Potential for flow rate to impact growth of *Legionella* in building plumbing

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💧Water INTERFace
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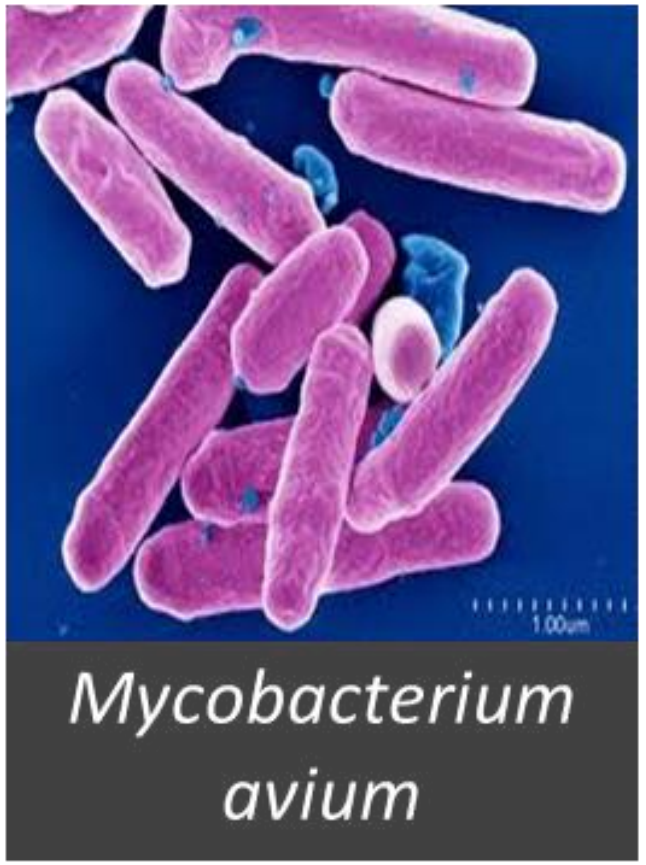
Opportunistic pathogens (OPs)-
infect (mainly) immunosuppressed individuals

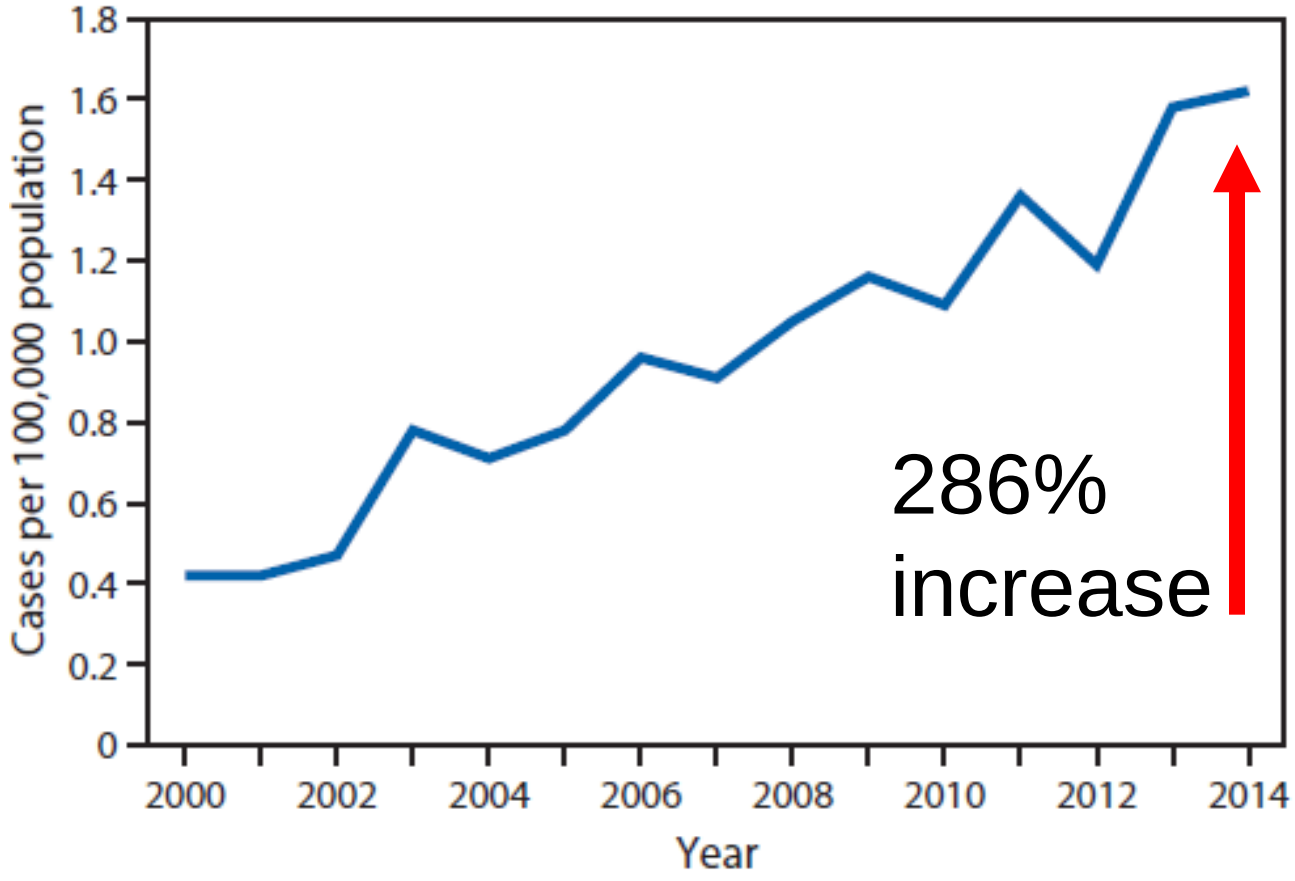
- **8k-18k cases/yr**
- **$430M/yr**
- Caused all 31 reported respiratory waterborne disease outbreaks 2007-10



