Considerations for testing building water systems to identify health risks

Andrew J. Whelton, Ph.D.
Civil, Environmental, and Ecological Engineering

Caroline Jankowski
Environmental and Ecological Engineering

www.PlumbingSafety.org

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]

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

We sample to identify health **risks**

Exposure Routes of Concern: Ingestion, Dermal, Inhalation

Low to No Water Use

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)

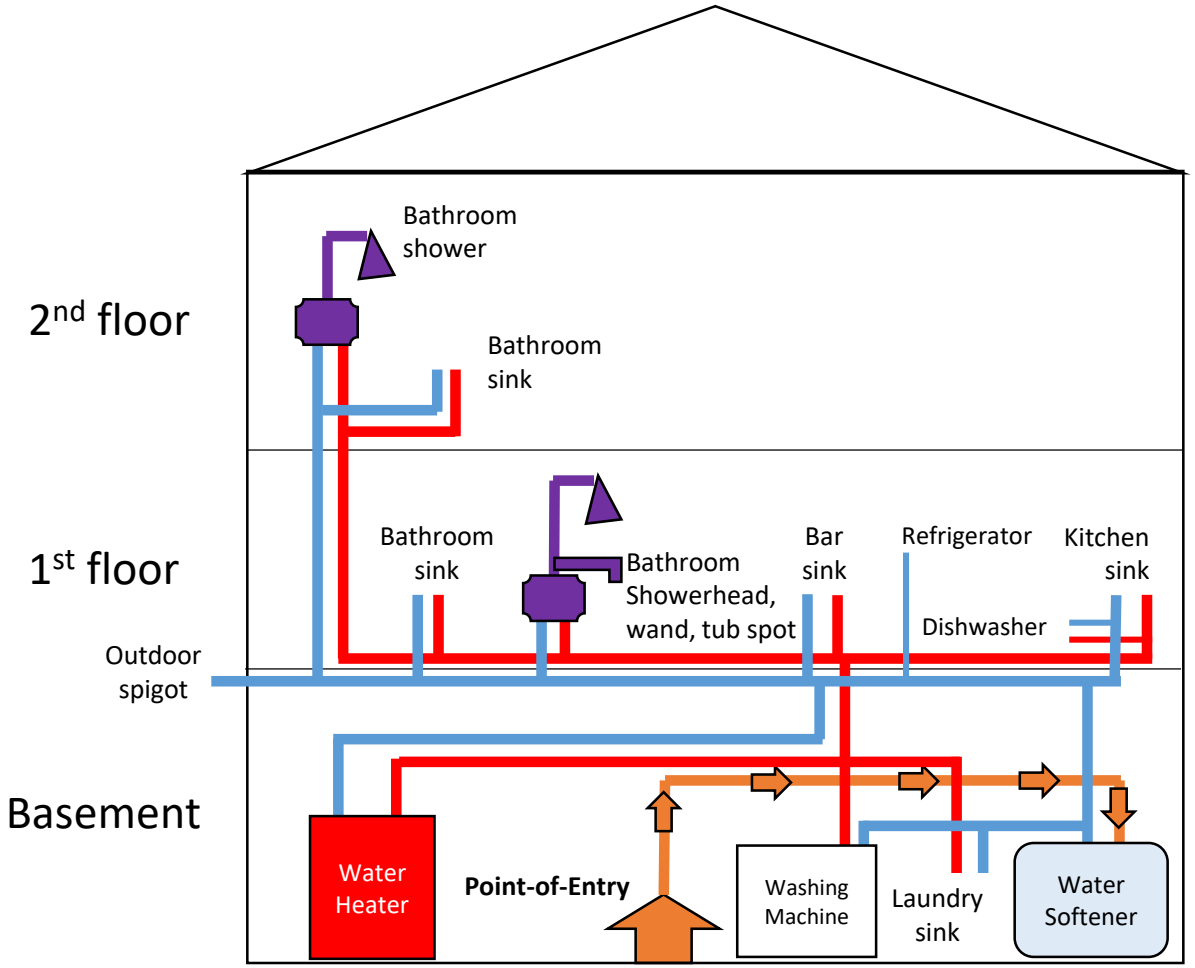
Post-Disaster

