New Developments in Building Water Safety

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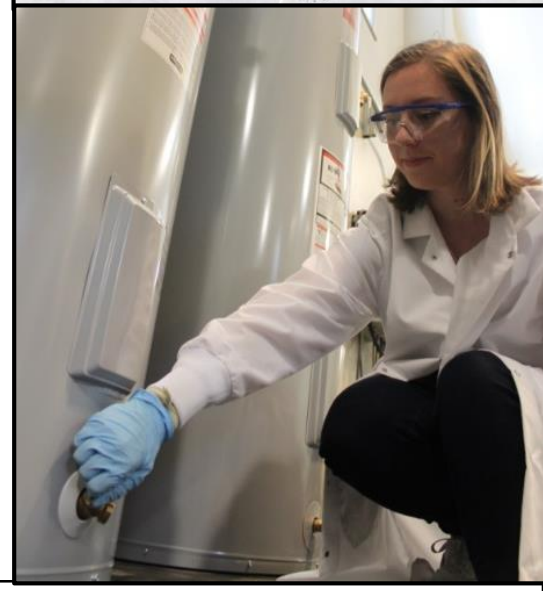
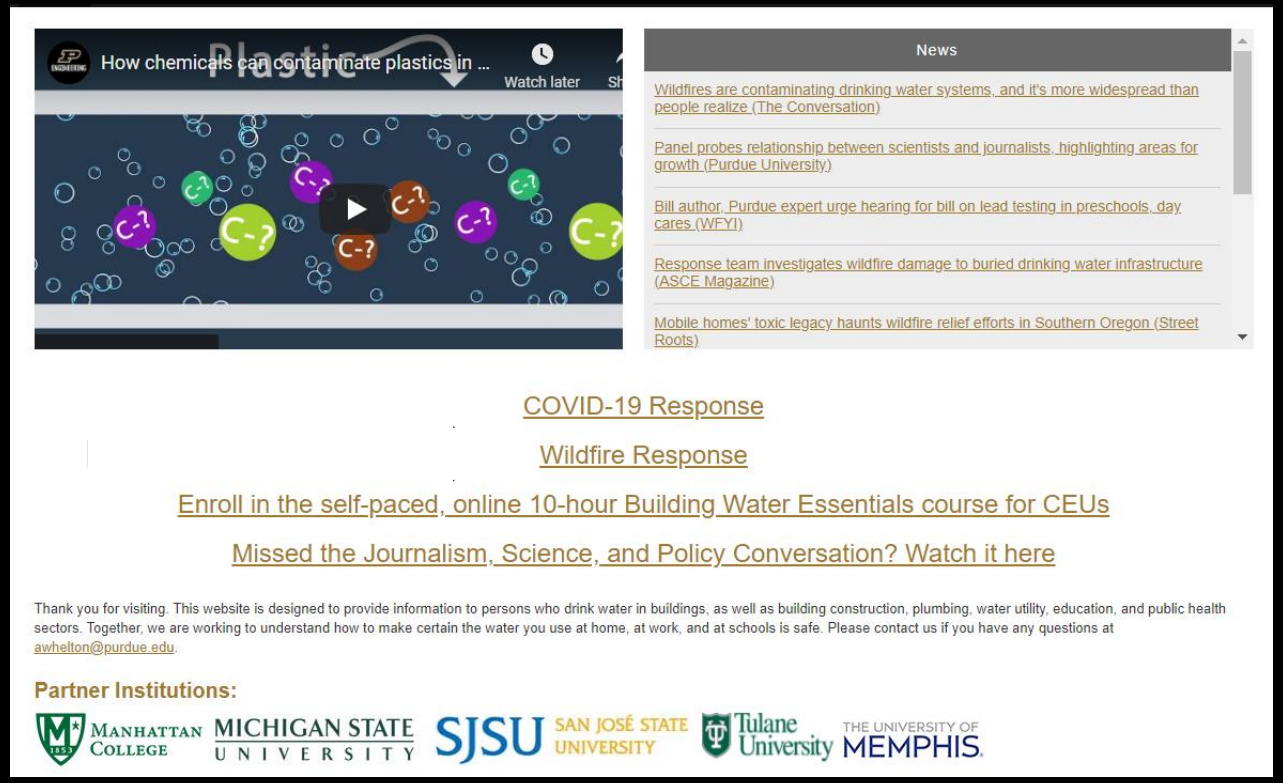
www.PlumbingSafety.org



A special thanks to the many people who made this possible

The Center for Plumbing Safety at Purdue

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



- ✓ 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

www.PlumbingSafety.org

System Basics

Building water system public health **risks**

Exposure Routes of Concern: Ingestion, Dermal, Inhalation

Routine Operations

Disinfectant residual may not be replenished

Heavy metals can leach (Cu, Mn, Ni, Pb, Zn..)

Organics can leach/form (VOCs, SVOCs, DBPs)

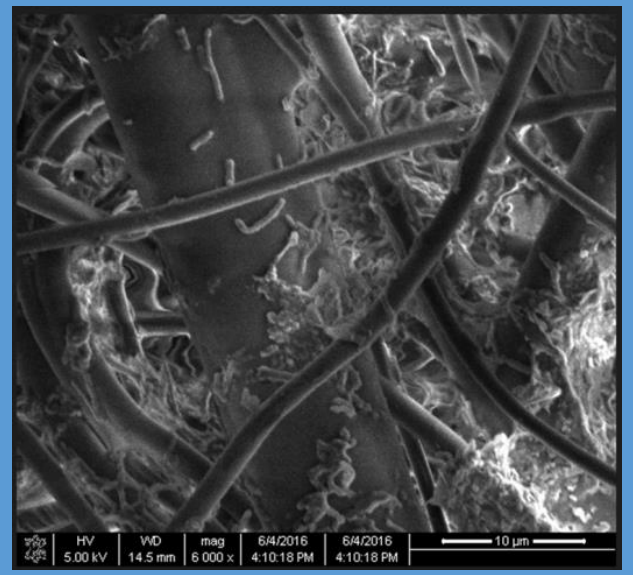
Scale can destabilize and suspend

Harmful organisms can grow (e.g., *L. pneumophila, MAC, P. aeruginosa* …)

Accident and Post-Disasters

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

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



Completed: 2017-2021

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

Funded by: United States Environmental Protection Agency

Purdue University · Michigan State University · SJSU San José State University · Manhattan College · Tulane University · The University of Memphis

1. **Improve the public's understanding of decreased flow** and establish a range of theoretical plumbing flow demands
2. **Elucidate the factors and their interactions that affect drinking water quality** through fate and transport simulation models for residential and commercial buildings
3. **Create a risk-based decision support tool** to help guide decision makers through the identification of plumbing characteristics, operations and maintenance practices that minimize health risks to building inhabitants.

