


# *Safer Plumbing Design, Use, and Recovery from Disasters*

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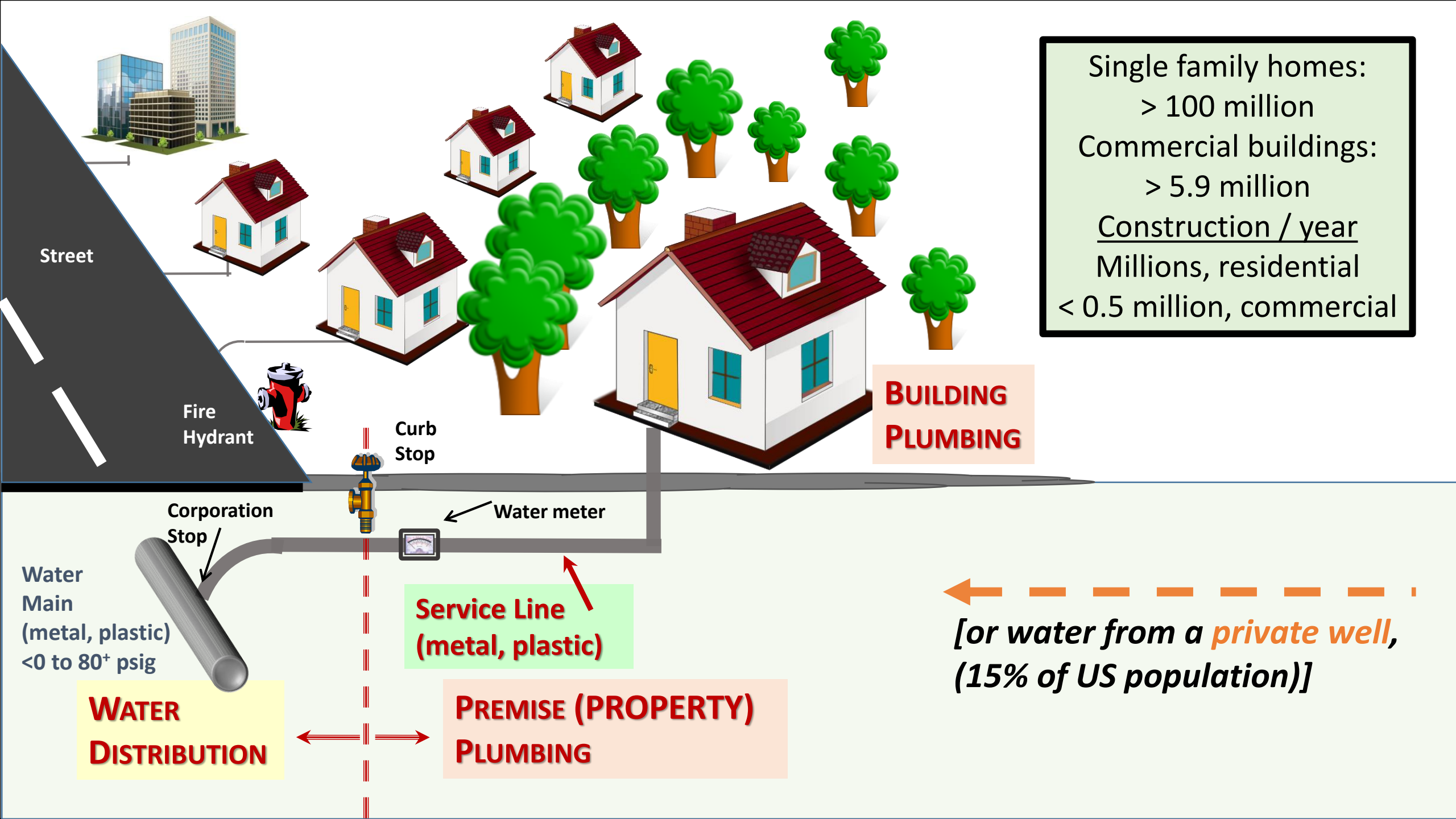
**Web: PlumbingSafety.org**


