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Can Disinfectant Residual within the Distribution System Control Building Plumbing Water Quality?

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Today's Talk

- Distribution system water quality goals
- Principal causes of distribution system water quality decay
- Water quality issues in premise plumbing
- Can disinfectant residual within the distribution system control building plumbing water quality?

Distribution System Water Quality Goal: Pathogen Free Water

- Water entering the distribution system needs to be pathogen-free
  - Primary disinfection should be robust
  - Continuous disinfection
  - Maintain adequate disinfection concentration
- Prevent pathogens from seeding the distribution system
- Secondary disinfection:
  - Secondary inactivation of organisms
  - Control biofilm growth
  - Indicator of distribution system integrity
- Risk reduction: SWTR; IESWTR; LT2ESWTR

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Modified from EPA, 2009. Best Practices for Simultaneous Compliance

Distribution System Water Quality Goal: Biological Stability

- Secondary disinfectant residual
- Bacterial growth/regrowth in distribution systems can also be reduced by removing nutrients (*e.g.*, TOC, AOC etc.)
- Disinfectant decay rates can be reduced by removing NOM
- Risk reduction: TCR; SWTR; Revised TCR

Modified from EPA, 2009. Best Practices for Simultaneous Compliance

Distribution System Water Quality Goal: Chemical Stability

- Oxidized forms of Fe, Mn, Sulfate and other inorganic contaminants should be removed by treatment
- DBP formation can be reduced by removal of NOM
- Primary disinfection via free chlorine stabilizes chloramine reactions in the distribution system
- Risk reduction: SWTR; Stage 1 & 2 DBP Rules

Modified from EPA, 2009. Best Practices for Simultaneous Compliance

Distribution System Water Quality Goal: Non-Corrosive Water

- Minimize Pb & Cu exposure
- Reduce iron corrosion
  - Iron corrosion increases disinfectant decay rates
  - Iron can stimulate biological growth
  - Tubercles and scales can provide habitat for biological growth
- Corrosion associated with aesthetics concerns (*i.e.*, taste, odor, color)
- Risk reduction: LCR

Modified from EPA, 2009. Best Practices for Simultaneous Compliance

Principal Causes of Distribution System Water Quality Decay

- Source Water/Treatment Deficiencies
- Chemical/Biological Reactions
  - Bulk water reactions
  - Reactions between water and pipe surfaces
- External intrusion of contaminants
- Poorly maintained storage facilities
- Premise Plumbing Issues

Modified from EPA, 2009. Best Practices for Simultaneous Compliance

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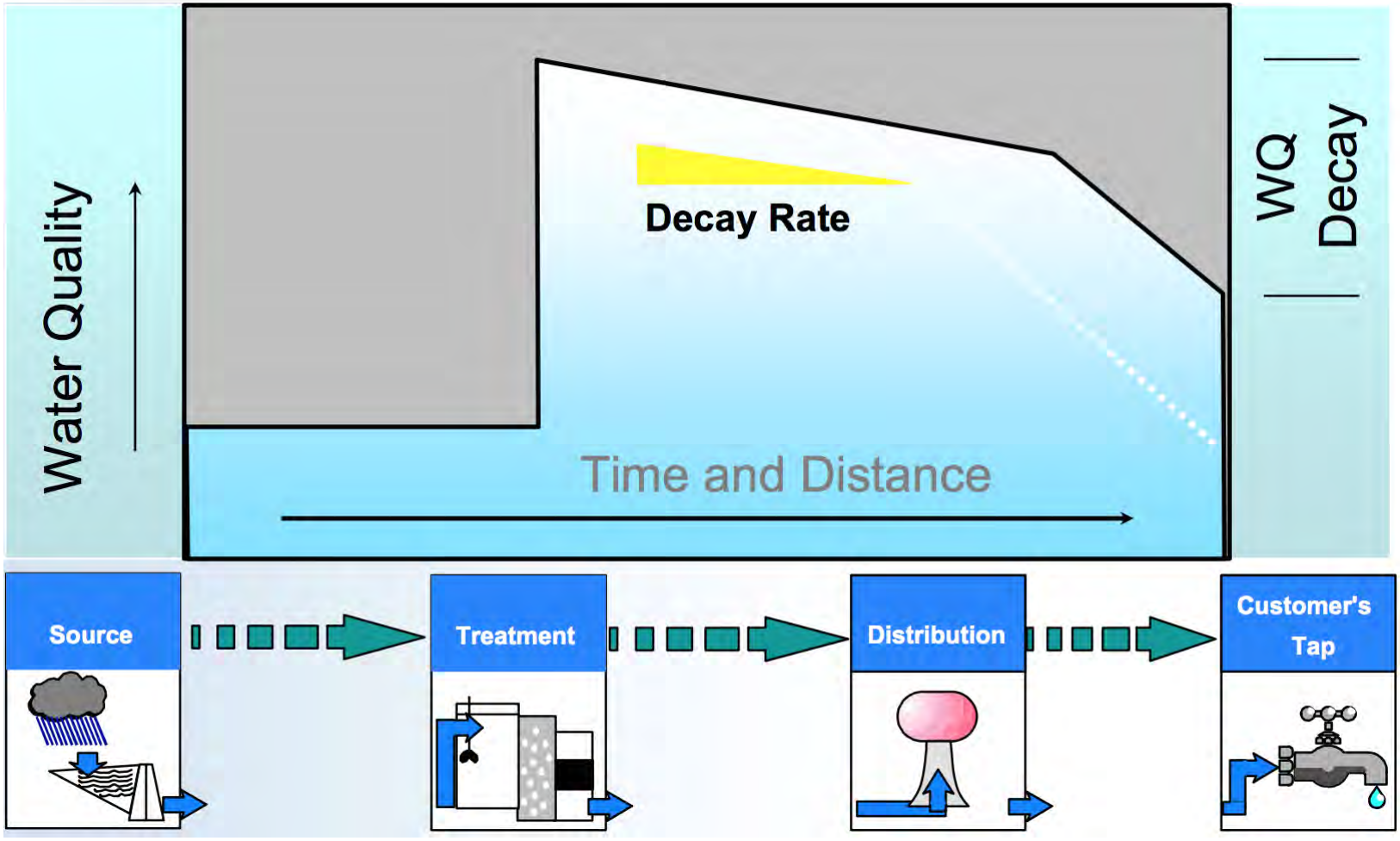
Water Quality Deterioration in Distribution Systems