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Some highlights

Education	>100 presentations to share knowledge Video and print materials publicly available (www.PlumbingSafety.org) 100,000(s)+ people reached Assisted all major sectors (plumbing, construction, public health, policy) Commercial and residential building sectors helped
Engagement	Direct support to building owners, designers, manufacturers, and consultants Supported US government agencies identify research priorities Helped develop and shape industry best practices Provided scientific opinions to agencies Direct support to communities following water contamination disasters LCR Federal Register comment Developed and provided example flushing plans
Discovery	Peer-review: 22 Published + 8 in Review + >10 in Development Industry innovation research priority identification Discovered chemical and microbiological water safety issues in buildings Explored fundamental processes that control building water safety Identified and tested building water system mitigation methods *Created a 1st of its kind Plumbing **D**ecision **S**upport **T**ool (DST)*

The Most Monitored Home in America

West Lafayette, Indiana
Less than 100 yards from Purdue
3 Bedroom, 1.5 baths
Water saving fixtures
Trunk-and-Branch design
PEX piping
Renovated in 2014

Thermocouples throughout piping, 1x /sec
Indoor air temperature, 1x /sec
Flowrates at every fixture, 1x /sec
Energy use per device, 1x /sec

www.ReNEWWHouse.com

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

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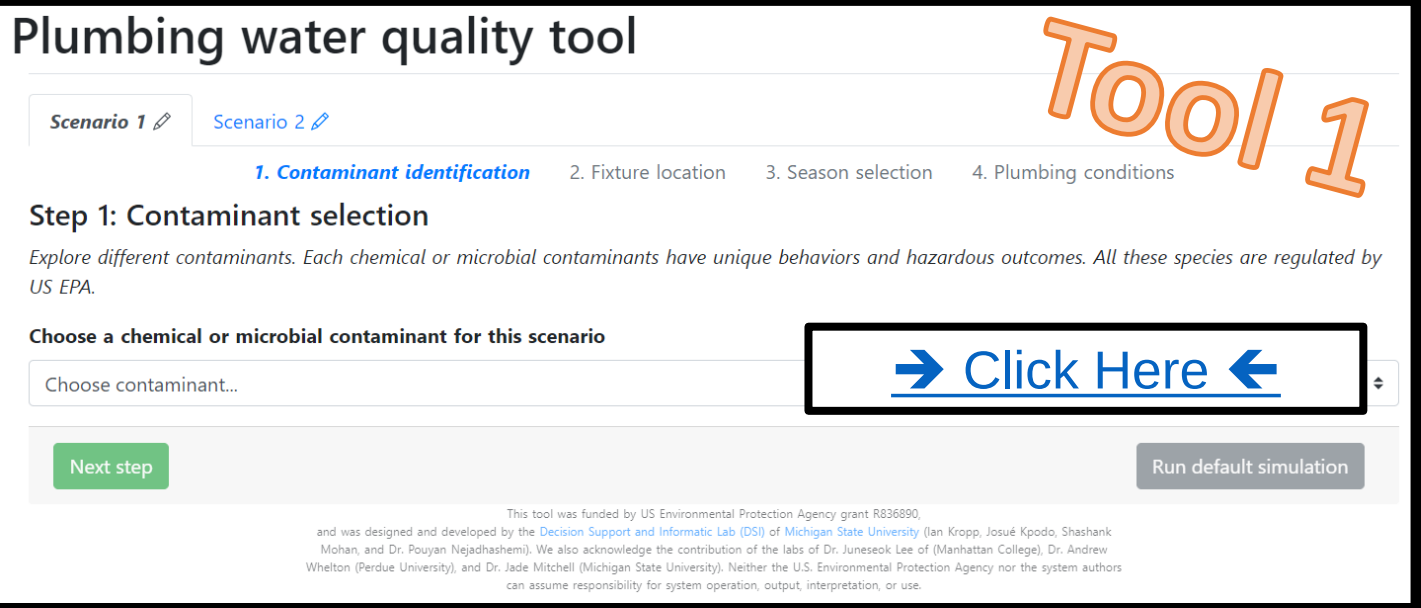

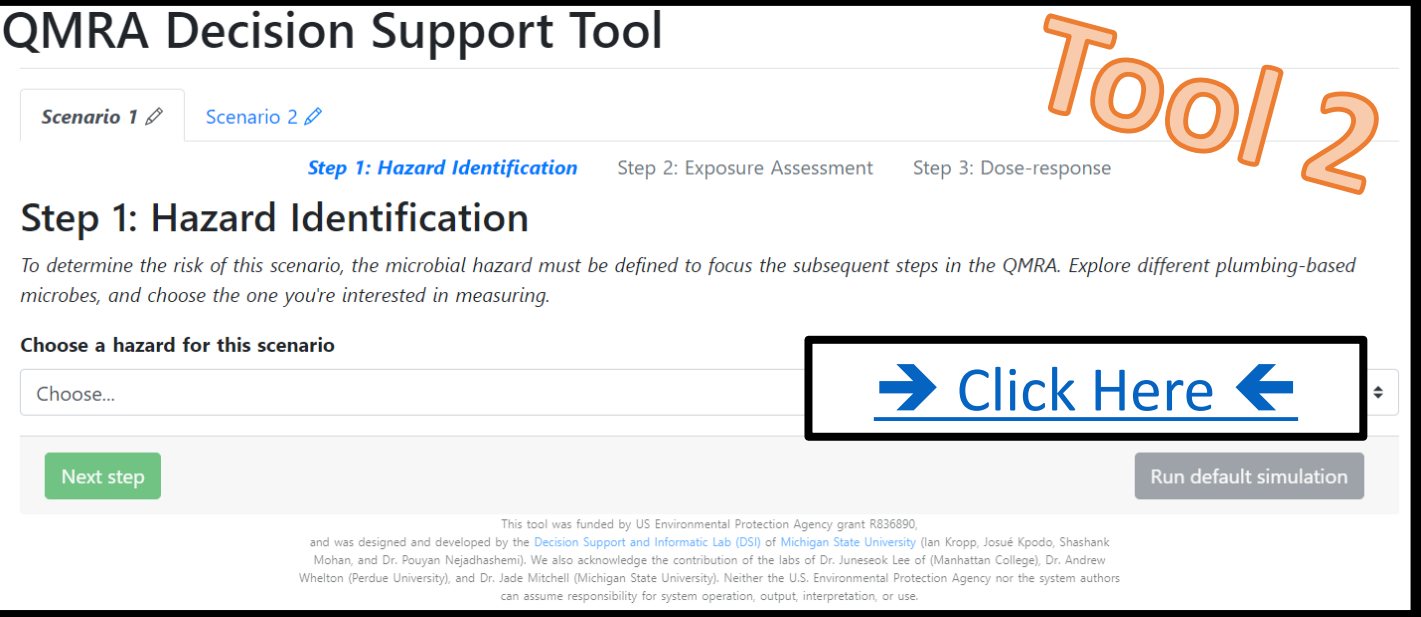

Online and FREE Building Water Quality Tools Now Available

Usefulness

Multiple contaminants: *Legionella spp.*, HPC, Cl_2, Cu, Fe, Pb, NO_3^-, TTHM

Compare exposure scenarios

Examine design impacts

Examine water use impacts

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Exact Slide from Andrew Whelton's
November 8, 2019 PMI annual meeting presentation