- **100 cases/10^5 people >60yrs**
- **$425M/yr**
- Only recently linked to drinking water

Legionella epidemiology

- ~5000 cases/yr reported
- ~9% fatal (5-32%)
- 2011-2012 – 66% potable-water-associated disease outbreaks *Legionella* related



https://www.cdc.gov/mmwr/volumes/65/wr/mm6522e1.htm#F1_down

Domestic plumbing characteristics and stakeholders

Utility

- General water quality
- Distribution system

Building Owner/Operator

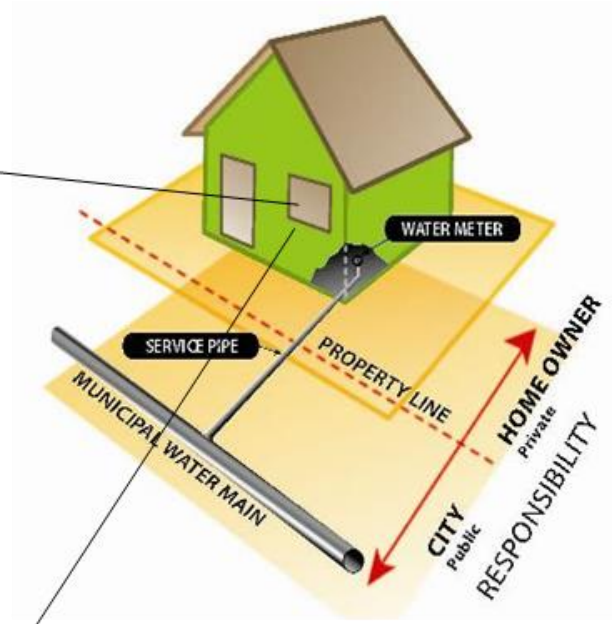
- Water use pattern
- Material selection
- In-building treatment

Everyone Else

- Plumbers, consultants, manufacturers, code/standard orgs

Domestic Plumbing

-High water age
-Low residual
-Warm Temp
-Variable material
-Variable flow
-SA:V ratio



Randi Brazeau,
Sheldon Masters

(Some of the) Engineering Control Strategies

1) Limiting Nutrient Strategies (e.g., AOC)
2) **Secondary Residual Type and Dose**
3) Upgrade Water Mains/**Corrosion Control**
4) In-Building Disinfection
5) Water Heater Set Point
6) Thermal Shock Treatments
7) Pipe Material Selection
8) **Flow Control**
9) Heater Selection
10) Water Age

Other important aspects of flow

- What conditions it delivers
- How frequently it occurs
- How the pipes are designed