Modified from EPA, 2009. Best Practices for Simultaneous Compliance

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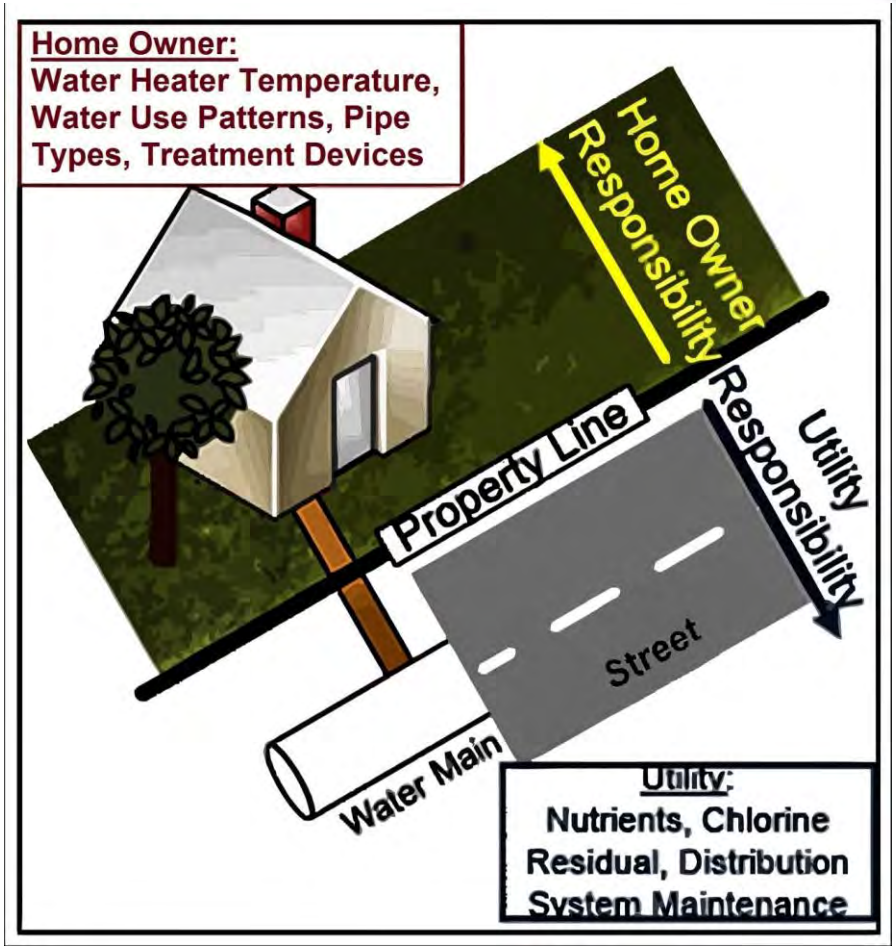
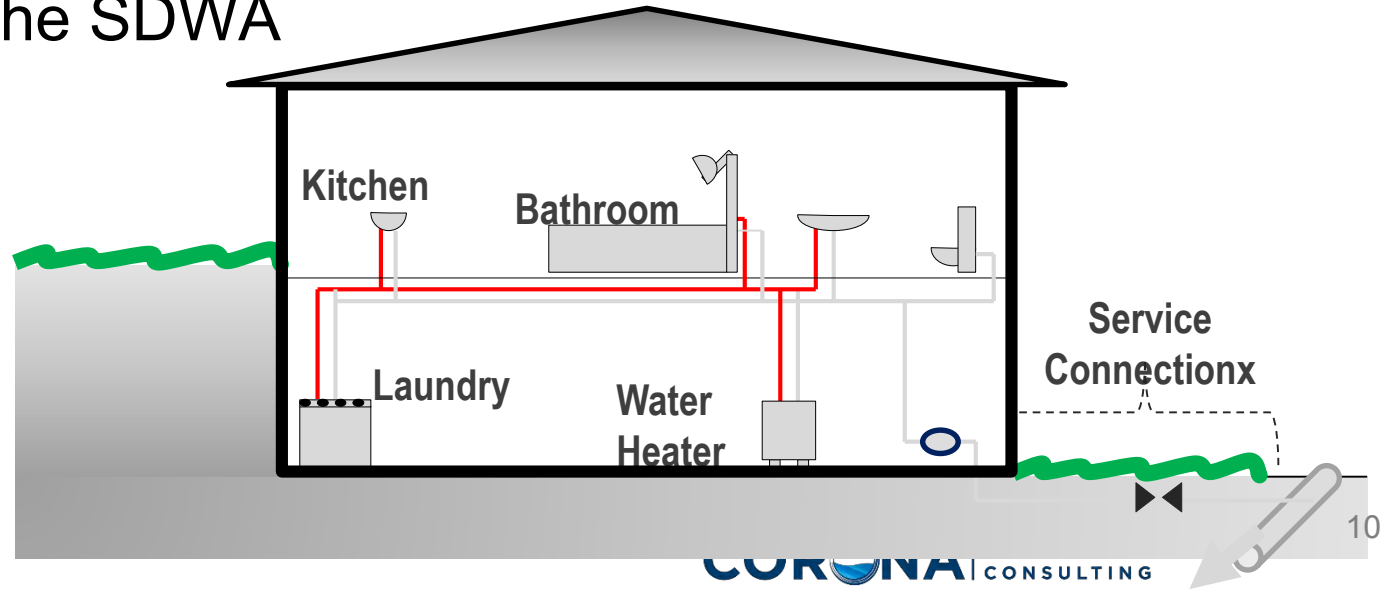
Premise Plumbing

