Continuous Disinfection Systems for *Legionella* Bacteria Control

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Barclay Water Management, Inc. History

- Founded 1932
- ISO 9001 Certified
- Oldest and largest employee-owned water treatment organization in North America

Waterborne Pathogens

Legionella **bacteria**
Legionnaires' disease

Legionella bacteria

- Over 70 species – vary in degree of virulence (ability to cause disease)
- *Legionella pneumophila* species responsible for 90% of reported cases
- 15 serogroups for *Legionella pneumophila*
- *Legionella pneumophila* serogroup 1 responsible for most reported cases
- Most common in summer months

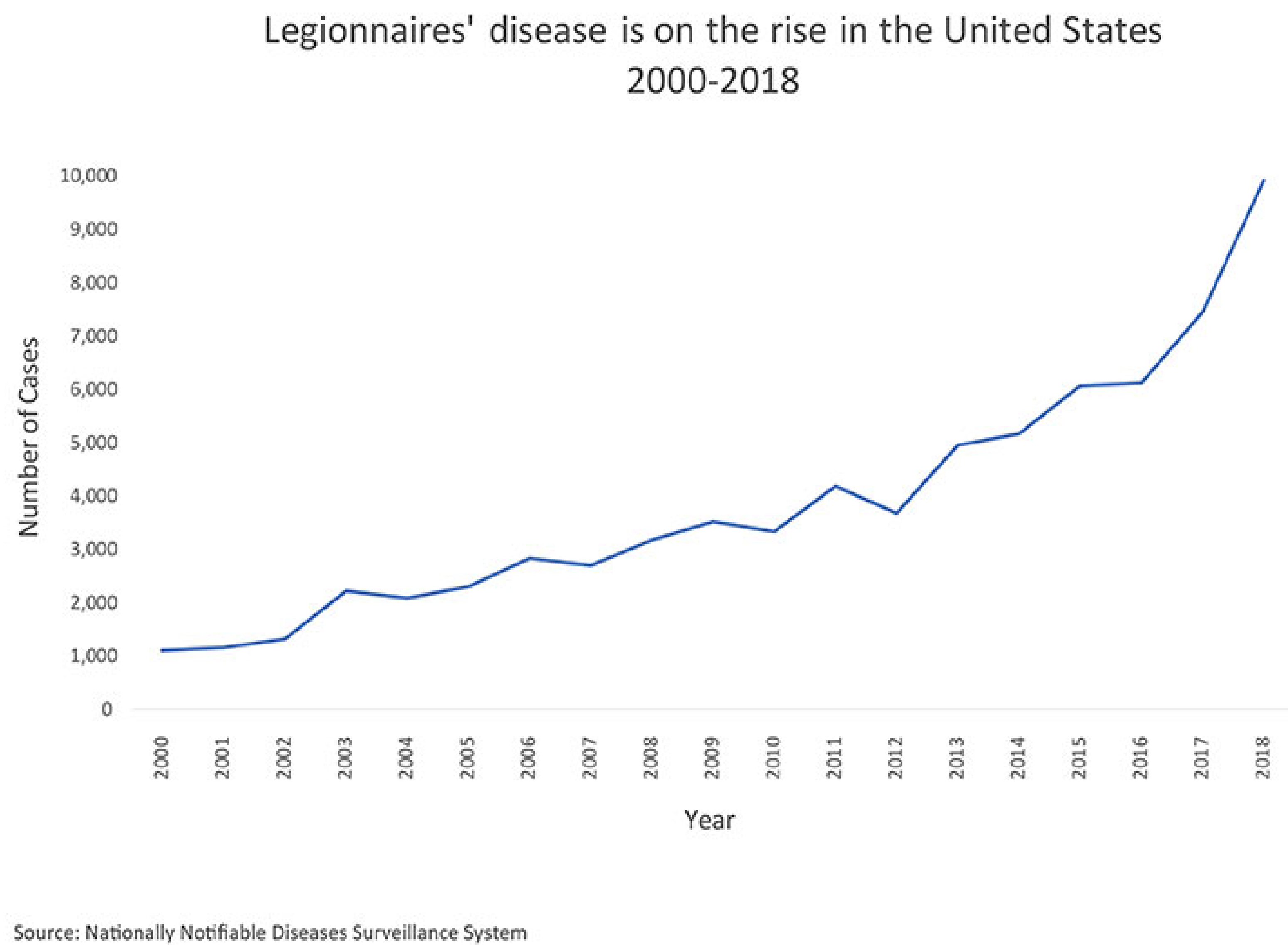
Legionella bacteria

- Inhale or aspirate water containing the bacteria to become infected, not transmitted person to person