Disasters Expose a Critical Lack of Plumbing Knowledge:

Federal, State, County agencies, and in Households

What's Needed

Basic understanding of plumbing design, use, materials, and aging

What products are in plumbing

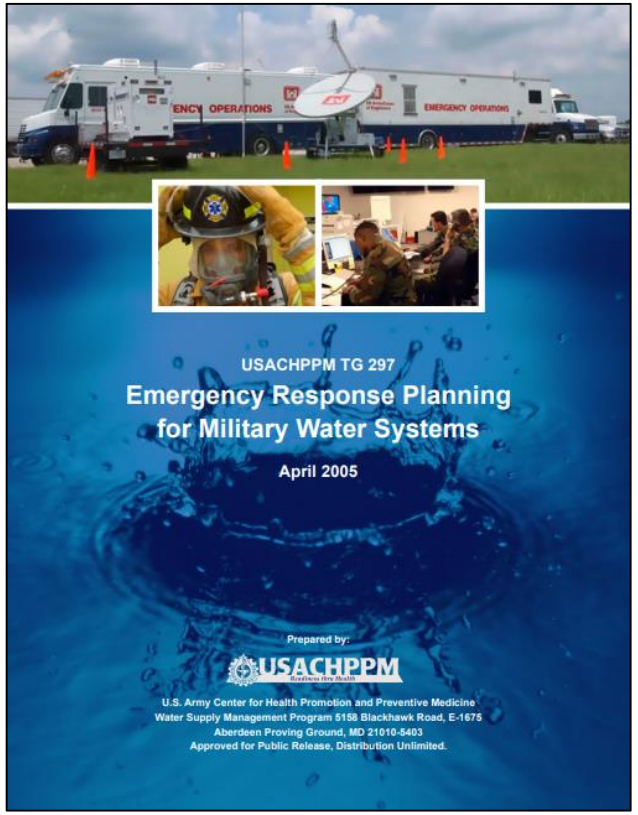
How to use damaged plumbing post-disaster

How to test plumbing post-disaster

How to clean plumbing post-disaster

https://doi.org/10.1007/s11069-021-04714-9

Looking back:

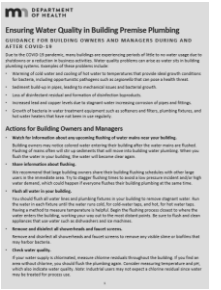


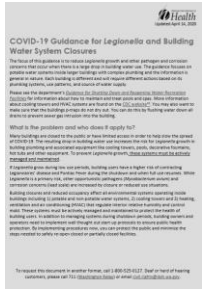
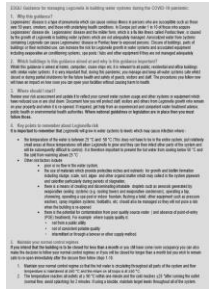
LESSONS LEARNED
from drinking water disaster and terrorism exercises

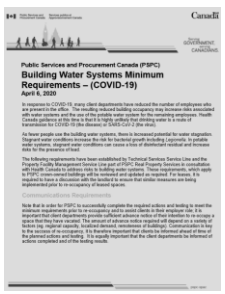
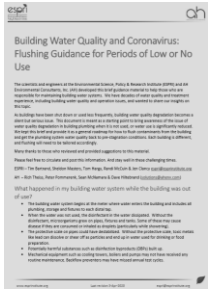
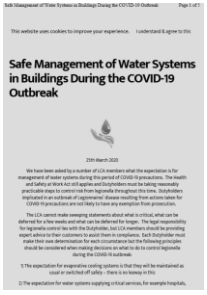
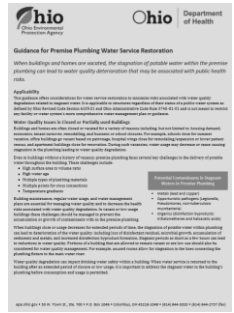
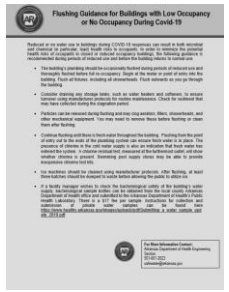
JournalAWWA

Whelton et al. 2006.
98 (8), 63-73.

16+ years ago with the US Army I was working on contamination/decontamination issues associated with water infrastructure systems

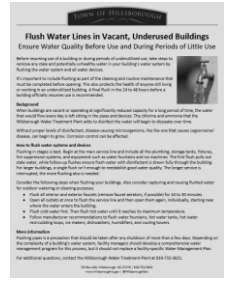
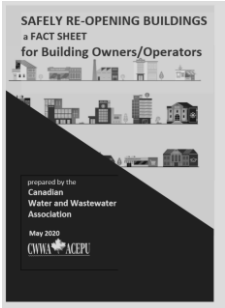


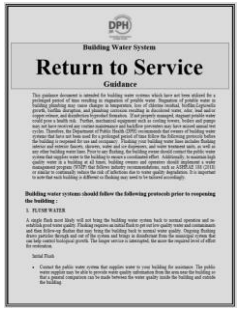
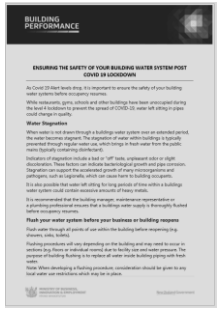






