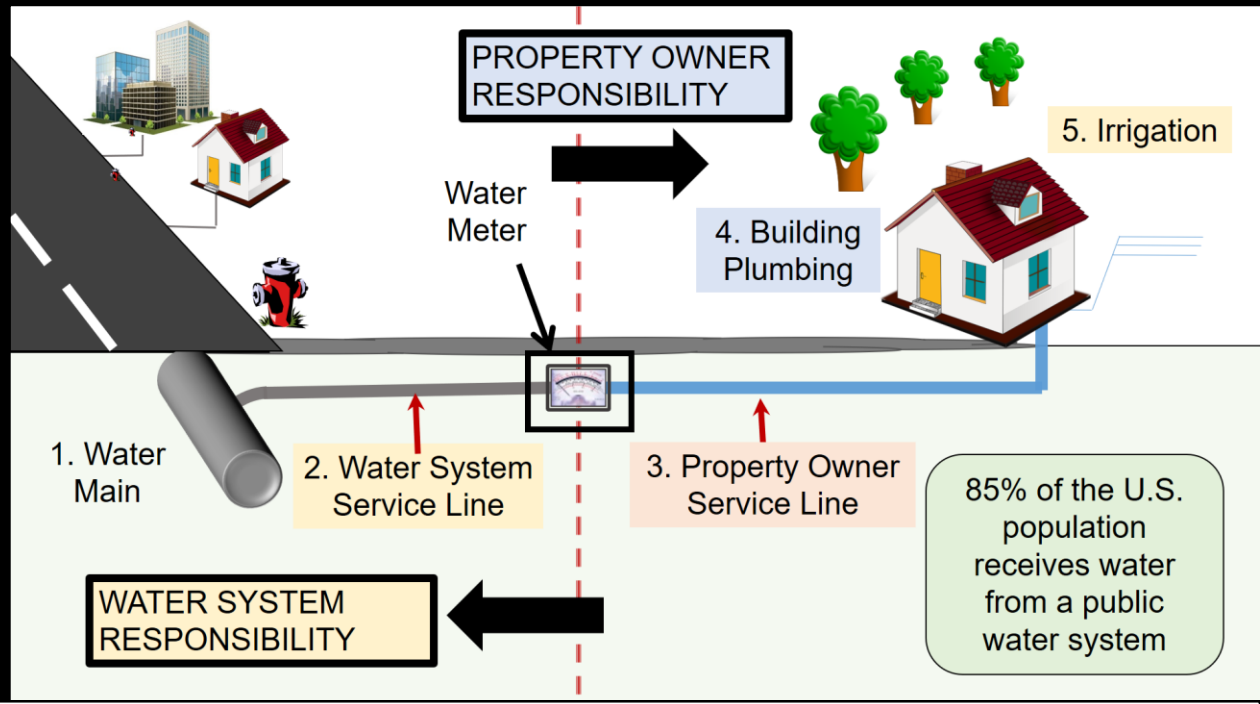

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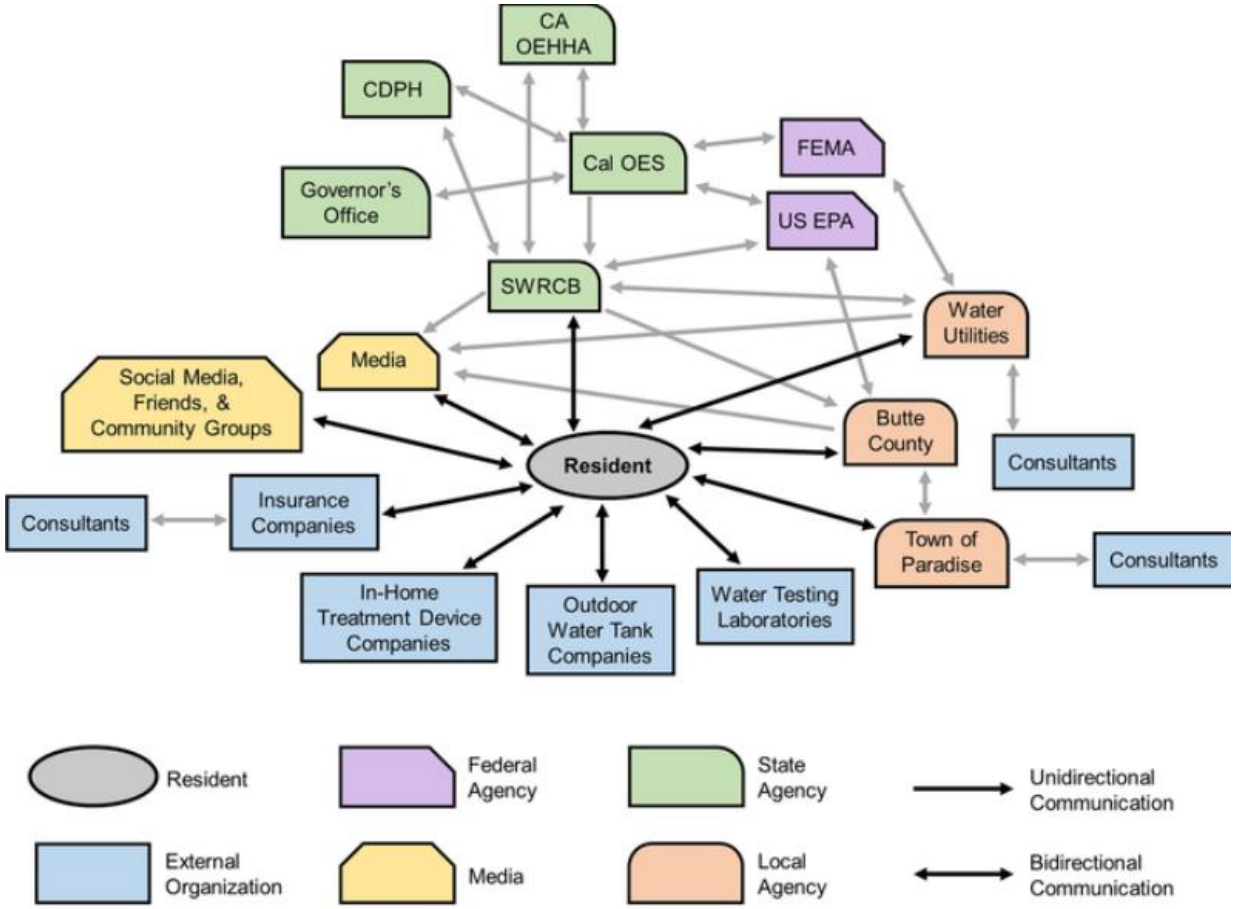
Water safety attitudes, risk perception, experiences, and education for households impacted by the 2018 Camp Fire

Natural Hazards, Published May 2021 https://doi.org/10.1007/s11069-021-04714-9

Critical Public Health Issues

1) Water use restrictions,