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)]

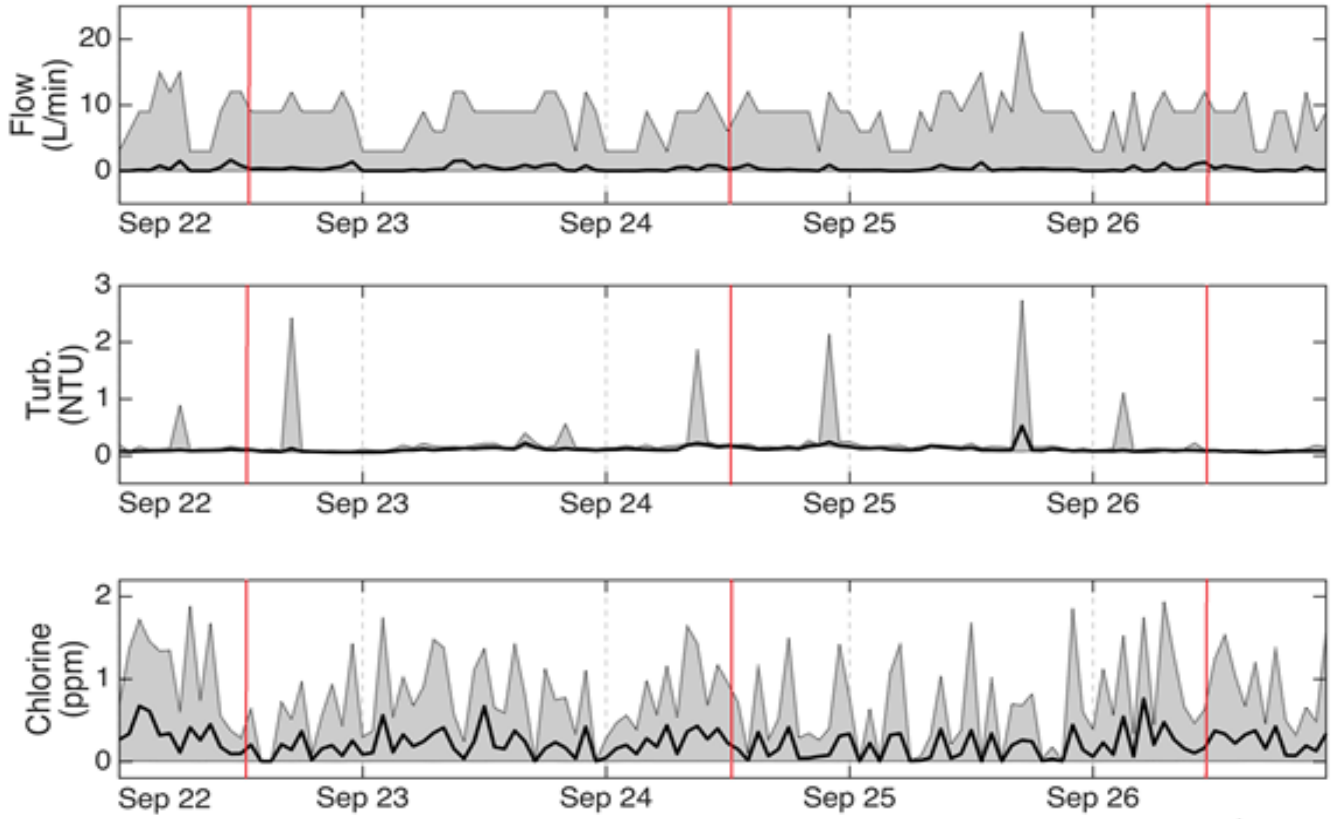
# Today: A patchwork of sometimes disparate actions

1. Occupancy permits are not linked to fixture water safety
2. Plumbing materials and devices often not tested under actual use conditions
3. Except for 1, drinking water safety regulations stop at the water meter
4. Building certification systems do not link to fixture water safety
5. Plumbing design practices/codes do not directly link to fixture water safety