"Premise plumbing systems can be colonized with *Legionella* and transmit the bacteria through aerosols generated from showers, humidifiers and spas associated with hot water distribution systems, as well as from respiratory therapy devices, ultrasonic mist machines, decorative fountains and industrial-use water. Aspiration of contaminated aerosols has also been associated with contaminated water and ice."
EPA Technologies for *Legionella* Control in Premise Plumbing Systems

- Legionnaires' disease:
  - 2-10 days after exposure – symptoms
  - Pneumonia-like illness
  - High morbidity rate (15-30%)
  - Long term effects for survivors

Legionella bacteria



Legionella Transmission From Nature to Human Disease

Steps 1 – 5 From The Environment To → Legionnaires' Disease

1.	2.	3.	4.	5.
Entry (*Legionella* entering Building Water Systems)	**Growth** (A significant increase in the numbers of *Legionella*)	**Transmission** (Aerosols from Faucets, Shower Heads, Cooling Towers, Fountains, Spa, Etc.)	**Exposure of Susceptible Human Host** (Multiply in Human Host)	**Legionnaires' Disease**
	Factors: Temperature Disinfectant Residual System Design Dirt/Sediment Nutrients Microbial Associations	**Factors:** Temperature Humidity Aerosol Production Distance from Source Microbial Associations	**Factors:** Ability of bacteria to cause disease Virulence Age Disease Immunodeficiency	
	Apply Control Measures	**Apply Control Measures**	**Apply Control Measures**	

Factors internal to buildings that can lead to *Legionella* growth

"The growth of *Legionella* within a premise plumbing system may be a function of the system's pipe or other plumbing materials, water temperature, water quality and other system-specific factors."

EPA Technologies for Legionella Control in Premise Plumbing Systems

Factors internal to buildings that can lead to *Legionella* growth

Biofilm: Protects *Legionella* from heat and disinfectant; provides food and shelter to germs; grows on any surface that is constantly moist and can last for decades

Scale and sediment: Uses up disinfectant and creates a protected home for *Legionella* and other germs

Water temperature fluctuations: Provide conditions where *Legionella* grows best (77°F–108°F); *Legionella* can still grow outside this range

Water pressure changes: Can cause biofilm to dislodge, colonizing downstream devices

pH: Disinfectants are most effective within a narrow range (approximately 6.5 to 8.5) Many things can cause the hot water temperature to drop into the range where *Legionella* can grow, including low settings on water heaters, heat loss as water travels through long pipes away from the heat source, mixing cold and hot water within the plumbing system, heat transfer (when cold and hot water pipes are too close together), or heat loss due to water stagnation. In hot weather, cold water in pipes can heat up into this range.

Inadequate disinfectant: Does not kill or inactivate *Legionella.* Even if the water entering your building is of high quality, it may contain *Legionella*. In some buildings, processes such as heating, storing, and filtering can degrade the quality of the water. These processes use up the disinfectant the water entered with, allowing the few *Legionella* that entered to grow into a large number if not controlled.

Water stagnation: Encourages biofilm growth and reduces temperature and levels of disinfectant. Common issues that contribute to water stagnation include renovations that lead to 'dead legs' and reduced building occupancy, which can occur in hotels during off-peak seasons, for example. Stagnation can also occur when fixtures go unused, like a rarely used shower in a hospital room.

Source: CDC

Decide Where Control Measures Should Be Applied

Control measures and limits should be established for each control point. See the diagram on the next page for the types of monitoring that could occur in Building A. You will need to monitor to ensure your control measures are performing as designed. Control limits, in which a chemical or physical parameter must be maintained, should include a minimum and a maximum value.

Examples of chemical and physical control measures and limits to reduce the risk of *Legionella* growth:

- Water quality should be measured throughout the system to ensure that changes that may lead to *Legionella* growth (such as a drop in chlorine levels) are not occurring.
- Water heaters should be maintained at appropriate temperatures.
- Decorative fountains should be kept free of debris and visible biofilm.
- Disinfectant and other chemical levels in cooling towers and hot tubs should be continuously maintained and regularly monitored. Surfaces with any visible biofilm (i.e., slime) should be cleaned.