Growth dependent on conditions delivered by flow

Conventional wisdom: Flow is better

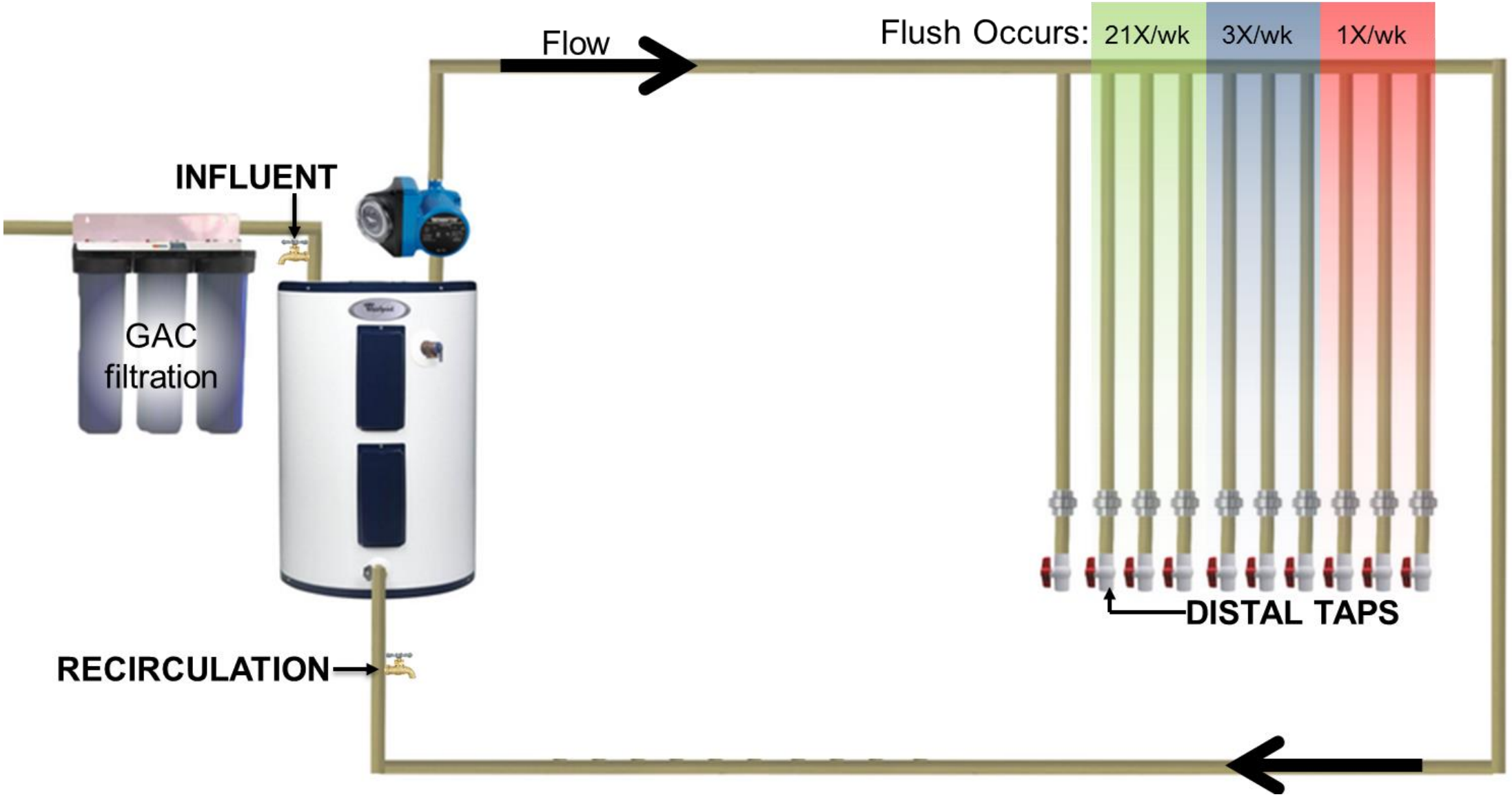
- When flow deliverers high temperature or chemical disinfectant to taps

Ciesielski et al., 1984; Harper, 1988; OSHA, ASHRAE; Muraca et al., 1987; Stout et al., 1987