# For example, we want to predict fixture water safety but…

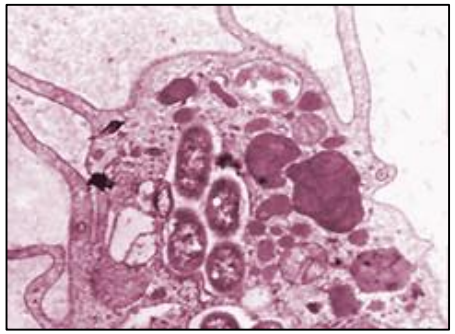
It's not widely known that water quality can vary drastically at the service line

*i.e., No detectable disinfectant entered*
*…in summer 25% of the time*
*…in winter 6% of the time*

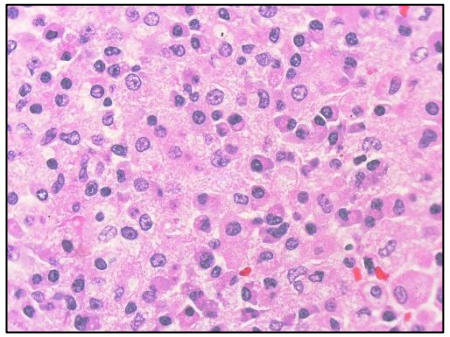



Shown: 5 day period, 1x/min, 24 hr/day
Water quality varied by season, time of day, and day of week

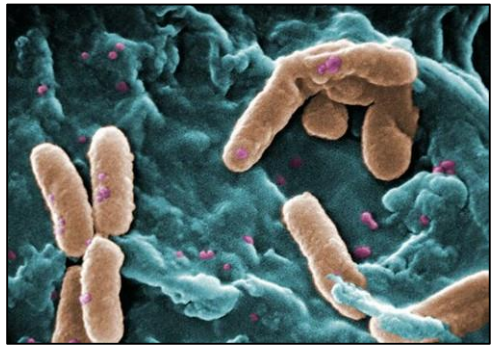
*Salehi et al. (2019),* https://www.doi.org/10.1016/j.buildenv.2019.106566



*Legionella pneumophila*



*Mycobacterium avium complex*



*Pseudomonas aeruginosa*

At a 7-yr old lead school
2-3 mg/L copper widespread

At a 10-yr old office building
1.3+ mg/L copper after 19 hrs

[ Acute Exposure Limit: 1.3 mg/L ]

# PWS compliant with *Lead and Copper Rule*

Other metals
Other organisms
DBPs
Organics
Plastics

# *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** | ~80 presentations<br>Materials publicly available,<br>100,000(s)+ ppl reached<br>Assisted all major sectors |
| **Engagement** | LCR Federal Register comment<br>Scientific opinions<br>Direct building owner and building designer support<br>Manufacturer technical assistance |
| **Discovery** | Peer-review: 18 Published + 5 in Review + >10 in Development<br>[DST coming and more] |

PURDUE UNIVERSITY MICHIGAN STATE UNIVERSITY SJSU SAN JOSÉ STATE UNIVERSITY MANHATTAN COLLEGE Tulane University THE UNIVERSITY OF MEMPHIS