The point from the service connection line from the public distribution system to private supply – schools, hospitals, hotels, businesses, private dwellings



Who is responsible for premise plumbing water quality?

- Water supplier is no longer legally responsible for WQ in the pipes
  - exception in US is the Lead and Copper Rule
- WQ responsibility becomes that of the building owner – individual, business, property manager
- Some buildings that receive treated water may be subject to the SDWA



Besides jurisdictional responsibility, is the premise plumbing simply an extension of the distribution mains?

Why is Premise Plumbing Unique?

- PP has all of the same WQ issues as the DW DS

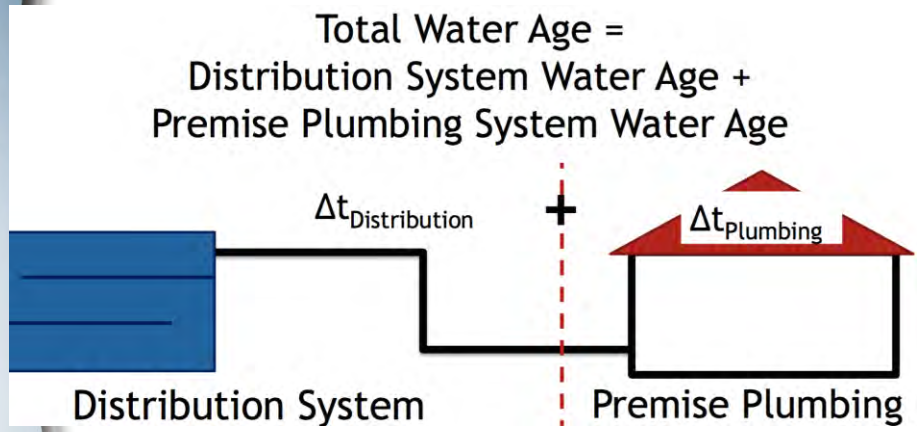
  ONLY TO A FAR GREATER EXTENT
- Lack of knowledgeable professionals to recognize, prevent or mitigate WQ problems
- Lack of regulation of WQ after it enters a building
- Addressed by the National Academy of Sciences (2006) in a report on water supply DS risks