Contrary to wisdom: Flow is worse

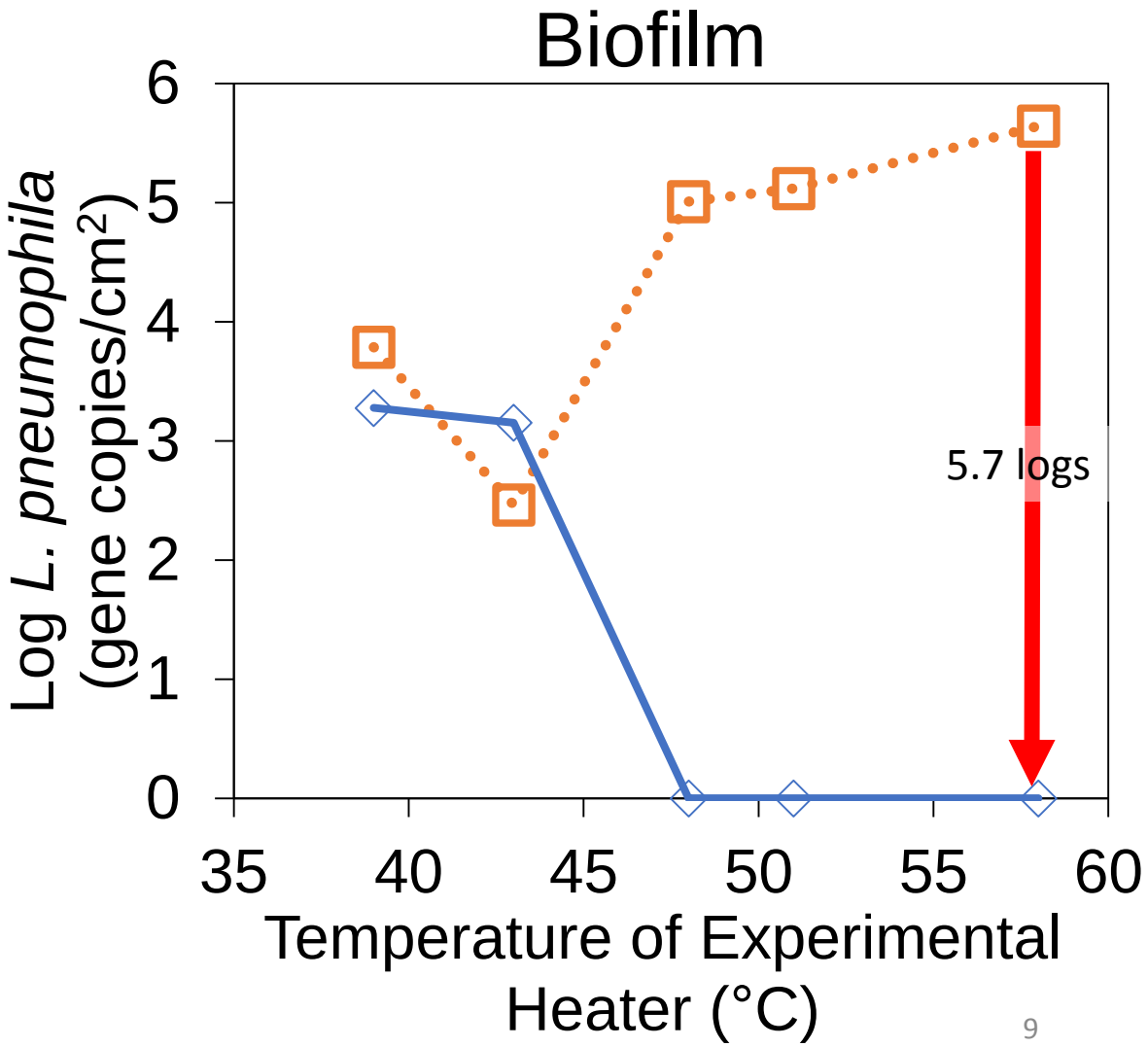
- When flow delivers ideal growth temperatures and nutrients

Liu et al., 2006