| Overview of Major Activities | Year 1 (2017) | | | | Year 2 (2018) | | | | Year 3 (2019) | | | | Year 4 (2020) | | | | Year 5 (2021) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| ***Obj 1. Water Conservation Trends*** | | | | | | | | | | | | | | | | | | | | |
| Review & Info. Syn. | | | | | | | | | | | | | | | | | | | | |
| Workshop | | | | | | | | | | | | | | | | | | | | |
| ***Obj 2. Effect of Flow on Water Quality*** | | | | | | | | | | | | | | | | | | | | |
| Residential – 1 year chem/micro | | | | | | | | | | | | | | | | | | | | |
| Residential – Pathogen exposure | | | | | | | | | | | | | | | | | | | | |
| Residential – Water Age/HRT | | | | | | | | | | | | | | | | | | | | |
| Residential – Hydraulics | | | | | | | | | | | | | | | | | | | | |
| Residential – Fixture prediction | | | | | | | | | | | | | | | | | | | | |
| Residential – Rainwater switch | | | | | | | | | | | | | | | | | | | | |
| Residential – Integrative Hydro-WQ model | | | | | | | | | | | | | | | | | | | | |
| LEED School Bldg – Chemistry / Microbiology | | | | | | | | | | | | | | | | | | | | |
| LEED School Bldg – Pathogens | | | | | | | | | | | | | | | | | | | | |
| LEED School Bldg – Pathogen exposure | | | | | | | | | | | | | | | | | | | | |
| LEED Univ Bldgs – Chemistry / Microbiology | | | | | | | | | | | | | | | | | | | | |
| LEED Office Bldg – Chemistry / Microbiology | | | | | | | | | | | | | | | | | | | | |
| Experiment – GIP/PEX plumbing | | | | | | | | | | | | | | | | | | | | |
| Experiment – Metal deposition in plumbing | | | | | | | | | | | | | | | | | | | | |
| Experiment – Building plumbing TTHMs | | | | | | | | | | | | | | | | | | | | |
| Experiment – PEX TTHMs and leaching | | | | | | | | | | | | | | | | | | | | |
| Experiment – Chem/Microbiology | | | | | | | | | | | | | | | | | | | | |
| Int. Hydro–Fate WDS/Prem Model | | | | | | | | | | | | | | | | | | | | |
| Risk Models with Building Model | | | | | | | | | | | | | | | | | | | | |
| ***Obj 3. DST Development*** | | | | | | | | | | | | | | | | | | | | |
| Development | | | | | | | | | | | | | | | | | | | | |
| Workshop | | | | | | | | | | | | | | | | | | | | |
| Upgrade | | | | | | | | | | | | | | | | | | | | |

# 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

***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 ….*

# COVID-19: An awakening for building water safety and public health

*Lower water use prompts degraded water quality and potentially greater health risks*


**NSF RAPID: Shutdowns and Consequences, 2020-Present**

11 buildings + lab experiments + policy + outreach with local, state, federal public health agencies + AWWA + IAPMO + ASPE + many others …

**NSF EAGER: Building Systems Collaborative, 2020-Present**

- Building Water Research Symposium, October 2020
- Journalism, Science & Policy webinar, February 2021
- Building Water SLAM, July 2021

National Science Foundation
WHERE DISCOVERIES BEGIN

# 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

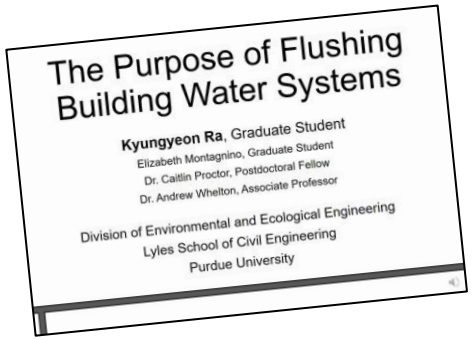
THE UNIVERSITY OF IOWA

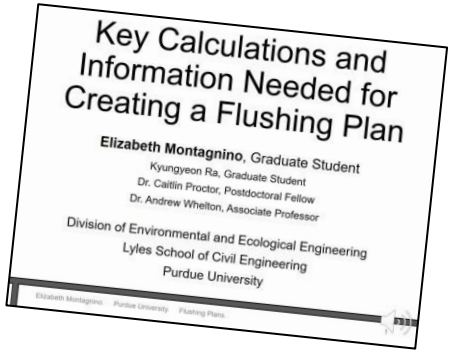
POLYTECHNIQUE MONTRÉAL

# *Preliminary Findings*

YouTube

**Plumbing Safety Channel**




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

Metal (Cu, Pb, Ni, Zn) 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.