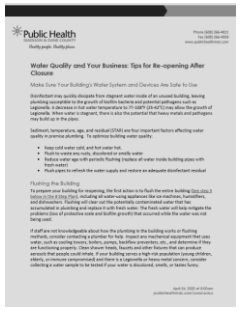
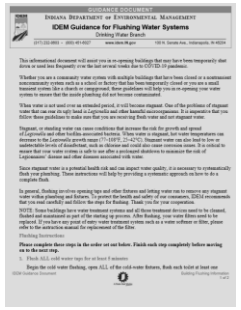
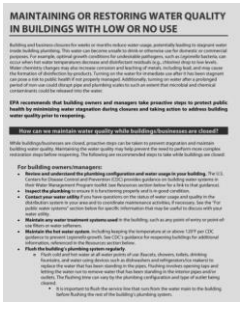
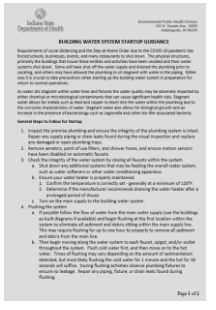
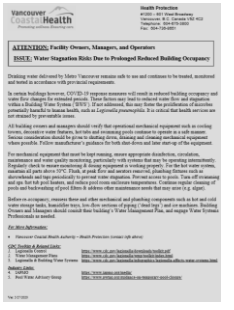
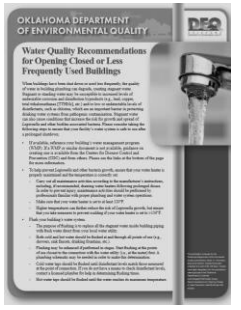
COVID-19 Pandemic Response

March to June 2020, more than ***45+*** guidance documents telling building owners what they could do to prevent and deal with stagnation situations.


Many differed quite dramatically. Some lacked key info (safety, devices, sensitive population, etc.).

YES!

Building Water Use 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*

TEXAS
The University of Texas at Austin

- ✓ 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

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

U.S. National Science Foundation RAPID Award 2027049

Shutdowns and Consequences - Extreme Plumbing Stagnation and Recommissioning

1. Support to the plumbing and public health sectors on building water safety guidance and decisions, ***ongoing***
2. Building water safety review due to prolonged stagnation with experts from 7 private and public sector organizations, ***complete***
3. Field testing to determine how impacted building water safety is in actual large buildings, ***complete***
4. Bench-/pilot-scale testing to determine how to fully recover contaminated building water system devices and equipment, ***ongoing***
5. Help transform public awareness, ***complete***

Helped..

SAFE WATER ENGINEERING

2020: 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

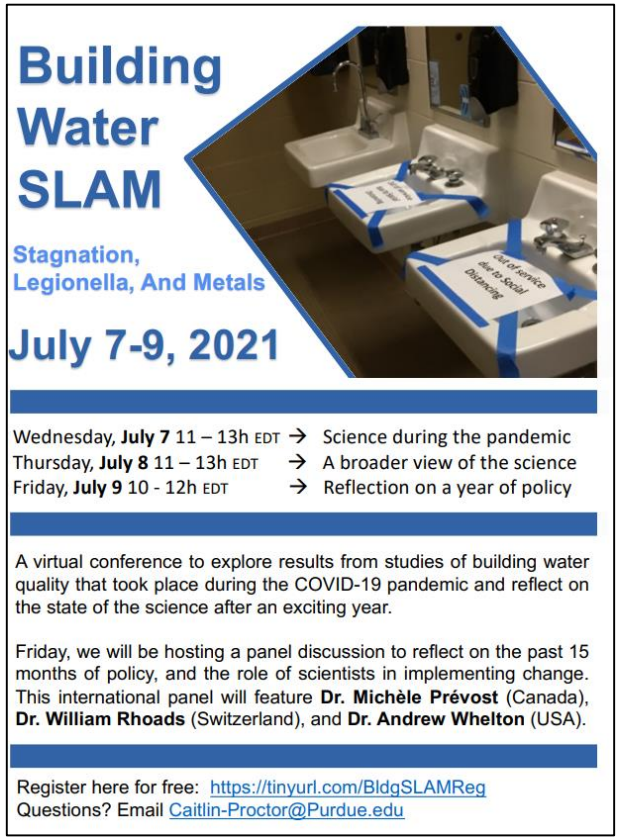
PURDUE UNIVERSITY VIRGINIA TECH

LEGIONELLA RISK MANAGEMENT THE UNIVERSITY OF MEMPHIS ASU Arizona State University Northeastern University THE UNIVERSITY OF IOWA POLYTECHNIQUE MONTRÉAL

U.S. National Science Foundation EAGER Award 2039498

Initiating a Transformative Building Water System Research Collaborative in Response to the COVID-19 Pandemic

➔Click Here←



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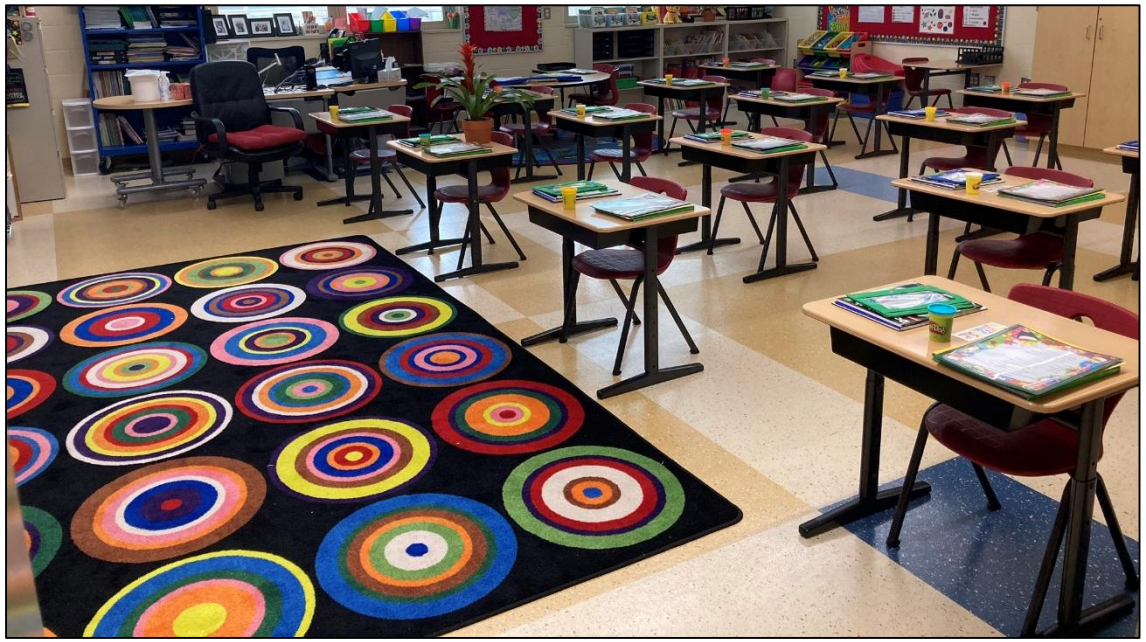
Some of our COVID-19 response efforts