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

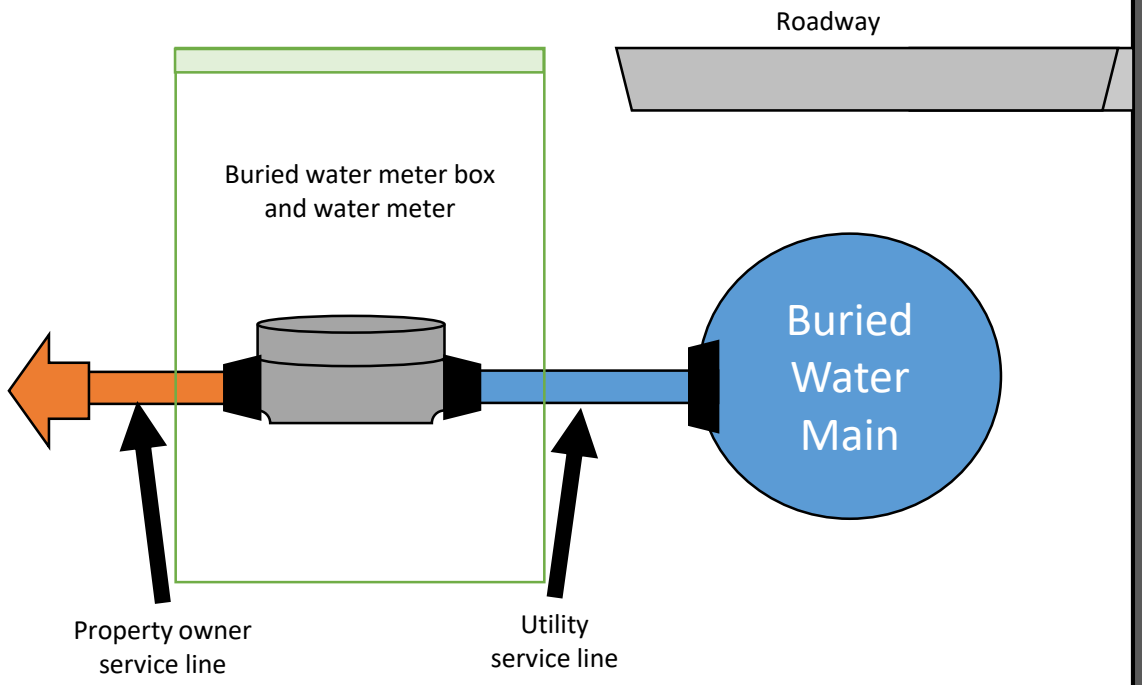
Today, best practices and standards are not compiled for building water system investigations. There are many rules of thumb without statistical challenge.

In my opinion, building water sampling must move towards “representativeness” and deliberately integrate plumbing design and operational conditions ***knowledge*** into the decisions.

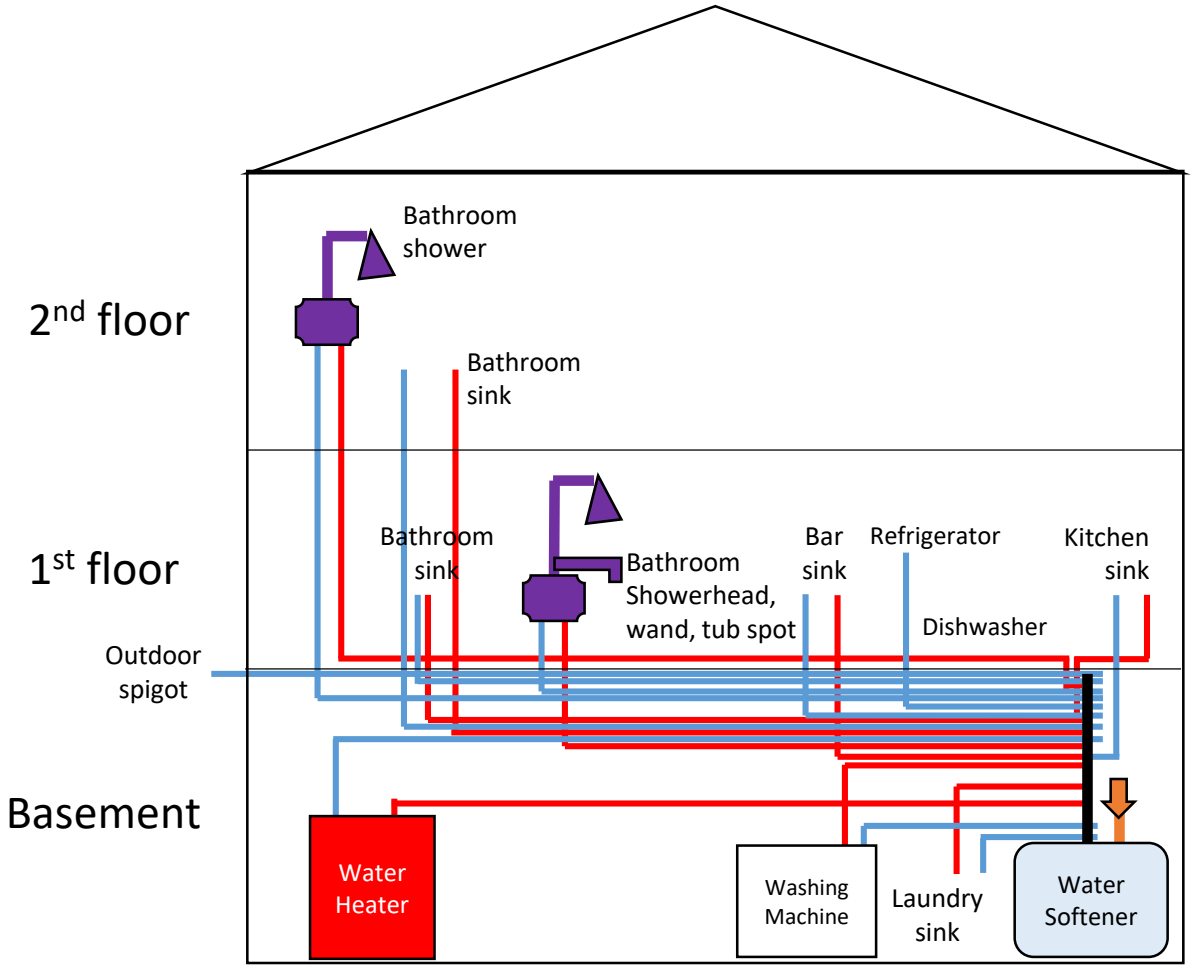
What do buildings look like? Single family home trunk and branch design with a centralized water heater