Hypochlorite disinfection levels varied (est. 160-340 mg/L+ for 3 hours). Likely due to ineffective mixing, reactions, and/or decay

Lack of accepted Go/No Go legionella levels

Some health departments discouraged any testing

# Disasters continue to expose a deficiency of knowledge and this has profound impacts on health, safety, and economic prosperity

| 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

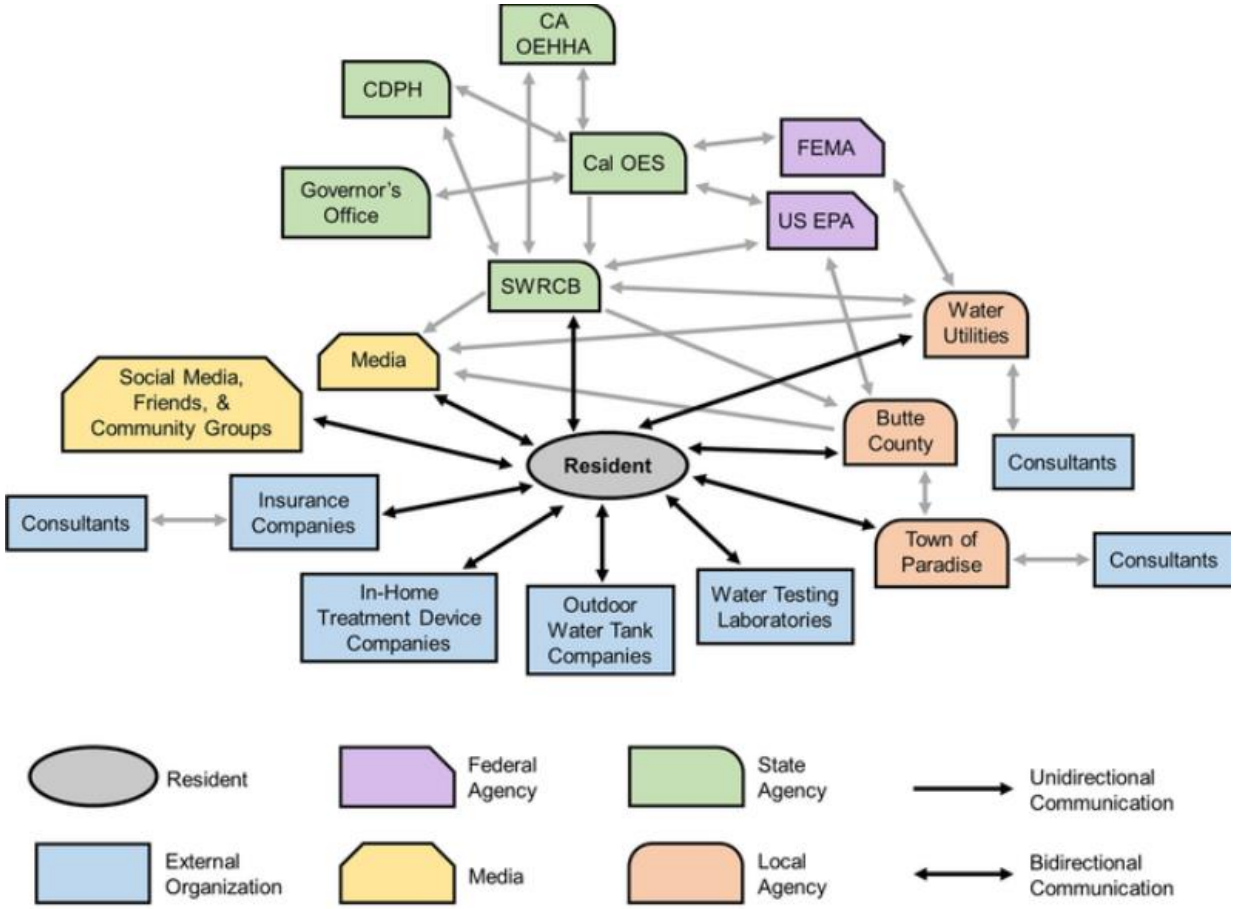
Some plastics uptake chemicals and leach them back out making clean water unsafe