Premise Plumbing Challenges: High Surface Area to Volume Ratio

- ~10 times more surface area per unit length compared to mains
- ¼ of the total surface area in the DS
- <2% of the total volume of water in the system
- The greater surface area increases microbial growth, chemical leaching and ultimately higher disinfectant residual decay rates

National Academy of Science, 2006

Premise Plumbing Challenges: High Water Age



Rhoads et al, 2015

http://www.firstdigitalghana.com/green-building-as-a-business-imperative/

Every building is a dead end:

Disinfectant decays

Nitrification and regrowth increases

DBP formation

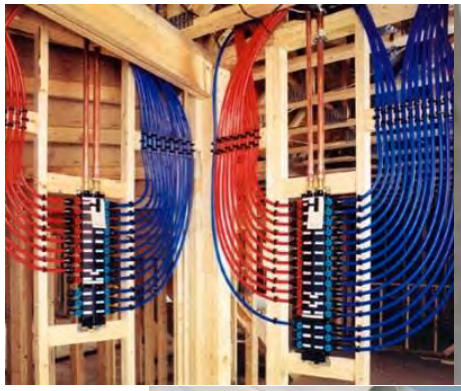
Water age issues likely to increase:

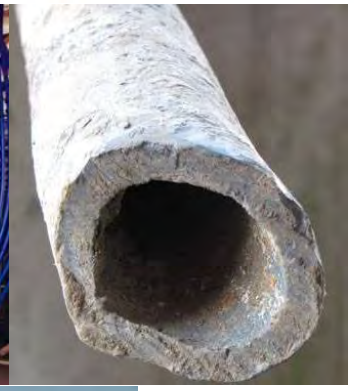
- More green buildings (water age orders of magnitude higher)
- Installing of low flow fixtures
- Changing consumer behavior

Premise Plumbing Challenges: Presence of Different Materials

Main Materials

Premise Plumbing Materials





Premise Plumbing Challenges:
Unit Processes in Premise Plumbing:

Photo from *MN Department of Health (2013)*

GAC Filters:

- Remove chemical contaminants but also remove disinfectant

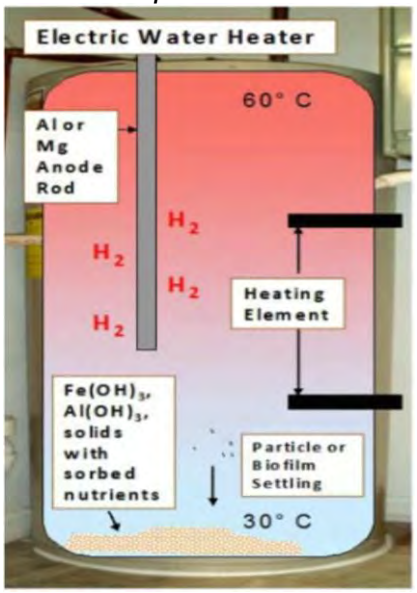


Photo from *Pruden et al. (2014)*

Water heaters:

- Extreme temperatures cause rapid disinfectant decay
- Can create ideal conditions for pathogen growth

Legionella

- Can grow at elevated temperatures and survive and multiply in hot water heaters (25-42°C, [77-108°F]).
  - Incubators for *Legionella*
- Becomes established in premise plumbing biofilms and is difficult to eradicate
- Colonize pipes, tanks, faucets, showerheads, etc.
- Outbreaks linked to all types of water features (pools, spas, showers, hot tubs, AC, ice makers, potting soils, windshield washer)

How can we maintain water quality in buildings?

How can we prevent Legionnaires' Disease?

We know how to control *Legionella* in building water systems

- Keep the cold water cold (below 20°C, 68°F) and the hot water hot (60°C, 140°F) – watch out for scalding
- Keep the water moving, avoid stagnation
- Maintain plumbing fixtures, clean hot water tanks
- Understand the building water system and how to manage it effectively
- Actively manage building water quality