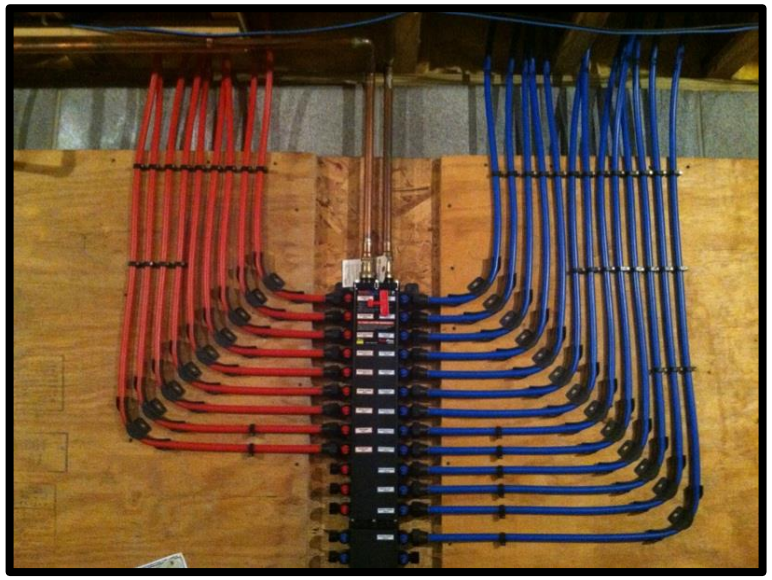
Cold and hot water flow through separate pipes
Some locations are downstream from others, but branch off into separate pipes