Source: CDC

Legionella Control Measures

Multiple physical, chemical, and operational *Legionella* control measures can be applied together or individually to manage the physical and chemical conditions that facilitate intrusion, growth, and transmission of *Legionella*. Multiple control measures are often used in the same system. Available control measures include the following:

- Temperature control
- Supplemental disinfection/treatment
- Filtration
- Flushing
- Recirculation
- Cleaning and maintenance

ASHRAE Guideline 12-2020

Supplemental disinfection systems overview

Legionella Control in Premise Plumbing Systems	
Chemical treatment technologies: • Chlorine-based disinfection • Copper-silver ionization (CSI) • Ozonation	**Physical treatment technologies:** • Thermal inactivation • Filtration • Ozonation
Emerging treatment technologies: • Ultraviolet (UV) irradiation • UV light emitting diodes (LEDs) • Innovative point-of-use (POU) filters	**Other strategies:** • Superheat-and-flush disinfection • Shock hyperchlorination

Figure 2. Current treatment technologies for control of *Legionella* in premise plumbing systems.

Chlorine based disinfection includes Sodium hypochlorite, Chlorine dioxide, and Monochloramine: combination of concentration and reaction time is expressed as C (mg/L) × T (min) or CT

Water **2020**, *12*, 676; doi:10.3390/w12030676

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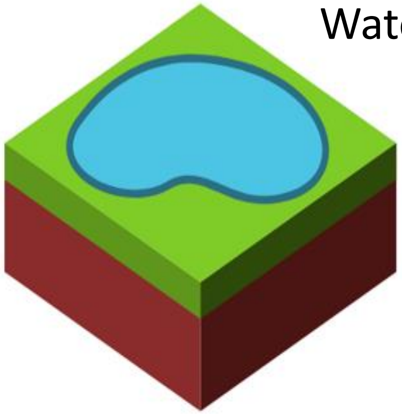
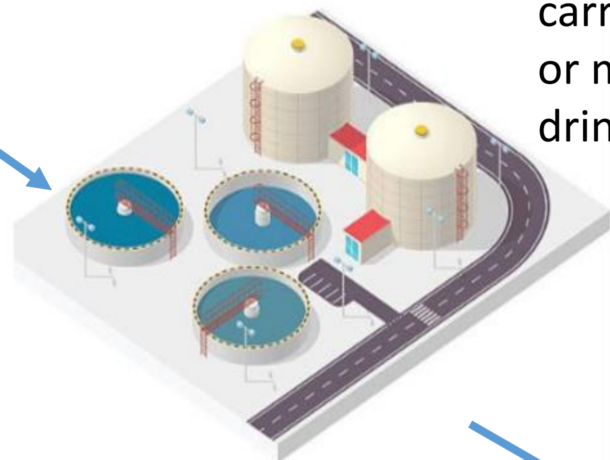
United States Environmental Protection Agency

Office of Water
EPA 810-R-16-001
September 2016

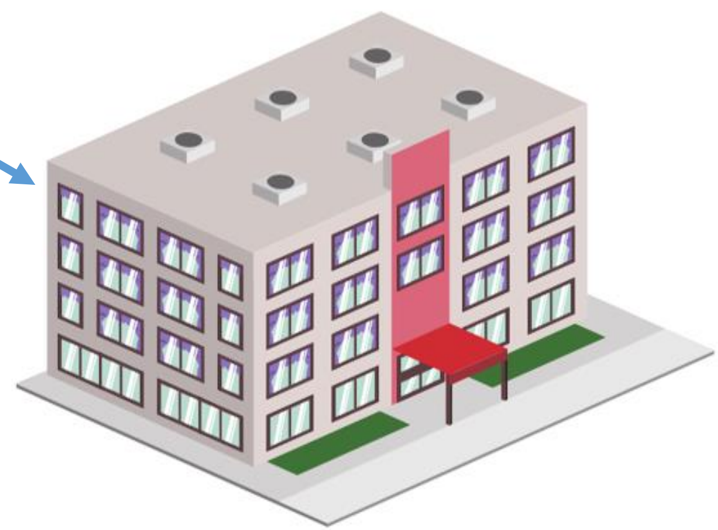
Technologies for *Legionella* Control in Premise Plumbing Systems: Scientific Literature Review



Water Source: Ground or Surface



Municipality applies many treatment strategies. The final carrying disinfectant is free chlorine or monochloramine per EPA drinking water regulations



Continuous Supplemental Disinfection – monochloramine, copper silver, chlorine dioxide, free chlorine – after backflow prevention

Continuous Disinfection: Public Water System

Public Water Systems:

Premise plumbing is used to deliver water intended for human consumption. The U.S. Environmental Protection Agency (EPA) defines water "intended for human consumption" as water used for drinking, bathing, showering, hand washing, teeth brushing, food preparation, dishwashing and maintaining oral hygiene.