2) **Plumbing** sampling and testing,
3) **Plumbing** decontamination methods and validation,
4) Water tank selection and maintenance,
5) In-home treatment device selection and maintenance, and
6) **Plumbing** design and material selection for property repairs and new construction.

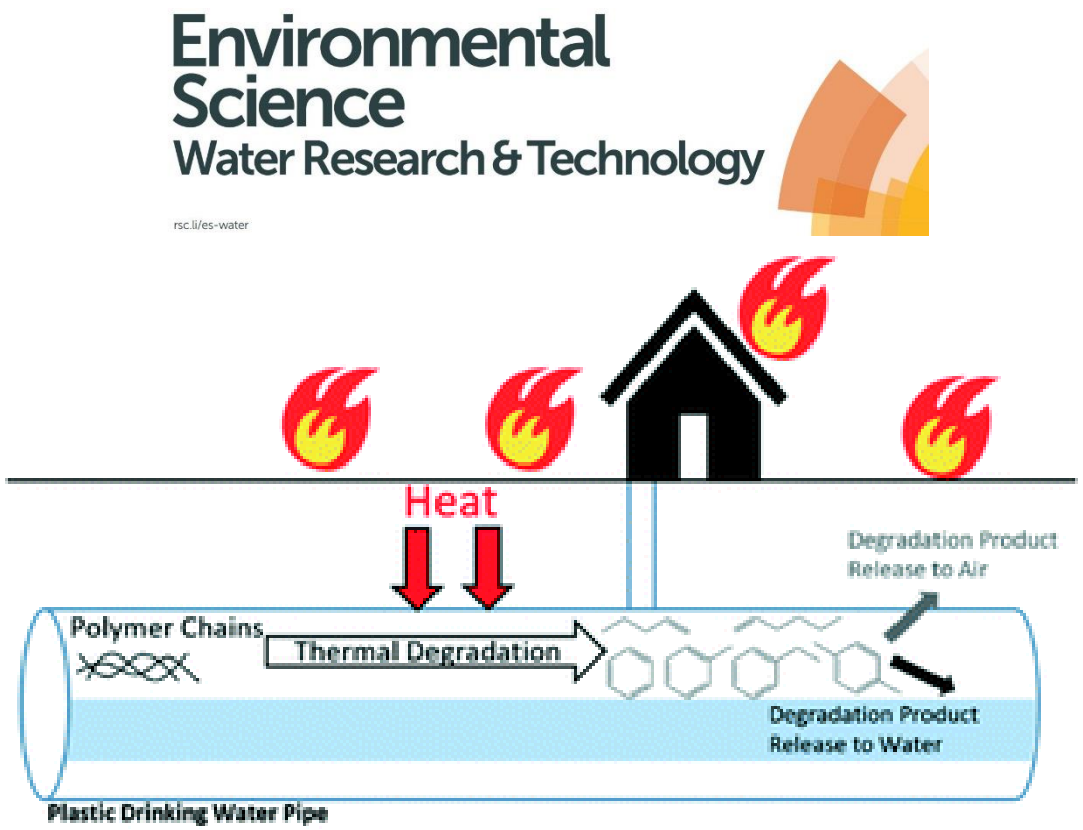


Damage

90%+ of their 172 mile water distribution system was depressurized for hours to weeks