# 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.



# The Future?

**Education: Plumbing, construction, and public health sectors**

**Revised and evidence-based codes and standards for new and renovated buildings**

**Evidence-based best practices for new plumbing startup and post-disaster plumbing safety response**

**Low cost sensors for intelligent building monitoring**

**Address water safety issues of existing buildings with improved policy, codes, and technology**

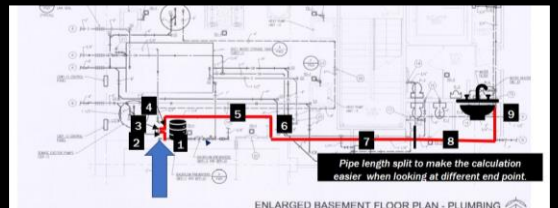
**The U.S. Safe Buildings Act?**

# *NEW:* Building Water Essentials – Open 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

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**

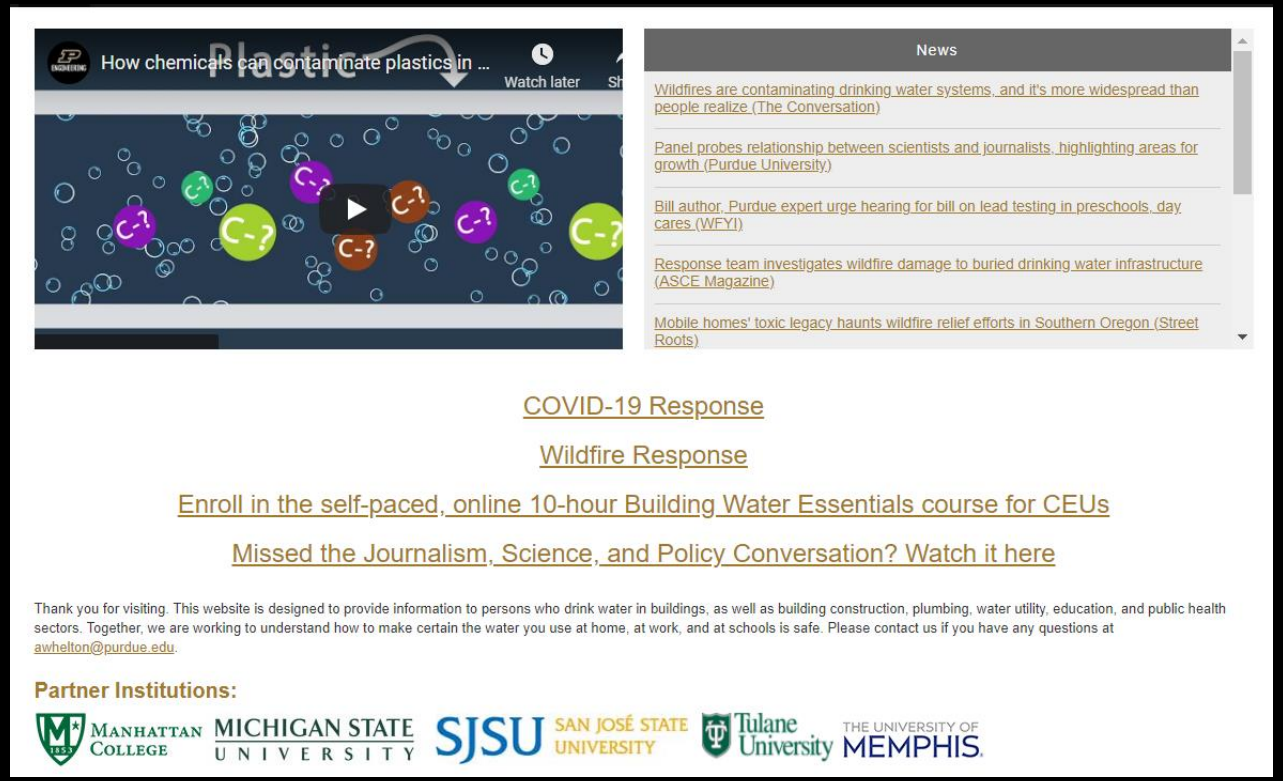
## Learning Objectives

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

More info and enroll: https://www.edx.org/course/plastics-in-infrastructure-and-the-environment

# *Thank you.*

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**

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