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

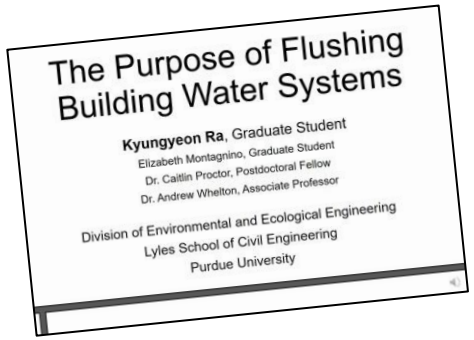
Not all had as-built drawings

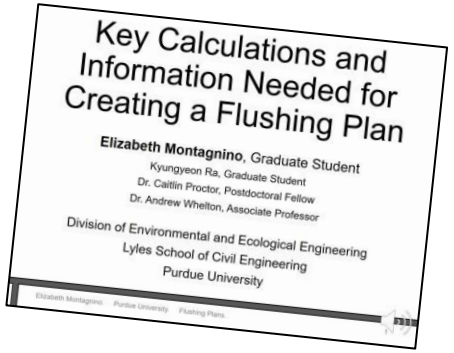
1. Elementary school, Indiana (Ra et al.)
2. Large residential building, Indiana (Angert et al., led by Proctor, Ph.D.)
3. Institutional buildings, Indiana (Ra et al.)
4. Elem/mid/high school, Ohio (Ley et al.)

Some of Our Discoveries

YouTube

Plumbing Safety Channel





Water management programs basically nonexistent at daycares, schools, colleges, and universities

Metal (**Cu, Pb, Ni, Zn**) health-based limit exceedances. Don't just look at water fountains.

Legionella pneumophila detected in 3 of 4 studies

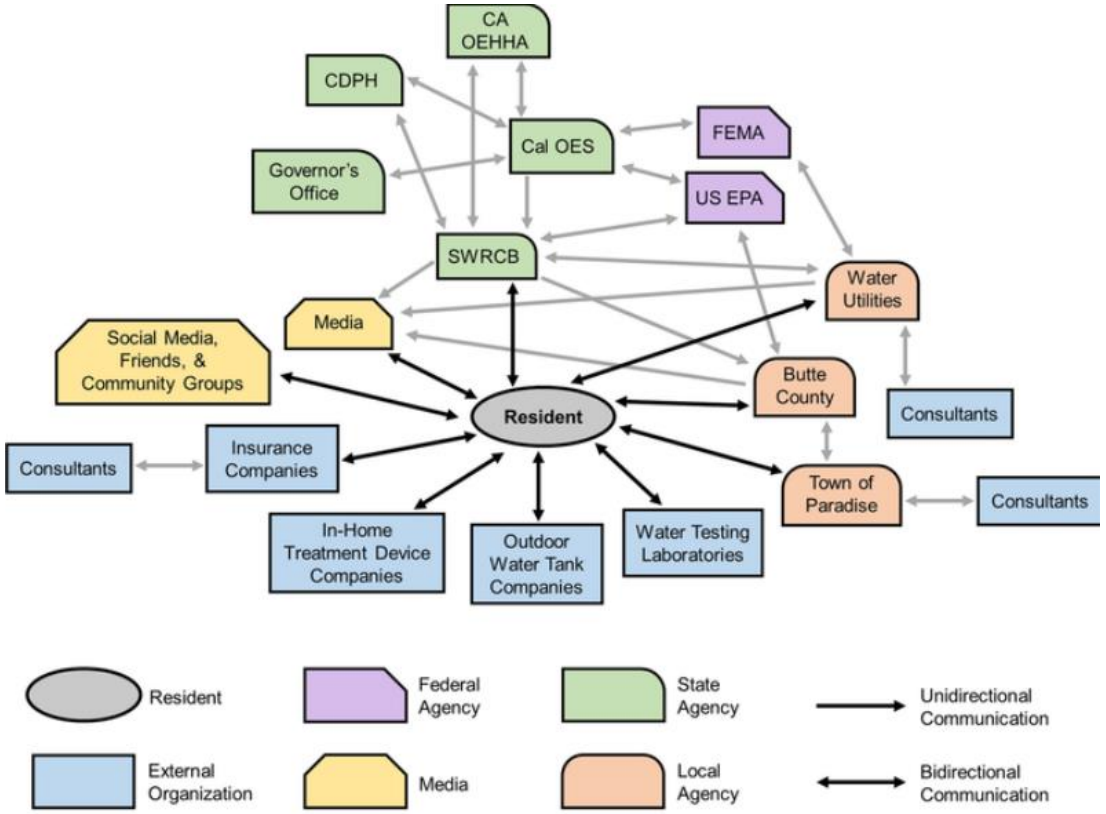
- 2 buildings where flushing applied, no legionella detected after flushing, 2 weeks later low levels (<10 MPN/100 mL)
- Highest levels found in cold water *not* hot water. Water fountain hot spots.

Super chlorination levels throughout building differed (est. 160-340 mg/L+ for 3 hours). Likely due to ineffective mixing, reactions, and/or decay

Much more found…..