But it is hard to disinfect a system with an established infestation

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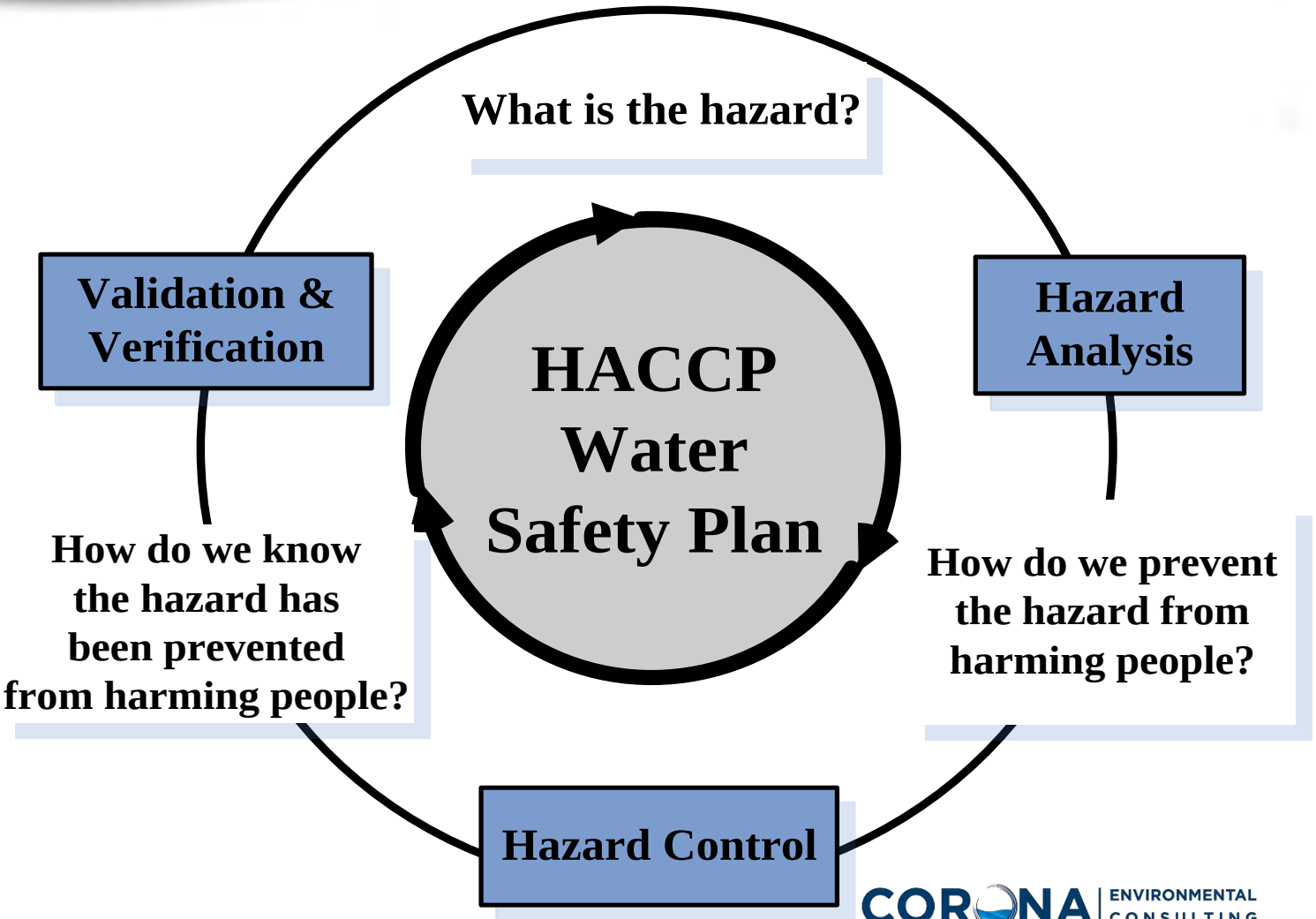
National Sanitation Foundation (NSF) International

Addressing building WQ in 2 ways:

- Developed and teach a course on Hazard Analysis and Critical Control Points (HACCP) for building water systems
  - "Buildings that have implemented HACCP have not had LD cases" - Claressa Lucas, Ph.D., Director of CDC's ELITE Program

- Developing a WQ standard for large buildings through the Joint Committee on Prevention of Injury and Disease Associated with Building Water Systems

HACCP *for* Building Water Systems



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Roles of Utilities vs Building Owners

- Utilities
  - Produce and deliver high quality DW to the customer
    - Require better understanding and management of DW quality at service connections
- Buildings
  - Take responsibility of WQ management from the meter
    - Education of building owners that this is their responsibility
    - Training (HACCP) as tool for this
    - Supplemental treatment when needed
    - Ongoing process to protect public health