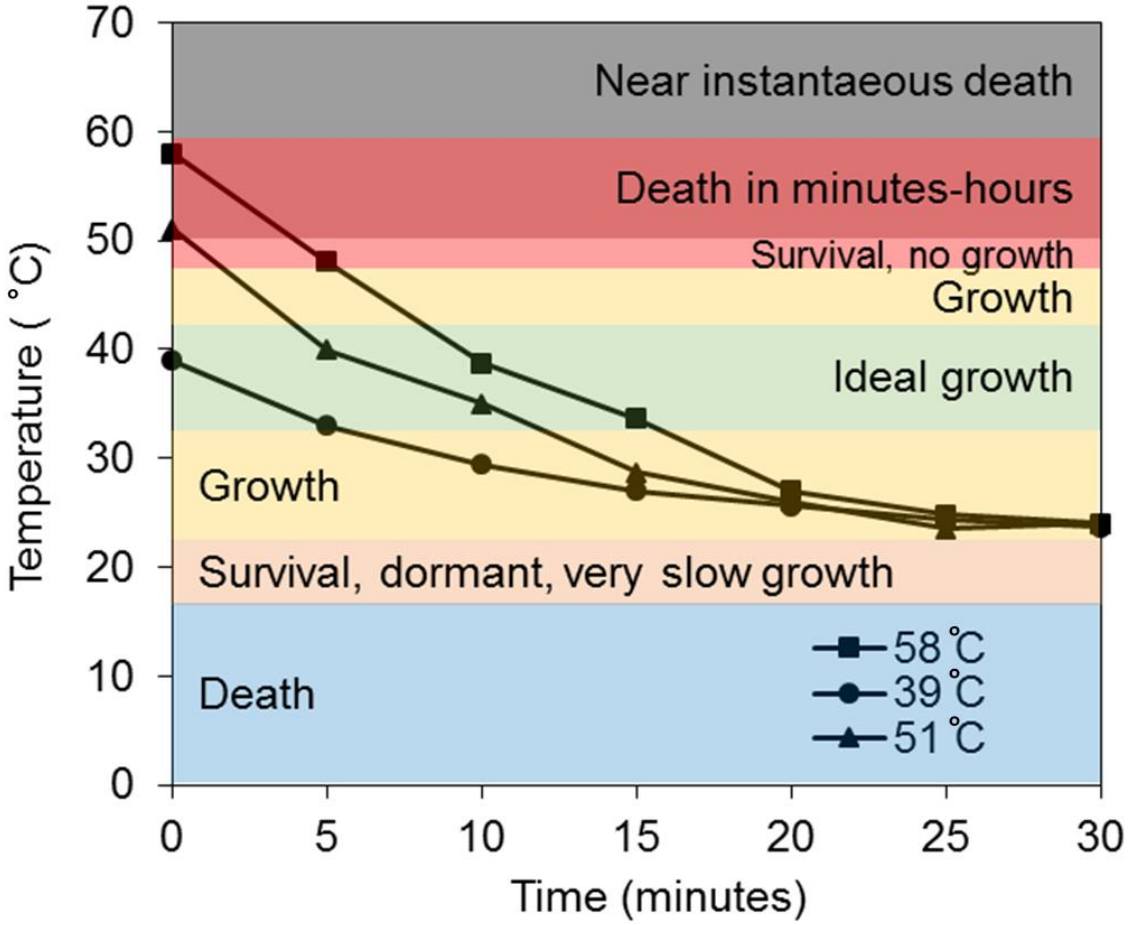
Two identical systems: 40° C vs Variable T (40-60 ° C)
Three use frequencies (water age in distal pipes): High, Med, Low
No disinfectant residual.