Infrastructure Contamination and Decontamination

Science, Technology, Policy and Impact



Heat and Fire Damage to Plastic Infrastructure Materials

Recognize Limitations

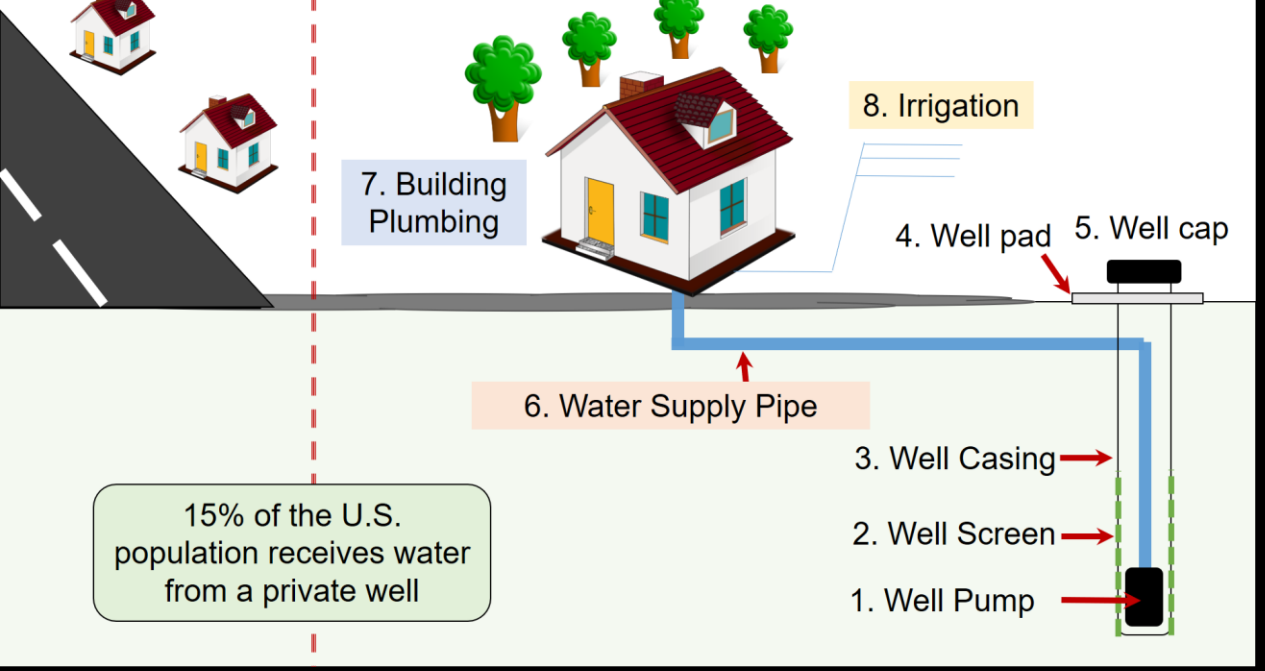
Better Inspect/Test

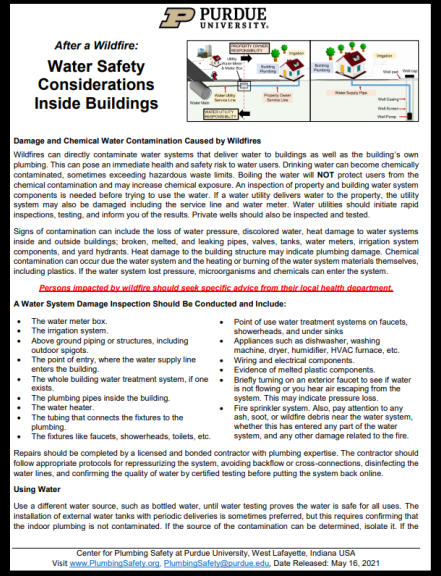
Better Defend

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

THE Water Research FOUNDATION

PURDUE UNIVERSITY





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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:

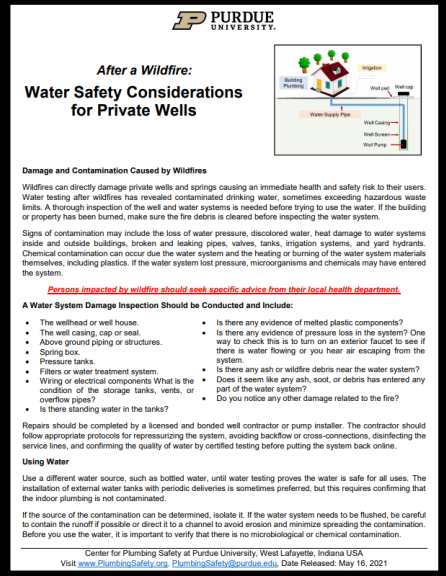
- The water meter box.
- The irrigation system.
- Above ground piping or structures, including outdoor spigots.
- The point of entry, where the water supply line enters the building.
- The whole building water treatment system, if one exists.
- The plumbing pipes inside the building.
- The water heater.
- 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



PURDUE UNIVERSITY

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?

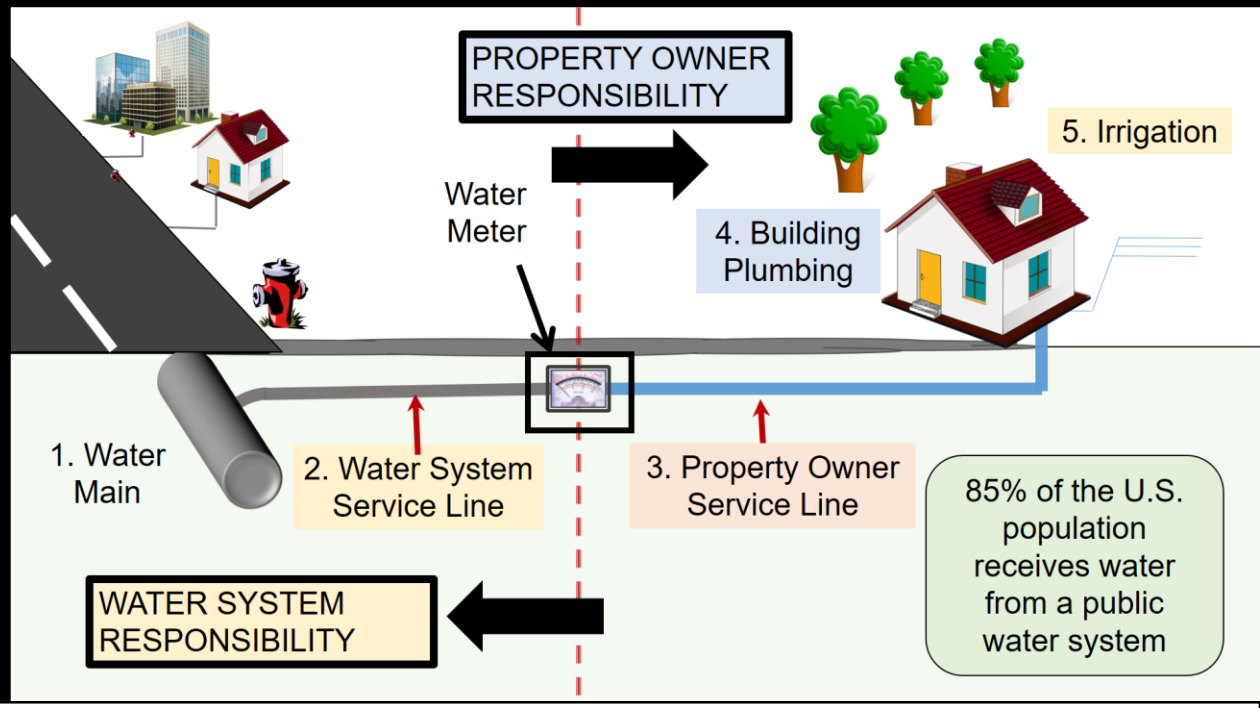
Repairs should be completed by a licensed and bonded well contractor or pump installer. The contractor should follow appropriate protocols for repressurizing the system, avoiding backflow or cross-connections, disinfecting the service lines, and confirming the quality of water by certified testing before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



We created two 1 page inspection and water testing guidance sheets for private wells and building water systems