A public water system provides water for human consumption through pipes or other constructed conveyances to at least 15 service connections or serves an average of at least 25 people for at least 60 days a year. A public water system may be publicly or privately owned.

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Continuous Disinfection: Public Water System

- When adding continuous disinfection, work closely with supplier to maintain Ohio EPA drinking water regulations
- Adding continuous disinfection to **hot or cold** domestic water systems: become a Public Water System
- Initial PWS application – may take months to create and get approved
- Ongoing monitoring requirements
  - Operator
  - Submission of data
  - On-site testing requirements
  - Grab sample requirements
    - Lead/Copper
    - DBP
    - Coliform

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Continuous Disinfection: Common Guidelines

- ✓ Flush systems to see adequate disinfection agent
- ✓ Maintain and service equipment
- ✓ Monitor levels
- ✓ Validate
- ✓ Document and keep records

Sodium Hypochlorite (Free Chlorine)

- Easy to access, install, and use
- Used in drinking water for over 100 years
- Inexpensive

- Extremely corrosive to piping
- Highly reactive (ie, not stable); does not penetrate biofilm
- In studies, less effective than monochloramine and chlorine dioxide against *Legionella* bacteria as measured by CT
- Taste and odor concerns

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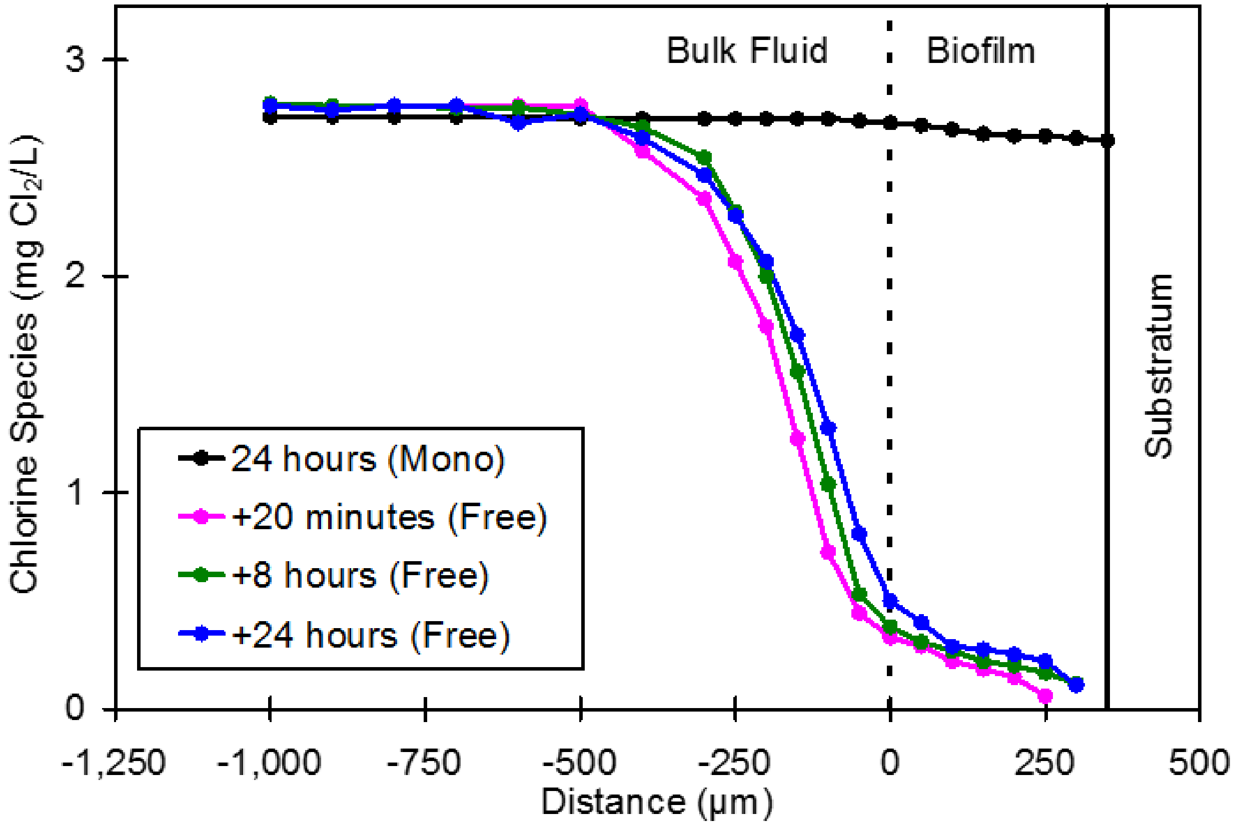
Monochloramine vs Free Chlorine