Growth dependent on conditions delivered by flow

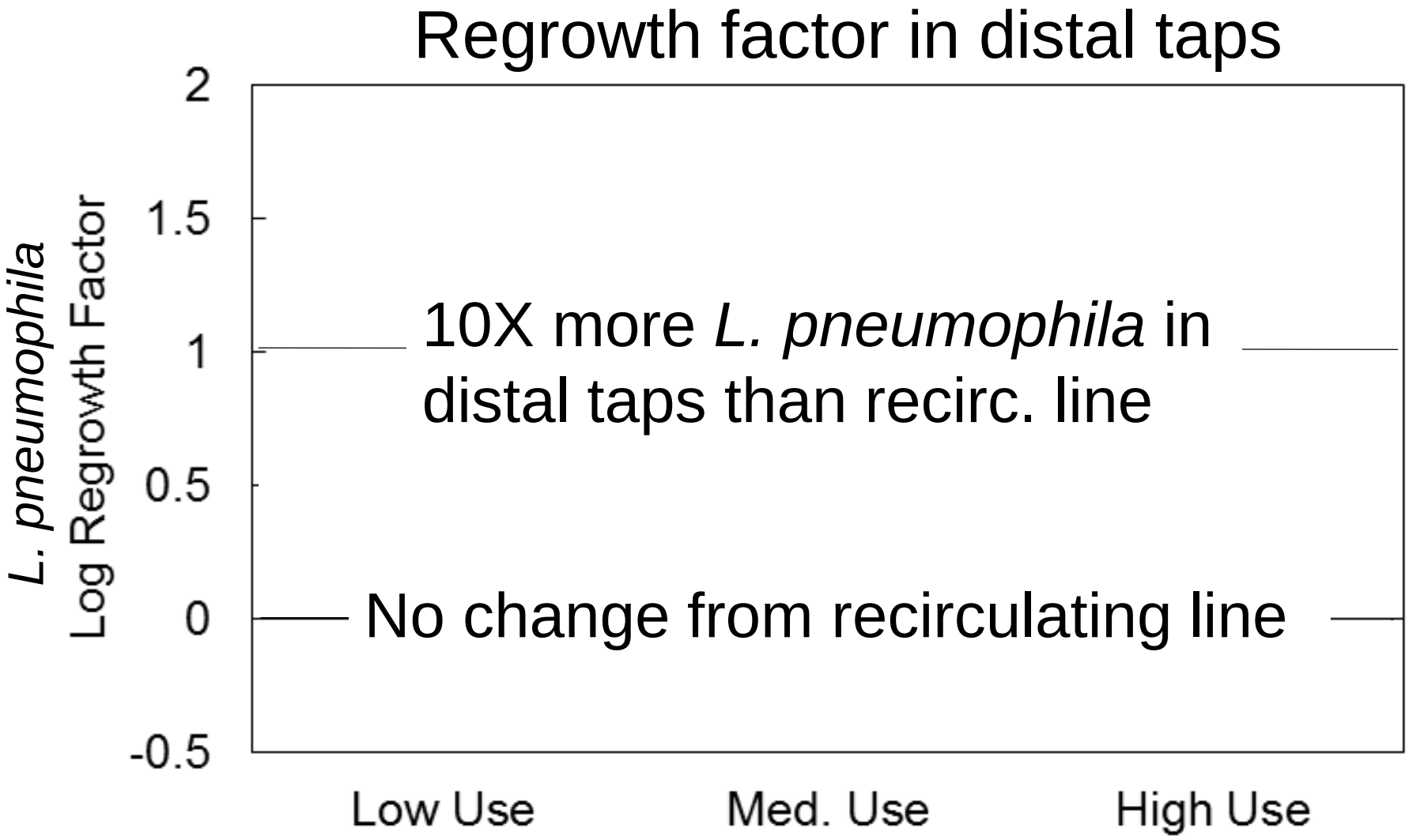


Growth dependent on frequency of flow

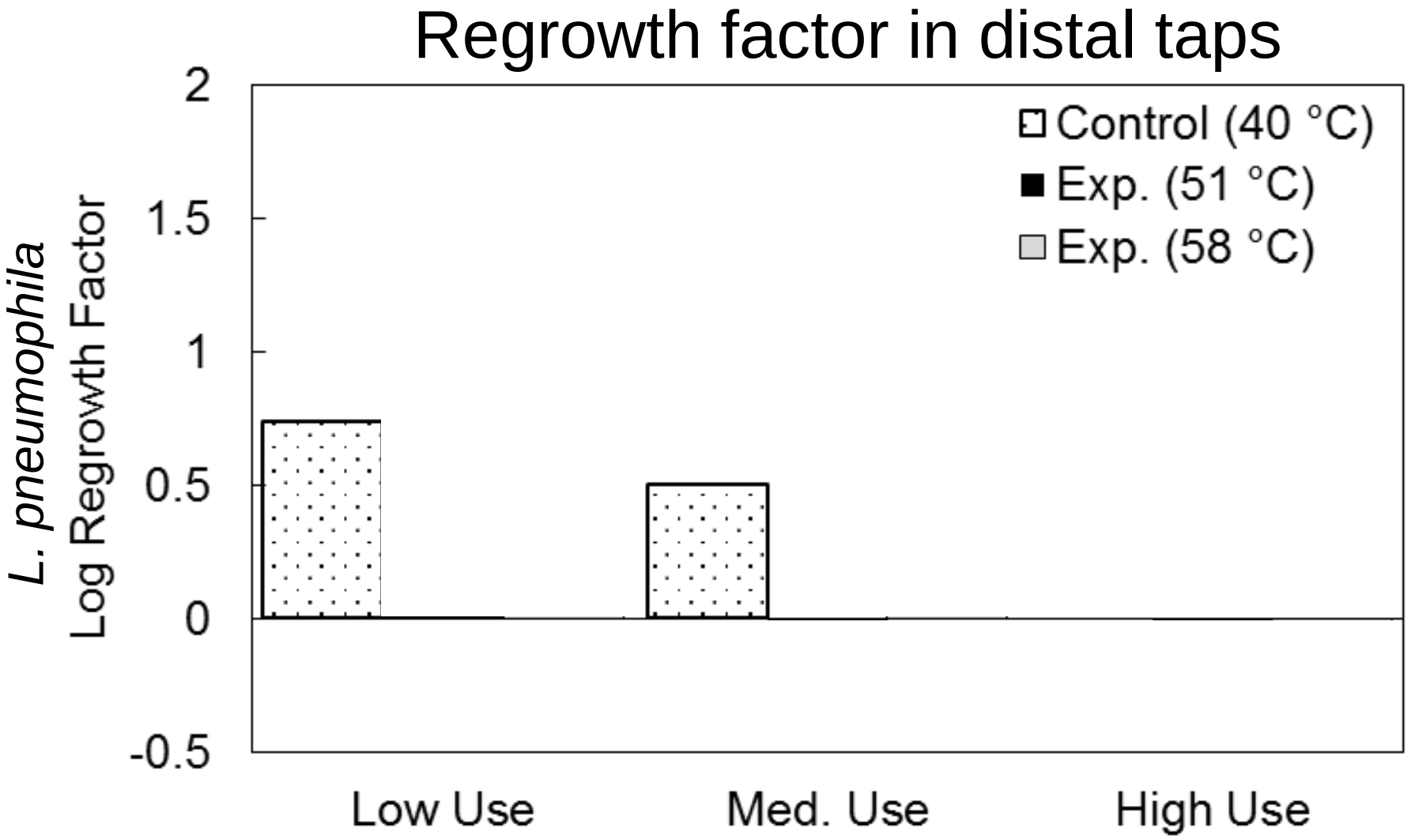
Temp. profiles after use



Growth dependent on frequency of flow



Growth dependent on frequency of flow



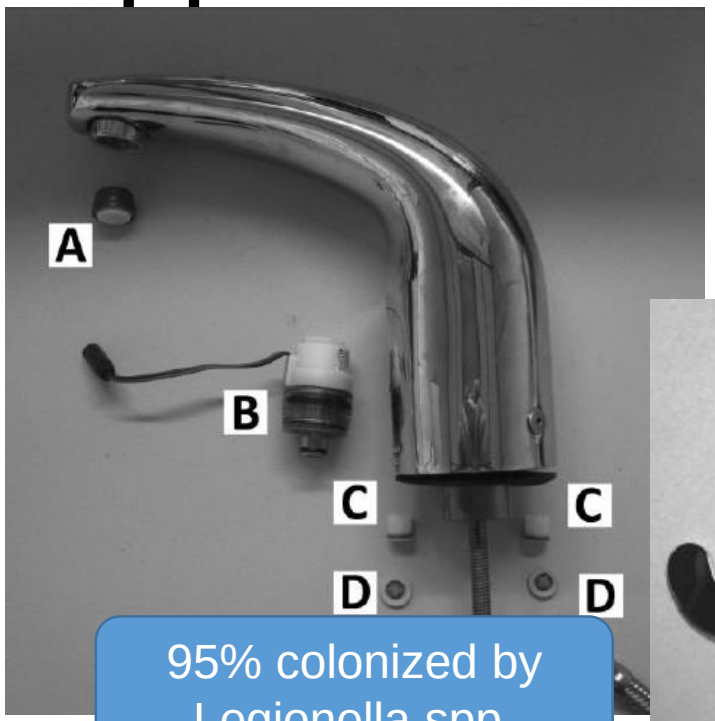
Growth dependent on how pipes are designed

50 sec flush through ¾” pipes

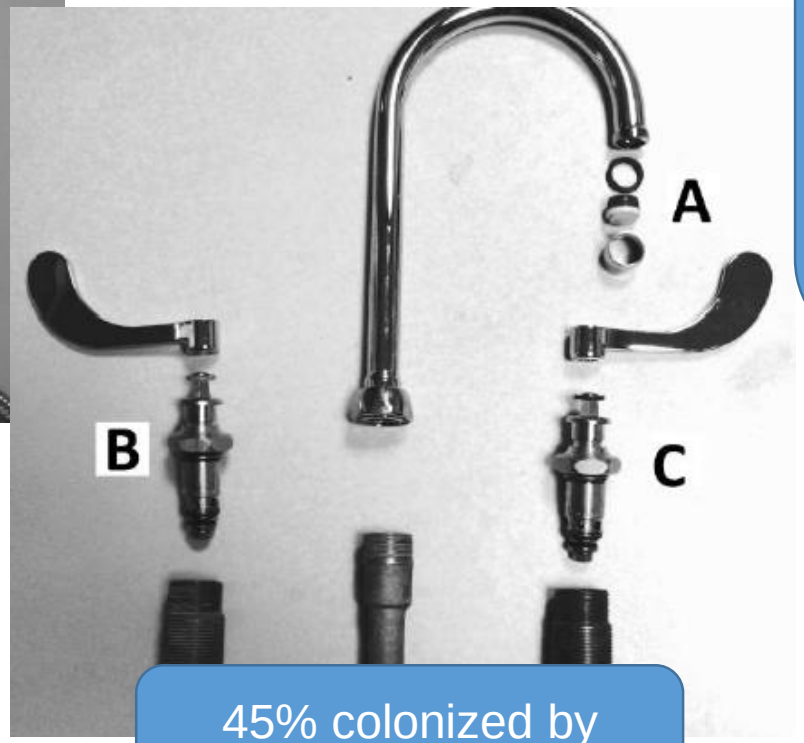
- T_{cold} = 10 °C; T_{hot} = 40 °C; T_{mix} = 37 °C
  - @0.5 gpm – 0.38 gallons hot water used – 16 ft of pipe
  - @2.2 gpm – 1.65 gallons hot water used – 71 ft of pipe
- T_{cold} = 30 °C; T_{hot} = 60 °C; T_{mix} = 37 °C
  - @0.5 gpm – 0.1 gallons hot water used – 4.2 ft of pipe
  - @2.2 gpm – 1.65 gallons hot water used – 18.6 ft of pipe

Conflict between using best management practice temperature setting, and water age in individual hot distal pipes

Opportunistic Pathogen Growth



95% colonized by Legionella spp.



45% colonized by Legionella spp.

Cause?