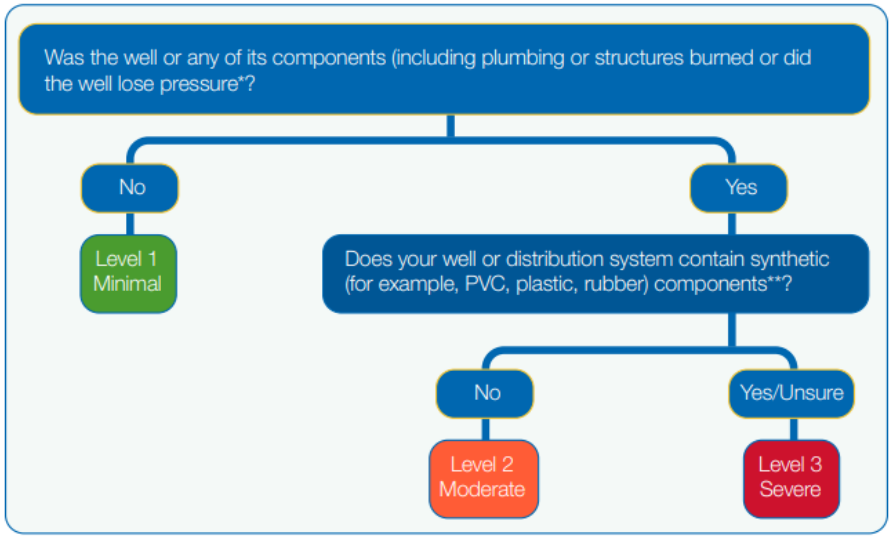
Access here → [Click]

Assessing damage to private wells

After the Fire

This tool is meant for properties that were damaged by wildfire or had a wildfire within 100 feet of the property.

Use this resource to assess damage level and identify next steps



* Check to see if the well lost pressure by watching water flow from faucets. If the water flow is interrupted by air escaping, the well lost pressure.

** Check to see if the well system and plumbing have plastic or rubber components that contact drinking water. This may include electrical wiring and controls in contact with water, plastic/PVC casings and liners, rubber gaskets, treatment equipment, and more.

Released January 2021

Oregon Health Authority
PUBLIC HEALTH DIVISION

Addressing Contamination of Drinking Water Distribution Systems from Volatile Organic Compounds (VOCs) After Wildfires

After the 2017 Tubbs Fire and the 2018 Camp Fire in California, volatile organic compounds (VOCs) were found in the drinking water of the impacted towns. Tests of the water revealed elevated levels of several VOCs, such as benzene, in water mains, service connections, and building fixtures. If unaddressed, VOC contamination can pose a potential health risk for consumers and result in a loss of consumer confidence.

Addressing VOC contamination can be a potentially long-term problem. Flushing is the primary method for removing VOC contamination; however, flushing may not always be effective or feasible. Infrastructure replacement is another option, but depending on the scale, can take time and be cost-prohibitive. Delays in addressing contamination can impact the return of residents to their homes and the restart of commercial businesses, significantly slowing community recovery. This factsheet examines VOC drinking water contamination from the Tubbs and Camp Fires and recommends practices to assist drinking water utilities in identifying and addressing contamination. While this information is intended for public water systems, it also may benefit private water systems and well owners.

The causes and remediation of VOC contamination in distribution systems is an emerging field of study. The cited research reflects the current understanding of wildfire impacts on drinking water distribution systems as well as the informational gaps. This document is meant to provide a resource for water utilities, communities, and state primacy agencies dealing with wildfire damage and public health concerns. Utilities should contact their state primacy agency or EPA Regional Office for additional technical assistance.

Wildfire VOC Contamination

VOC contamination may occur when water distribution infrastructure (e.g., pipes, valves, meters, etc.) is impacted by a wildfire. VOC contamination has been observed primarily in areas that were damaged during the wildfire and experienced pressure loss in the water system. Research into the exact cause of the VOC contamination is ongoing, but two possible explanations have been proposed that may account for such contamination either alone or in combination.

1. Contamination may be released into the water from infrastructure containing polyvinyl chloride (PVC), high density polyethylene (HDPE), or other plastic materials that degrade when exposed to heat.[1]

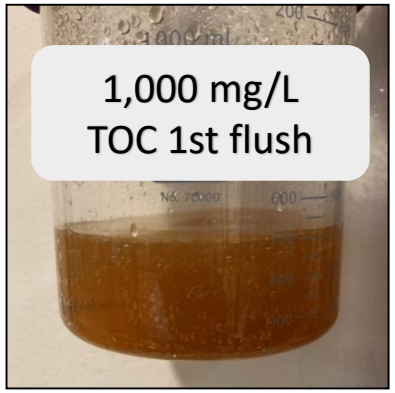
Released September 2021

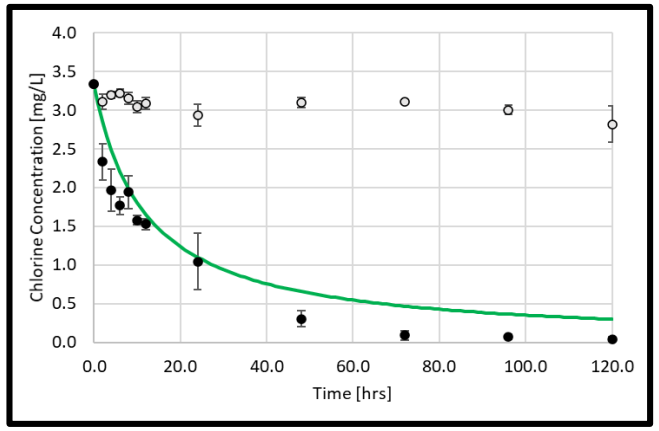
For more information, please visit **www.epa.gov/waterutilityresponse** 1