Biofilm Penetration

- Monochloramine → complete penetration
- Free chlorine → penetration depth stabilizes
- Different reactivity with biofilm



Lee, W. H.; Wahman, D. G.; Bishop, P. L.; Pressman, J. G., Free chlorine and monochloramine application to nitrifying biofilm: comparison of biofilm penetration, activity, and viability. *Environ. Sci. Technol.* **2011,** *45*, (4), 1412–1419.

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Chlorine Dioxide

- Effective against *Legionella* and other types of bacteria
- No taste and odor concerns
- Effective over a wide range of pH levels

- Extremely corrosive to piping
- Degrades quickly (especially in hot water systems)
- Dosage limit of 0.8 ppm; 1.0 ppm chlorite
  - Daily testing for chlorite
- Penetrates biofilm more effectively than free chlorine; not as effectively as monochloramine

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Chlorine Dioxide

- Case study:
  - Treated for *Legionella* for 40 months with Chlorine Dioxide concentrations between 0.5 and 0.7mg/L
  - Significant reduction in *Legionella*
  - Percent positivity was still 20% in cold water, and 10% in hot water after 40 months

Water **2020**, *12*, 676; doi:10.3390/w12030676; source 93

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Copper- Silver Ionization

- No precursor chemical storage needed; not much room needed for equipment
- Copper and Silver used in conjunction result in a higher inactivation rate
  - Copper destroys cell wall permeability, silver interferes with synthesis of proteins and enzymes

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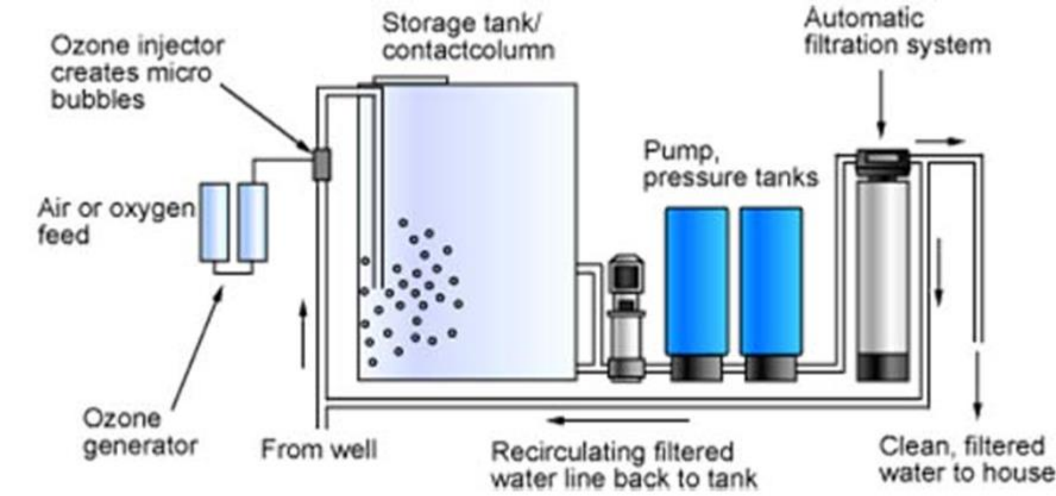
- pH restriction of 8.0; otherwise will precipitate out causing galvanic corrosion
- Plates must be soaked in strong acid to clean
- Dosage limit: 1.3 ppm Copper, 0.1 ppm Silver
- Negative aesthetic effects (stains in sink porcelain)
- Unreliable results in reducing bacteria especially in distal sites

Ozonation

- Oxidizer; works by disrupting the cell
- Widespread use in drinking water
- Ozone and UV disinfection do **not** produce a disinfectant residual. Therefore, water may be susceptible to subsequent contamination unless supplemental treatment is provided. For these reasons, more than one type of treatment or control measure may be necessary to inhibit *Legionella* growth in these systems
- Rapid decay under tap water conditions
- Can produce byproducts (bromate)



Water **2020**, *12*, 676; doi:10.3390/w12030676; source 121-123

Ozonation

- Case study:

Table 5. Comparison of positivity before and after ozonation in a premise plumbing system. Adapted from Blanc et al. [121].