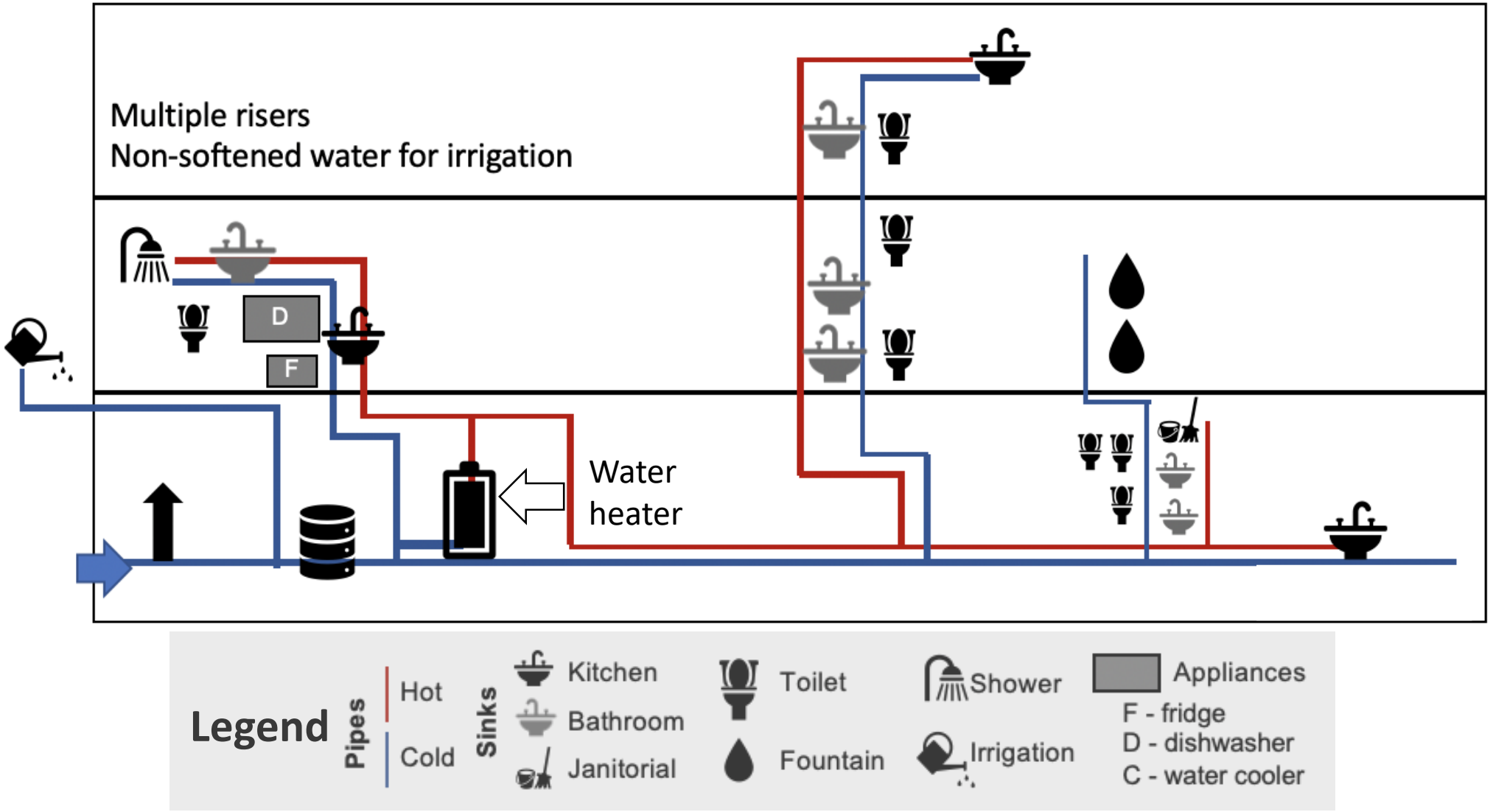
A home with PEX manifold plumbing



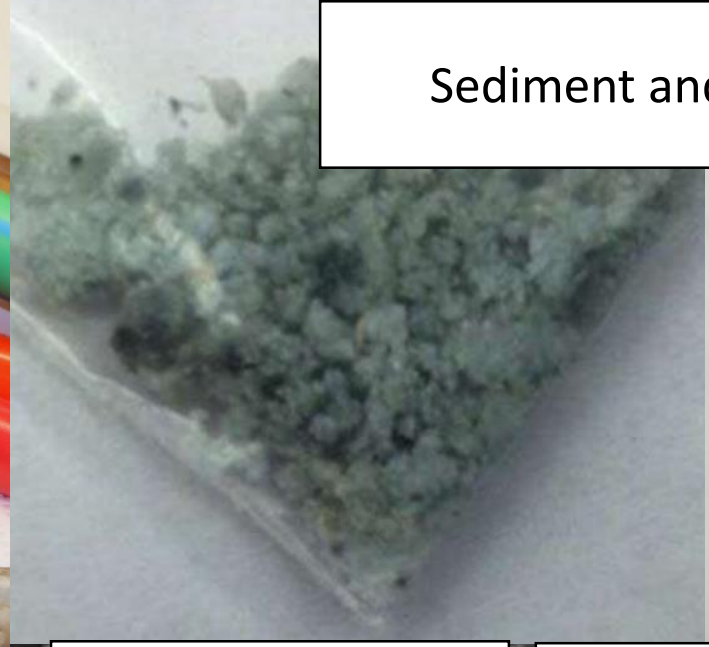
Cold and hot water flow through separate pipes
Each fixture has it's own isolated pipe
No 2 pipes convey the same water
Co-located shutoff location for all each fixture
Smaller diameter pipes compared to T/B design



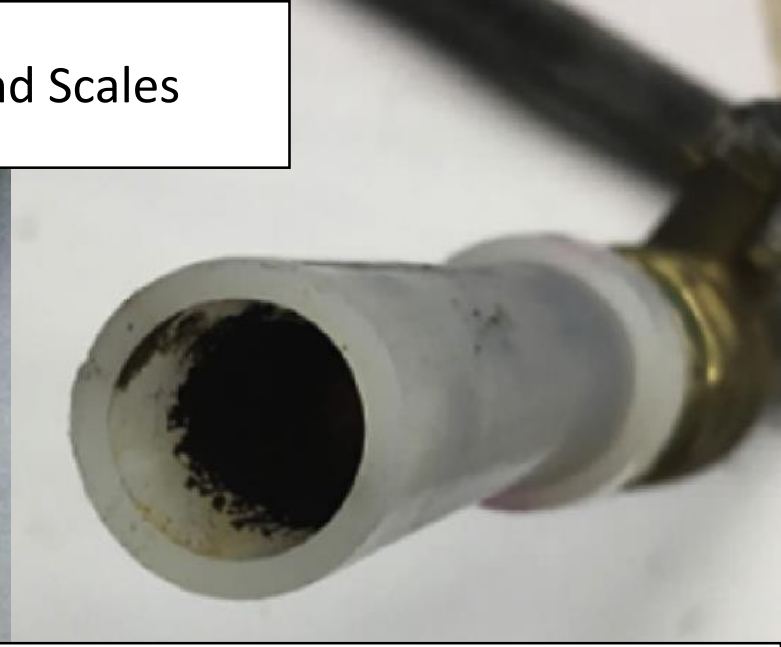
3 story office building with 3 risers and a centralized water heater