The Role of Water Softeners

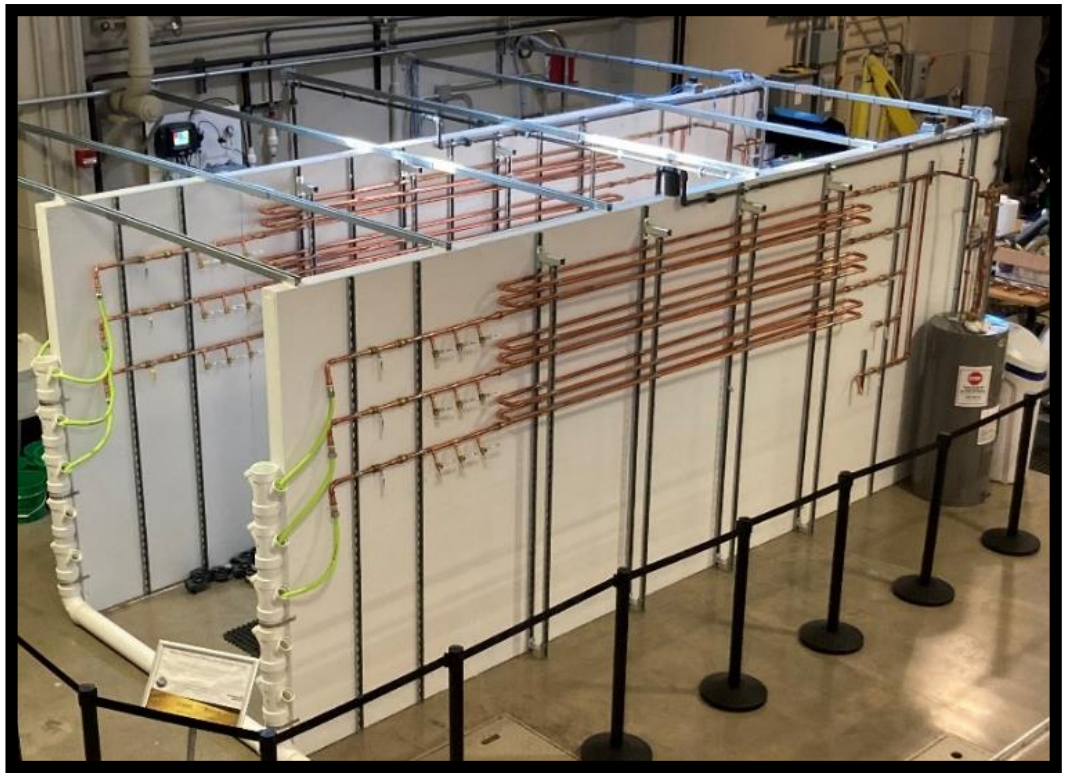
Reservoir of *Legionella spp.* growth and chloramine breakdown to NH_3 (Ra et al. 2019)

↑pH, ↓ disinfectant residual, ↑ THMs (Richard et al. 2021)





NEW: Plumbing Testing Facility



1,000 sqft, Online water quality and flow monitoring
Auto flushing, POE/POU treatment and wall storage
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Voice activated fixtures
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IWQ sensors
Refreshing fixtures
Communicative appliances
Integrated home intelligence
Greywater to landscaping
And more…

The Healthy Plumbing Consortium

Mission: To advance health and quality of life by innovating new and existing technologies and providing transformative education.

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1. Technological and operational approaches for maximizing building water health
2. Smart technology for improved building water health
3. Education of systems and technology

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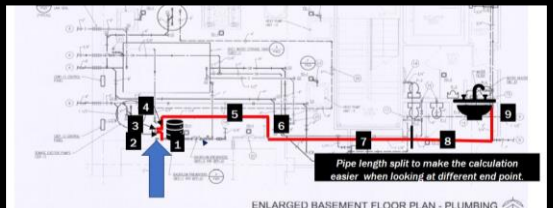
Building Water Essentials
10 Hour, Online Short-Course

Public health, code officials, manufacturers, architects, engineers

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.

8 modules do not have to be taken in sequence.



If interested e-mail EngrOnline@purdue.edu

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

PurdueX: Massive Open Online Course (MOOC)

Plastics in Infrastructure and the Environment

Summers 2020, 2021, 2022
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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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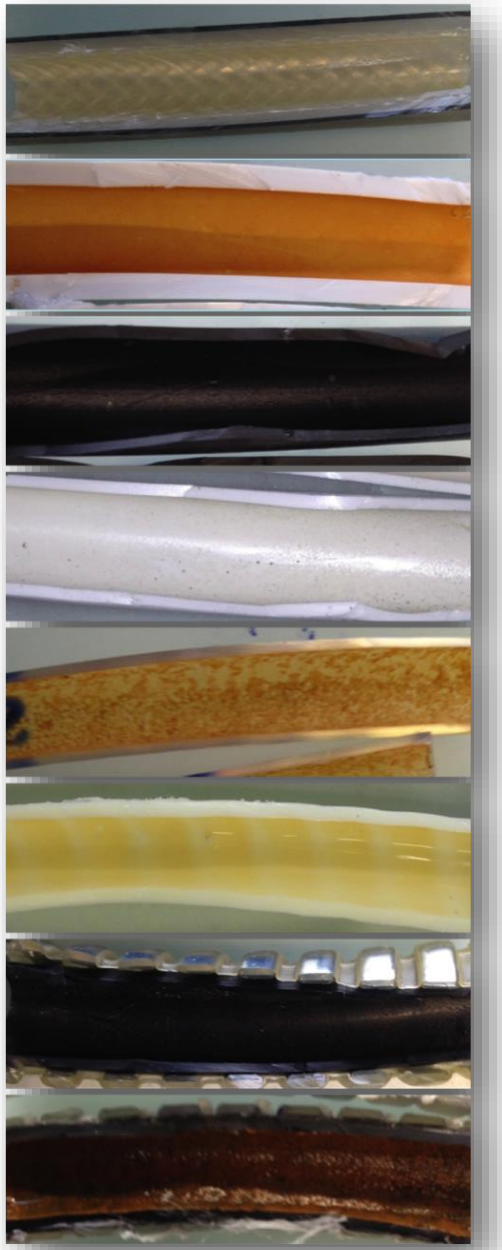

^ Variety in shower hose biofilms

PROFESSOR PROCTOR LAB GROUP

Working to manipulate microbial aquatic systems by taking advantage of ecological principles of selection within biofilms.

- Biofilms
- Bacteria and microbiomes
- Opportunistic pathogens
- Drinking water quality
- Public health and policy

^ The pipes that deliver drinking water accumulate biofilms with a diverse and thriving ecosystem

^ Bath toys harbor biofilm just like drinking water pipes

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Thank you. Questions?

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News

- Wildfires are contaminating drinking water systems, and it's more widespread than people realize (The Conversation)
- Panel probes relationship between scientists and journalists, highlighting areas for growth (Purdue University)
- Bill author, Purdue expert urge hearing for bill on lead testing in preschools, day cares (WFYI)
- Response team investigates wildfire damage to buried drinking water infrastructure (ASCE Magazine)
- Mobile homes' toxic legacy haunts wildfire relief efforts in Southern Oregon (Street Roots)

COVID-19 Response

Wildfire Response

Enroll in the self-paced, online 10-hour Building Water Essentials course for CEUs

Missed the Journalism, Science, and Policy Conversation? Watch it here

Thank you for visiting. This website is designed to provide information to persons who drink water in buildings, as well as building construction, plumbing, water utility, education, and public health sectors. Together, we are working to understand how to make certain the water you use at home, at work, and at schools is safe. Please contact us if you have any questions at awhelton@purdue.edu.

Partner Institutions:

Manhattan College · Michigan State University · SJSU San José State University · Tulane University · The University of Memphis

www.PlumbingSafety.org

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