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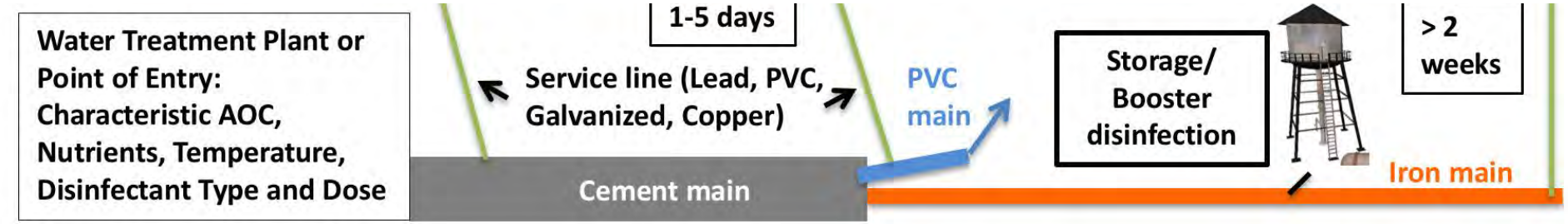
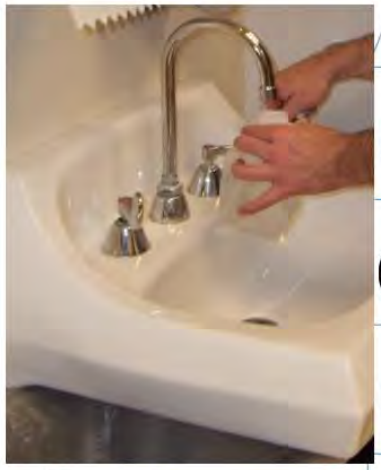
Influence of Utilities vs. Building Owner/Operators