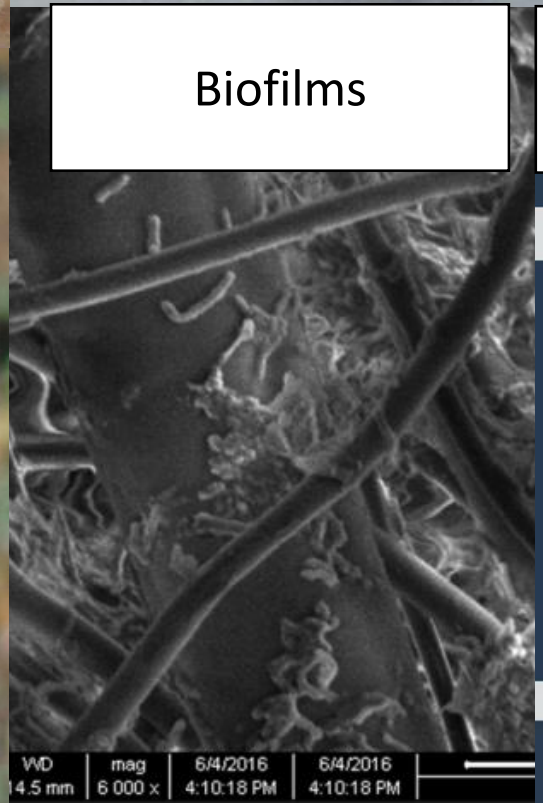


Piping and Tubing Types, and Coatings



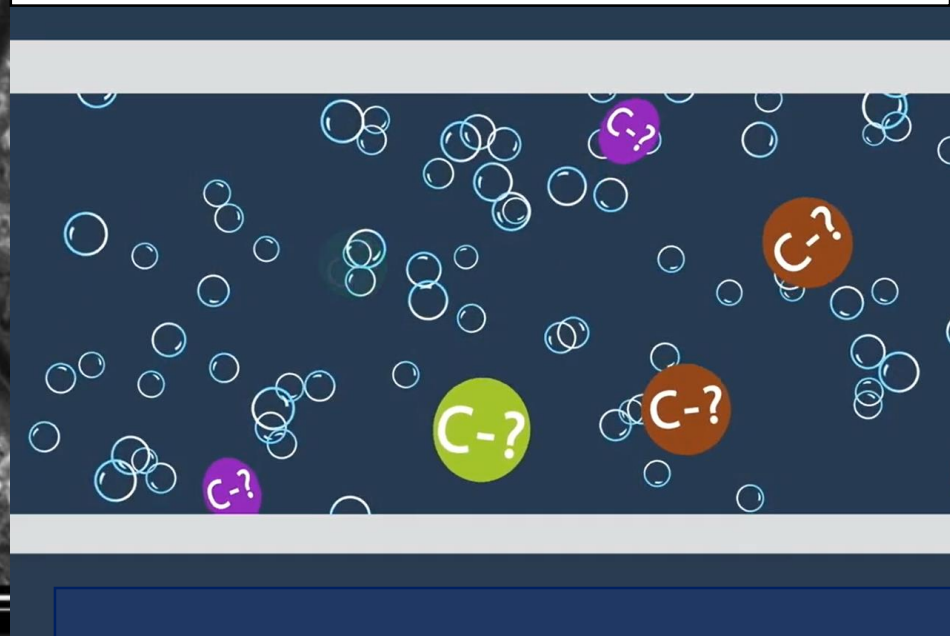
Sediment and Scales





Biofilms

Plastics can Uptake Organic Chemicals



Other Issues: Plumbing components, design, and hydraulics are complex

Service line (single vs. shared)