	Percent Positivity	CFU/mL	*p*-Value
Before ozonation	(66/100) 66%	10.9 ± 17	0.12
After ozonation	(67/120) 56%	5.2 ± 9.7	

- Studies show may not be as effective at controlling *Legionella* as other strategies

Water **2020**, *12*, *676*; doi:10.3390/w12030676; source 121-123

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UV Irradiation and UV Light Emitting Diodes (LEDs)

- Studies indicate reduction in *Legionella*
  - May prevent *Legionella* from entering a system
- No disinfection residual
  - Will not protect against downstream biofilm
- No byproducts formed

- Hazardous- Mercury contamination if lamp breaks
  - If LED lamps are used, no possible mercury contamination
- LED may be more effective by using targeted wavelengths
- Need to maintain cleanliness of UV (iron, manganese, hardness may build up on UV)
- Need to replace UV periodically to maintain intensity

Water **2020**, *12*, *676*; doi:10.3390/w12030676; source 137-141

Filtration/ Point-of-use Filters

- Placed on faucets and showers
- No disinfectant residual
- <0.2 micron size
  - Needs routinely replaced to remain effective
- Has been proven in studies to eliminate *Legionella* bacteria in the finished water
- Ongoing costs for filters and labor
  - Typically used for temporary measures for remediation due to ongoing costs and labor

Water **2020**, *12*, 676; doi:10.3390/w12030676; source 127. 128, 113

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Monochloramine

- Very effective against *Legionella* bacteria (CT) and biofilm penetration
- Stable under varying water temperatures
  - Persists in the water system
- Less corrosive than free chlorine or chorine dioxide
- Like free chlorine, used in drinking water for over 100 years

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- Proper ratio of precursor chemicals must be used

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Monochloramine

"Our study demonstrated that *Legionella* colonization in a plumbing system was effectively eliminated by monochloramine. Hospitals or other facilities colonized with *Legionella* spp. might control *Legionella* growth and prevent disease transmission by adding monochloramine to their potable water system."

San Francisco transition from free chlorine to monochloramine

Flannery et al 2006- EID- CDC 12:588-595

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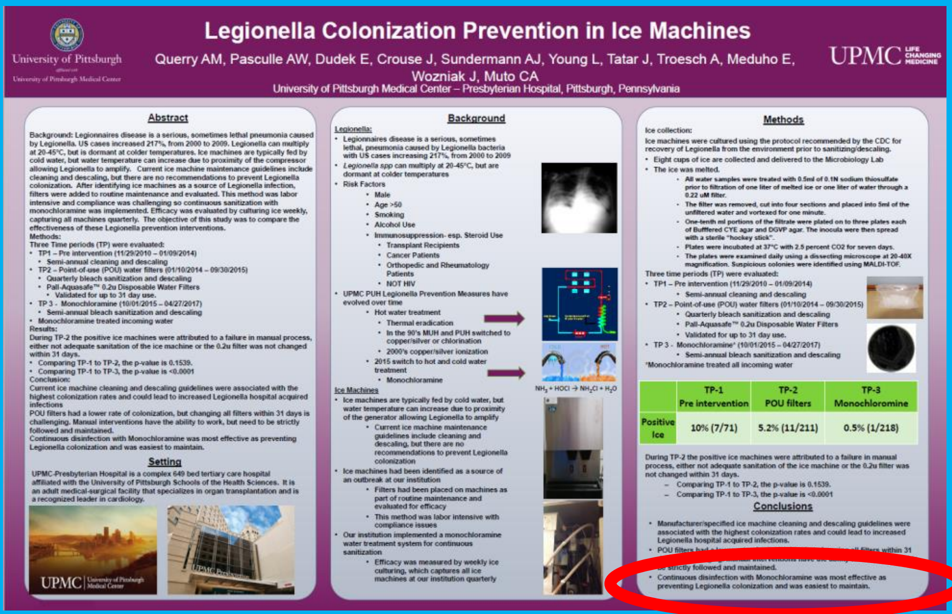
Monochloramine: Ice Machines



“Continuous disinfection with Monochloramine was most effective at preventing *Legionella* colonization and was easiest to maintain.”

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Thank You!