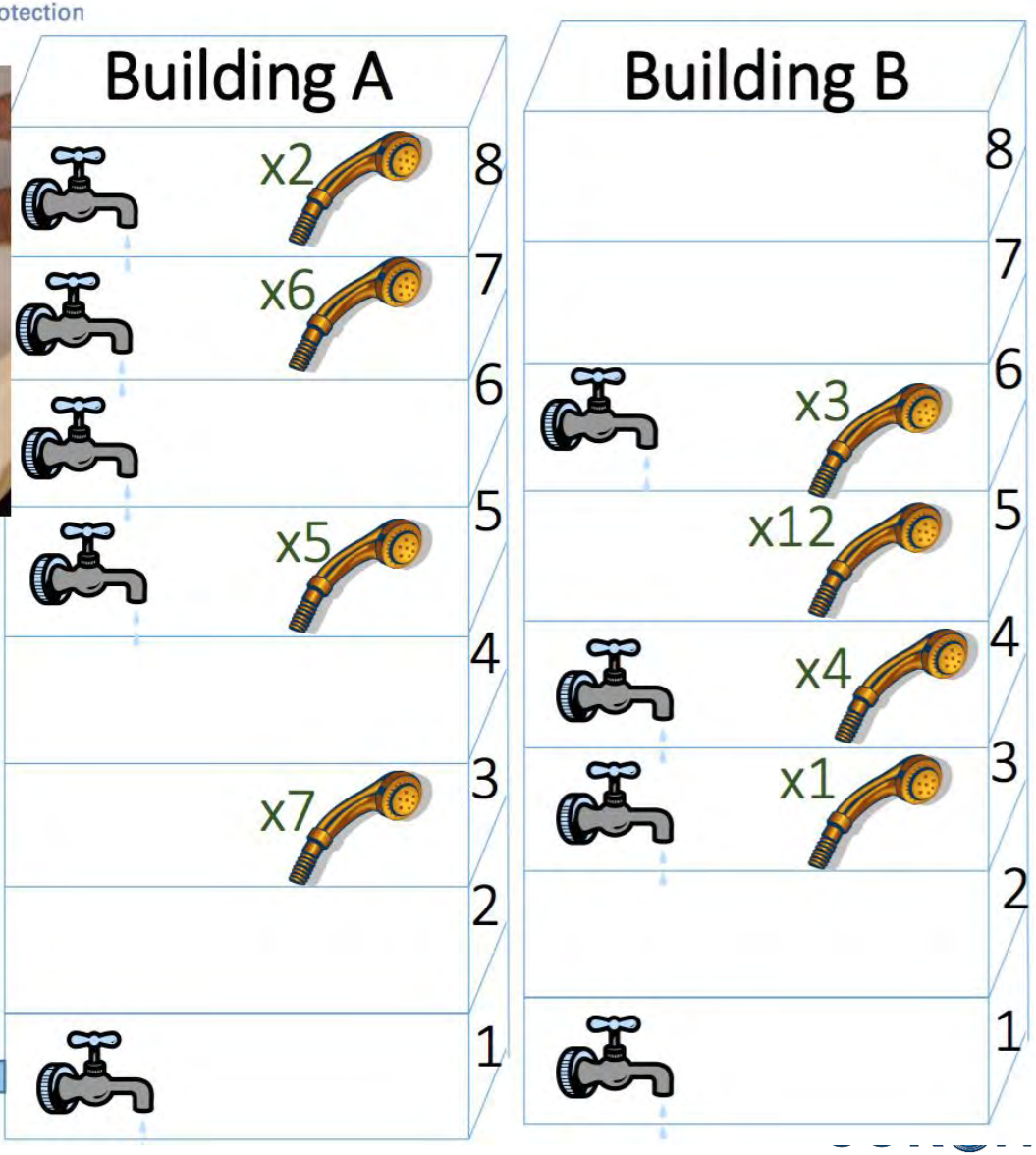


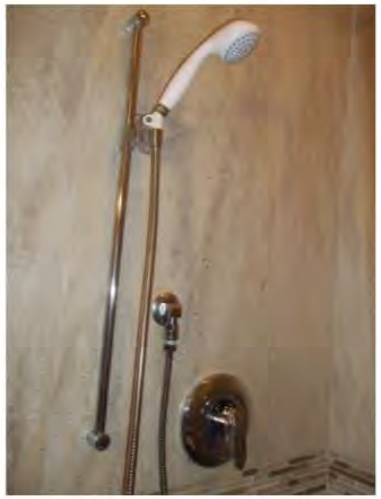
From Pruden et al. 2014

Hospital Buildings

EPA United States Environmental Protection Agency





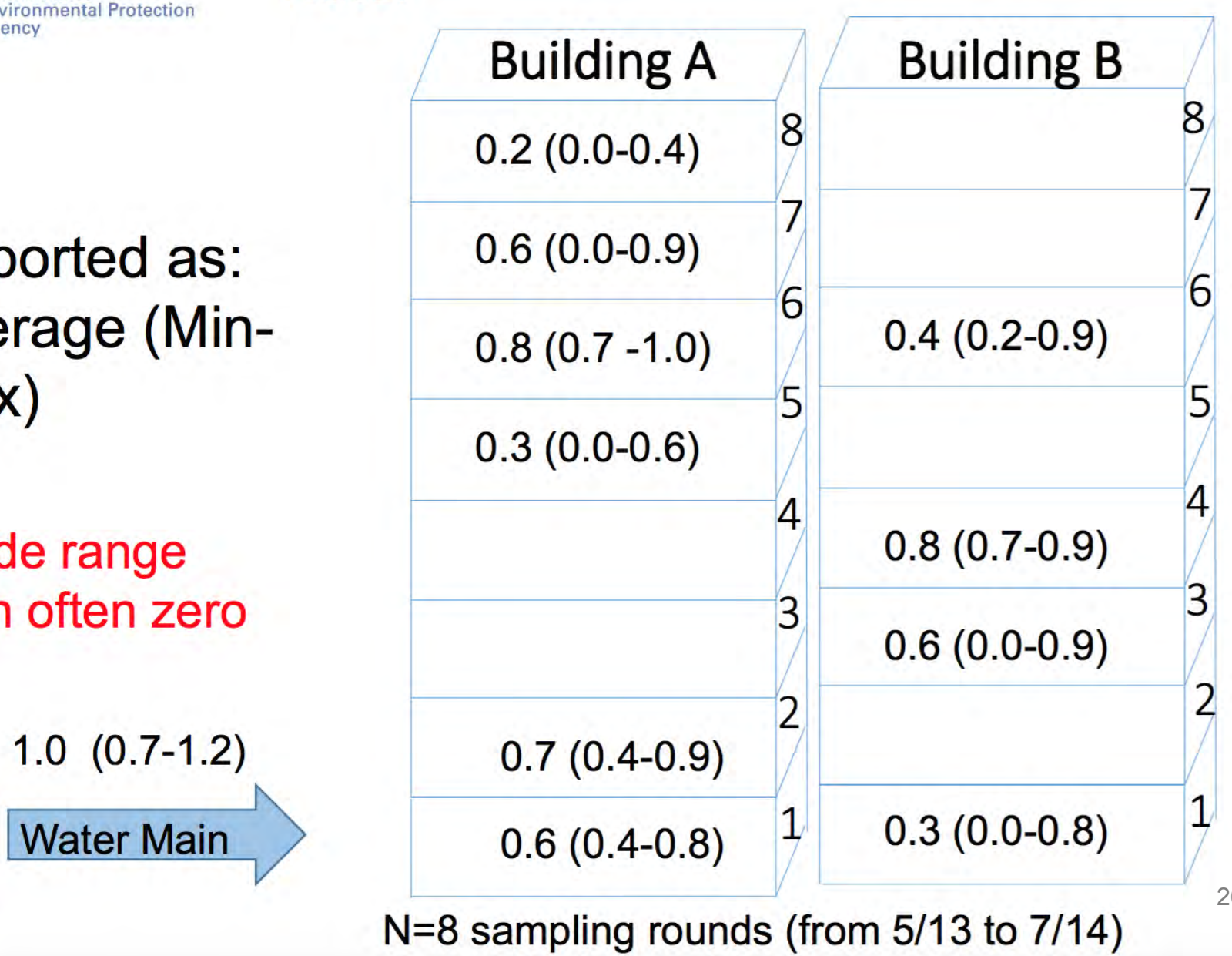


Free Chlorine (mg/L) in First-Draw Cold Water

United States Environmental Protection Agency

Reported as: Average (Min-Max)