POE/POU devices

Recirculation loops

Mixing valves

Faucet connectors

Fixture types and internals

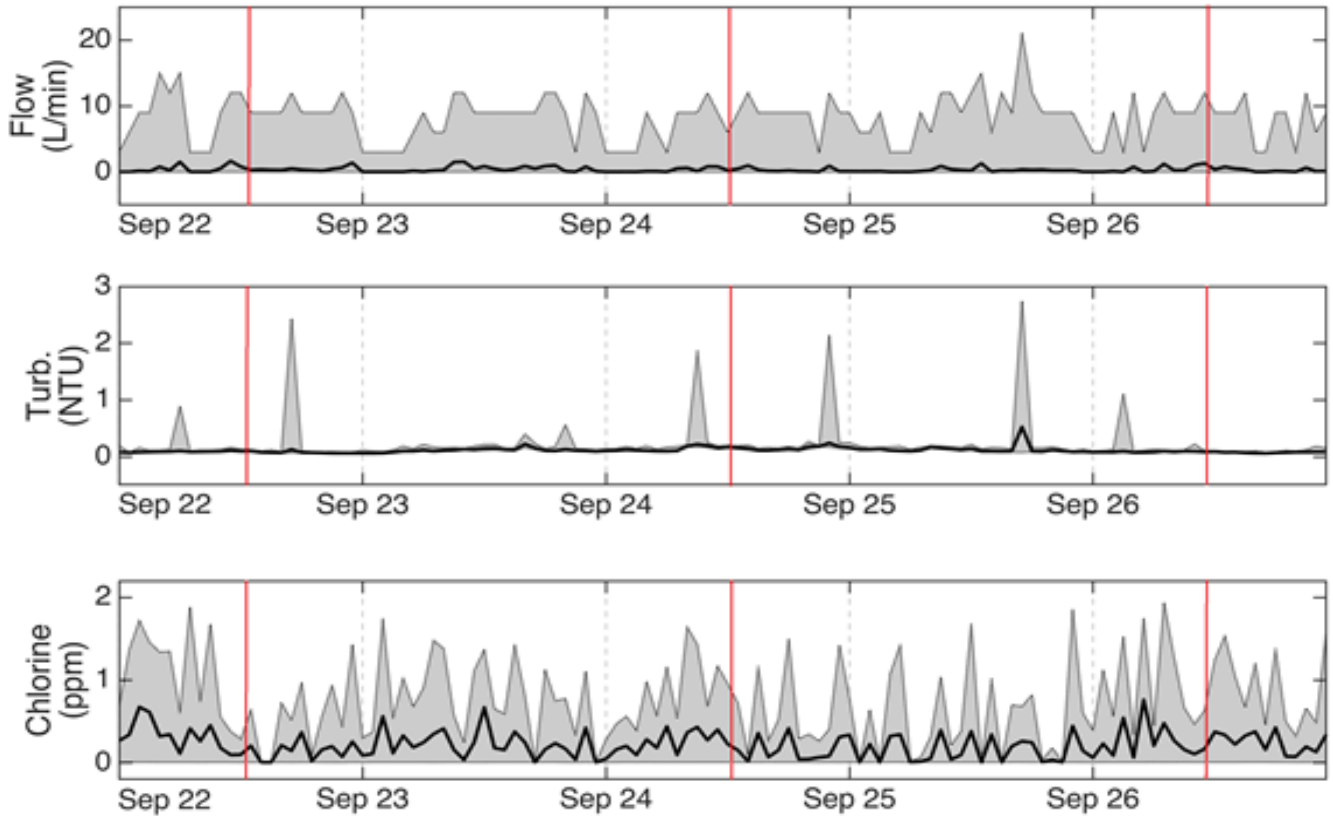
Faucet gaskets and aerators

Water quality at the meter varies - 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

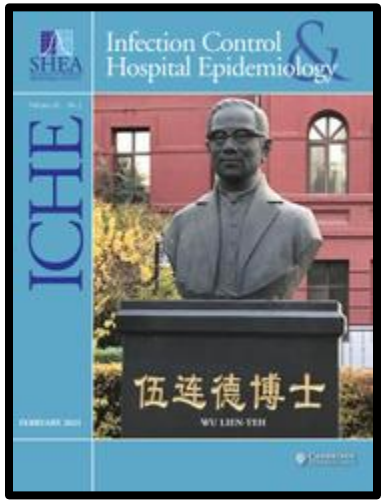
No detectable disinfectant residual entered the building
…in summer 25% of the time
…in winter 6% of the time



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

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

Legionella water sampling recommendations are still unsettled, but critical for detecting problems



Understanding the distribution of positive *Legionella* samples in healthcare-premise water systems: Using statistical analysis to determine a distribution for *Legionella* and to support sample size recommendations

Nagy et al.

Published October 2020 **https://www.doi.org/10.1017/ice.2020.384**

There's an ongoing debate of claims for healthcare buildings

- Intervention when >30% positive in a sample cycle: Best et al. *Lancet.* 1983.
- 10 samples per 100 beds: Freije. *HC Information Resources.* 1996.
- % distal-site positivity is accurate in predicting risk, but CFU/mL criteria are inaccurate and should be abandoned: Stout et al. *Infect Control Hospital Epidemiol.* 2007.

Lead drinking water sampling recommendations are still debated, but critical for detecting problems

Review article

Variability and sampling of lead (Pb) in drinking water: Assessing potential human exposure depends on the sampling protocol

Triantafyllidou et al.