100s+ of leaks

December 2020 Study: Thermally damaged plastic pipes can be a source of water contamination



Drinking water contamination from the thermal degradation of plastics: implications for wildfire and structure fire response

Download FREE here:

https://doi.org/10.1039/D0EW00836B

Heating new HDPE, PEX, PVC, CPVC, and PP pipes < Tdeg generated VOCs and SVOCs

Benzene was generated by all pipes except PP

Once plastic cooled, chemicals leached into water

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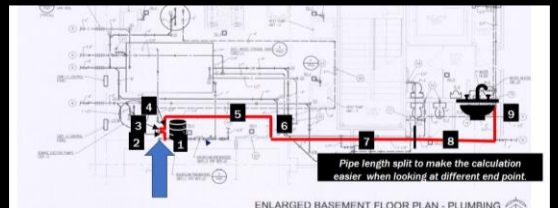
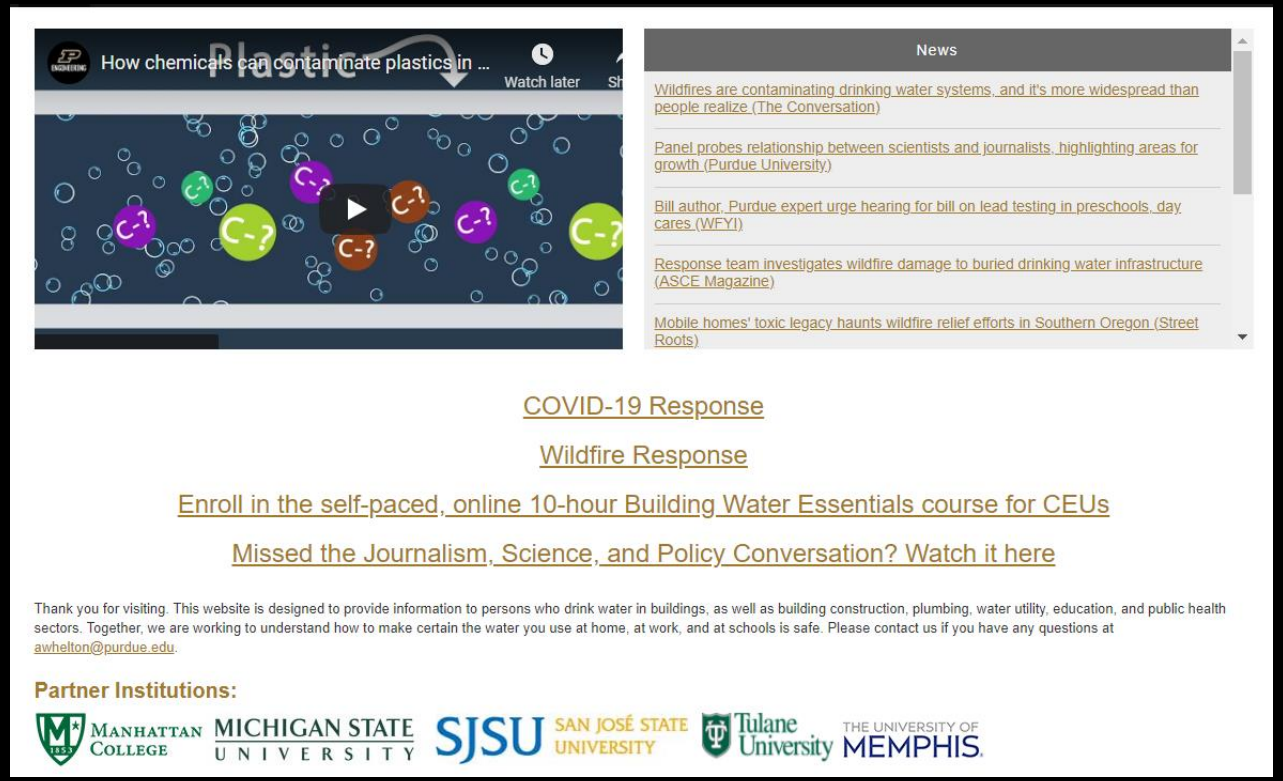


If interested e-mail awhelton@purdue.edu

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

Thank you.

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



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https://engineering.purdue.edu/online/certifications/building-water-essentials

www.PlumbingSafety.org

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