Wide range
Min often zero



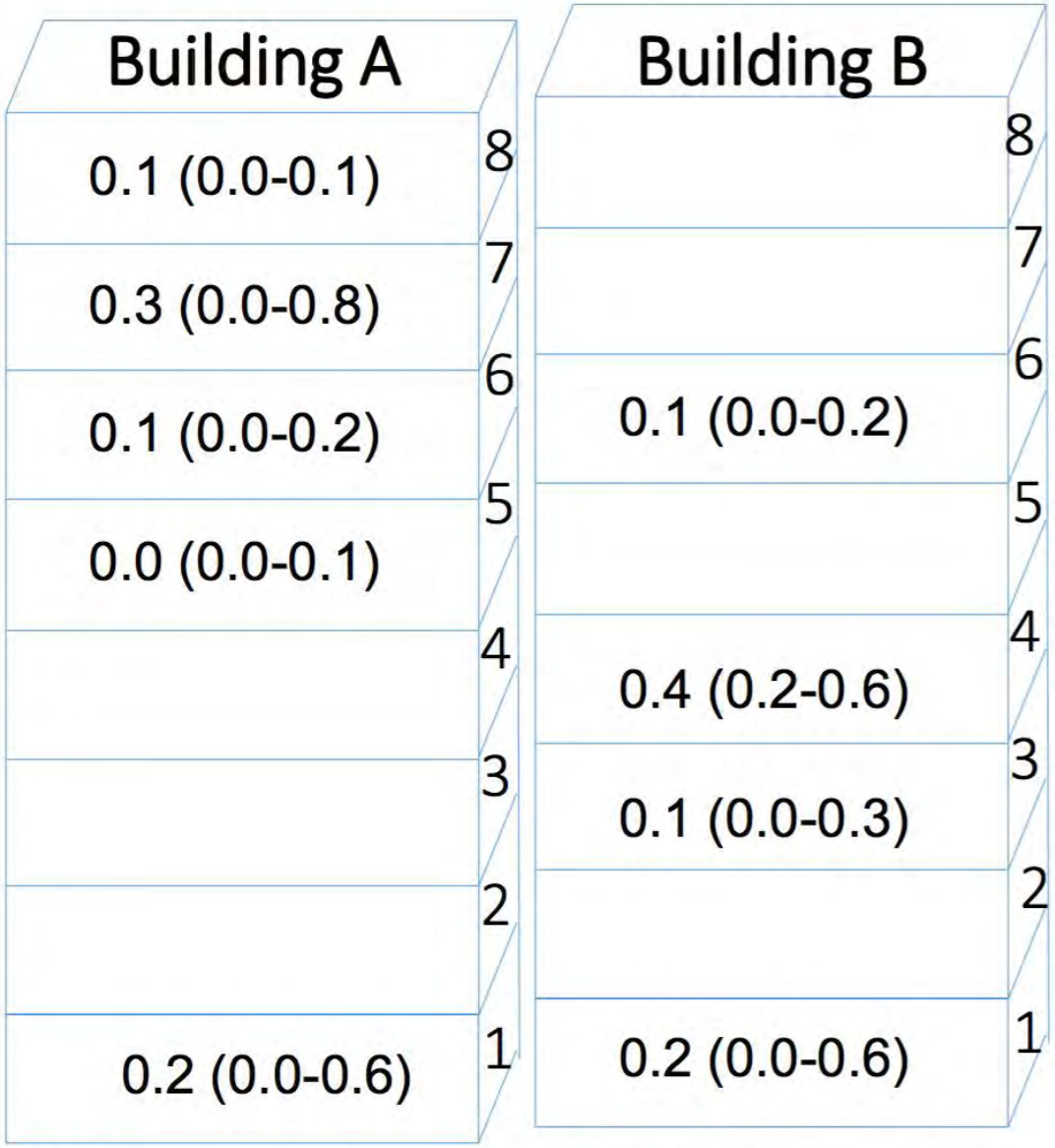
N=8 sampling rounds (from 5/13 to 7/14)

Free Chlorine in First Draw Hot Water

United States Environmental Protection Agency

Reported as: Average (Min-Max)

As expected, very low



1.0 mg/L (0.7-1.2)

Water Main

N=8 sampling rounds (from 5/13 to 7/14)

Conclusions

- Expect the water quality in buildings to change
- PP has the perfect storm for disinfectant decay:
  - High SA:V
  - Reactive pipe materials
  - Extreme temperatures
  - Long stagnation times
- Good water quality in the mains does not guarantee good water quality in buildings
- Create a plan for managing building water quality