Published January 2021 **https://doi.org/10.1016/j.envint.2020.106259**

Sampling serves many purposes, results do not answer the same question

- Regulatory compliance for public water system
- Source determination (service line vs. solder joint vs. faucet)
- Form determination (particulate vs. dissolved)
- Exposure assessment (cumulative samples)
- "Exposure assessment may conceivably also employ frequent random single samples, but this approach warrants further investigation."

Simple Example: 2018 Camp Fire, Paradise California

Question: Is single family home plumbing safe to use?

Situation

- ❑ >2,200 ppb benzene + 1,000s of ppb of other VOCs enter plumbing
- ❑ 6-12 months of contaminated water delivered to plumbing
- ❑ Ingestion risk + inhalation risk
- ❑ Drinking and hot water bans in effect
- ❑ Utility tested with 72 hr stagnation, multiple locations, multiple VOCs
- ❑ Multiple VOCs above safe limits
- ❑ 11 months postfire benzene found in home drinking water

What was done…

- ❑ State (0-7 months postfire): follow testing labs, who flushed kitchen faucet for 15 min. before taking sample, cold only, benzene only
- ❑ State (0-7 months postfire): no stagnation, kitchen faucet, cold water only, benzene only
- ❑ State (>7 months postfire): 8 hr stagnation, kitchen faucet, cold water only, benzene only
- ❑ Consultants paid by insurance companies: Whatever they wanted, no oversight
- ❑ Homeowners on their own (paid testing labs): Depended on who they talked to

Testing often ignored multiple chemicals present (methylene chloride above MCL), the service line, hot water, inhalation exposure, multiple locations in the building, PEX plumbing, and more.

In 2020 Oregon recommended 72 hr stagnation after wildfires

1. What's prompting you to sample?

Building startup, new construction
Routine water safety monitoring
Building re-start after temporary dormancy
Building re-start after shutdown
Post-disaster to find contamination
Post-intervention to see if the safety problem still exists (shock disinfection, flushing)
General interest (What's in the water?)

If no sampling has ever been conducted it may be that unsafe water already existed, the building owner just never knew.

2. What is the main question you want answered?

How much will this cost me?

Are the contaminants inside the biofilm?

What's in the water?

Will the hot water cause harm?

Should I remove and replace the plumbing?

Did the decontamination action work?

Is the service line or well contaminated?

When should I collect water samples?

Did the contaminants sorb to biofilm?

Are the pipes contaminated?

Is the water heater contaminated?

How many water samples do I need to collect?

Is the fixture contaminated?

Will the cold water cause harm?

How long do I need to stagnate water before sampling?

Did the contaminants sorb to scales?

Where are the contaminants in the plumbing?

Other questions to help guide your approach

3. Do you care about plumbing outside the building such as the buried water service line, onsite drinking water well, tanks, etc.?

4. How will building water be used? This will define the exposure routes of concern: ingestion, inhalation and dermal contact.

5. Who are the building occupants? Healthy adults vs. children vs. immunocompromised vs. pets

6. What are the contaminants of concern? Disinfectant residual; Heavy metals; Other inorganics and radionuclides; VOCs; SVOCs; *L. pneumophila, N. fowleri, P. aeurigonosa, E. coli, NTM*, others

Example: Heavy metals (As, Cu, Mn, Pb, Zn …)

Exposure

Ingestion only

Sampling locations

Cold water only ingestion locations (drinking water, formula, cooking, teeth brushing)

Data interpretation

- Age of fixtures
- Areas of buildings with older plumbing
- Scale destabilization and equilibrium

Considerations

- Contam to look for: Chemicals identified
- Stagnation time before sample: >6 hr vs. weekend
- Initial volume vs dump 1st then collect?
- Volume collected
- Bottle type: Plastic preferred
- Fixture flowrate: Partial vs. full open
- Headspace: Not applicable
- Aerator on vs. aerator off
- Acidify vs not acidify

Example: VOCs

Exposure

Ingestion, inhalation, dermal + degradation products

Some plastics can uptake, and then slowly leach out VOCs. All results subject to stagnation time. Thermally damaged plastics can be a source of VOCs.

Sampling locations

Cold water and hot water

POE device, drinking water, formula, cooking, teeth brushing, shower, shower wand, tub spout, sink faucets, bathroom faucets, water heater, dishwasher, refrigerator water, laundry pipes, Jacuzzis >>> urinals, toilets, outdoor spigots

Considerations

- Contam to look for: Parents + daughter products
- Stagnation time: 72 hrs, others
- Initial volume vs. dump 1st then collect
- Volume collected
- Bottle type: Clear or amber VOA glass bottles with Teflon septum-cap
- Flowrate: Partial vs. full flow
- Headspace: No headspace
- Aerator on vs. aerator off
- Acidify vs not acidify

Example: Legionella

Exposure

Inhalation (Legionella)

Sampling locations

Hot water, maybe cold water
Entry point, central water heaters, recirculation loops, hot water use points, whirlpool spa
If cold water > 77F then sample

Considerations

- Contam to look for: Specific microbiological agents
- Stagnation time: ?
- Initial volume vs. dump 1st then collect
- Volume collected: 50 mL to 1000 mL (depends on source)
- Bottle type: Plastic 1 L
- Flowrate: Partial vs. full flow
- Headspace: 1 inch
- Preservative
- Aerator on vs. Aerator off
- Acidify vs not acidify

Other comments

Number of test locations ➔ **What question are you trying to answer?**

What's a health protective approach?

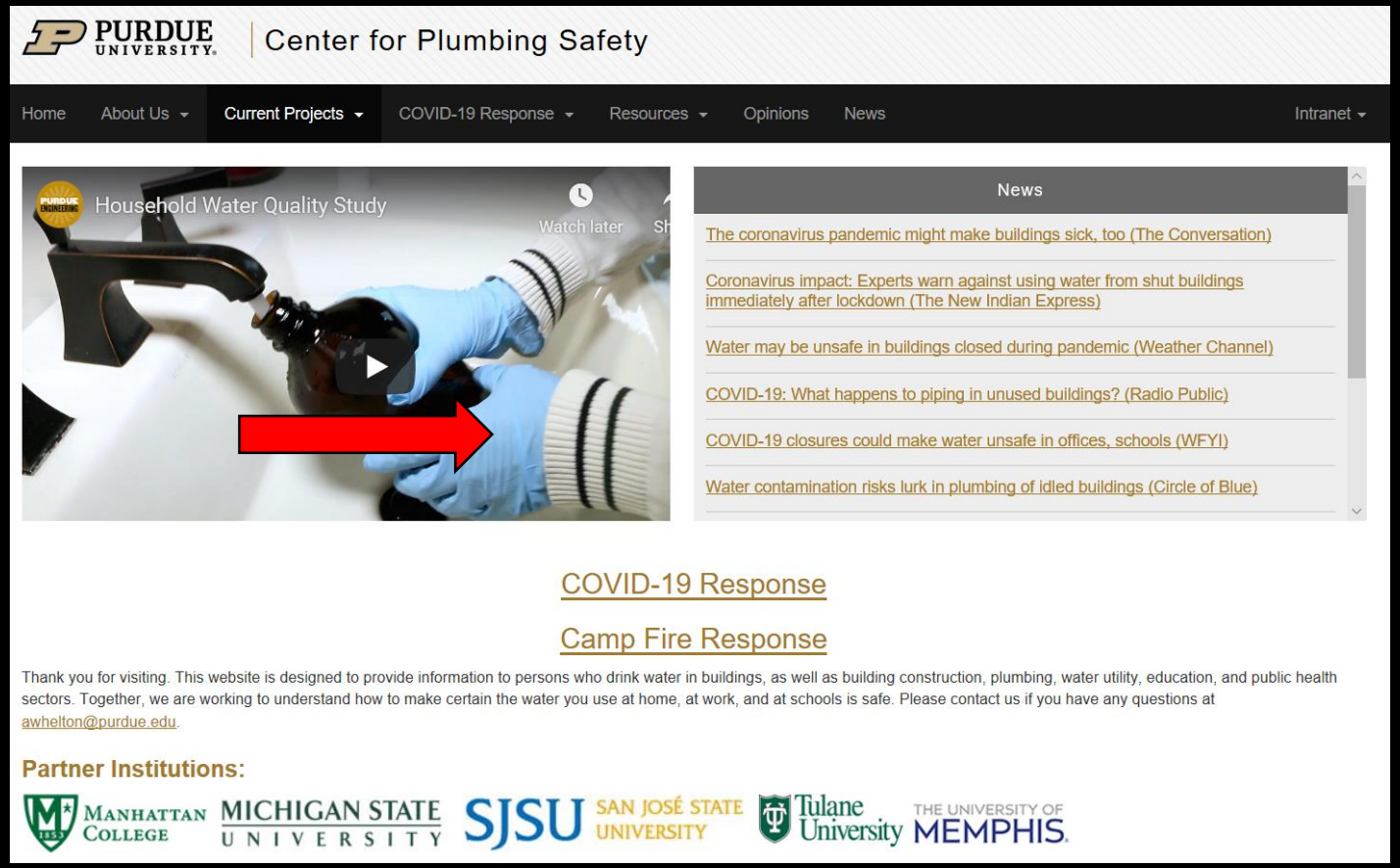
- Consult CDC and state health department guidance for legionella testing.
- Disinfectant residual and temperature are go to parameters
- Copper, lead, and other metals…. ingestion locations (i.e., schools)
- *L. pneumophila*, etc. … major exposure locations
- VOCs/SVOCs post wildfire… major exposure locations

What is a "**representative sample**"?

Proportionately reflect characteristics of plumbing design, fixture types, locations, and water use conditions. We should be able to apply statistics to determine the probability that you would have an exceedance at a location that you did not sample

Thank you. Let's talk.

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



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