- Materials
- Mixing volume
- Distance to tap
- **Flow rates**

Devices were removed and replaced with conventional devices….

Sydnor et al. 2012

Hypothesized impact of low flow

- Less volume delivered (higher water age)
  - Time for reactions/growth to occur
- Less delivery of disinfectant (thermal or chemical) to distal pipes
- Less delivery of corrosion control
- More biofilm/sediment build up

Proving the Obvious

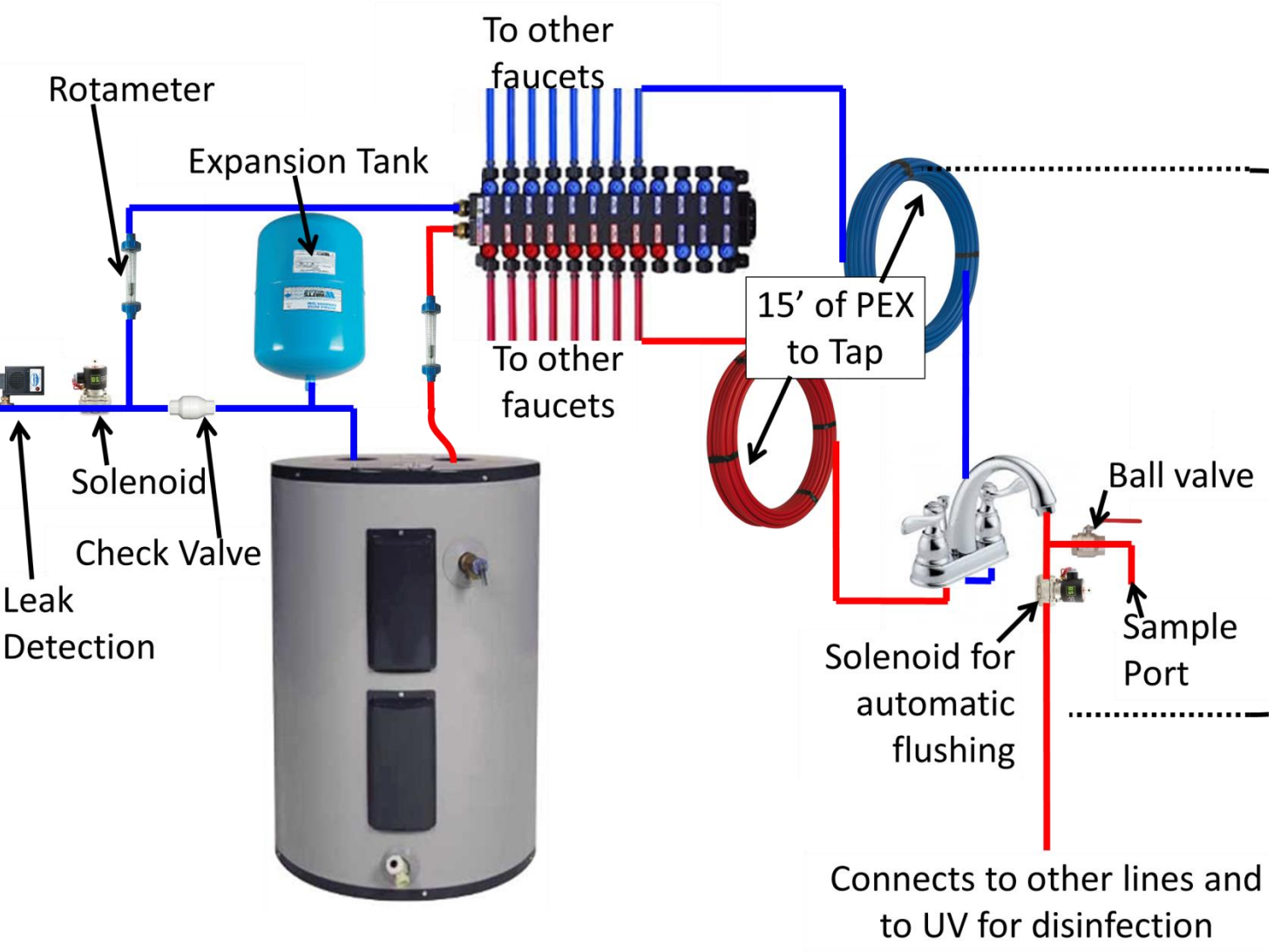
Clear PVC seeded with organics at very low flow

0.2 gpm
82% retained

0.6 gpm
60% retained

2.6 gpm
8% retained

On-going Experiment at VT



Q = 0.5, 1, 1.5, or 2 gpm

In duplicate

T_{hot} = 49 °C

T_{cold} = 10-18 °C

T_{mix} = 37 °C

No disinfectant

Experimental Design

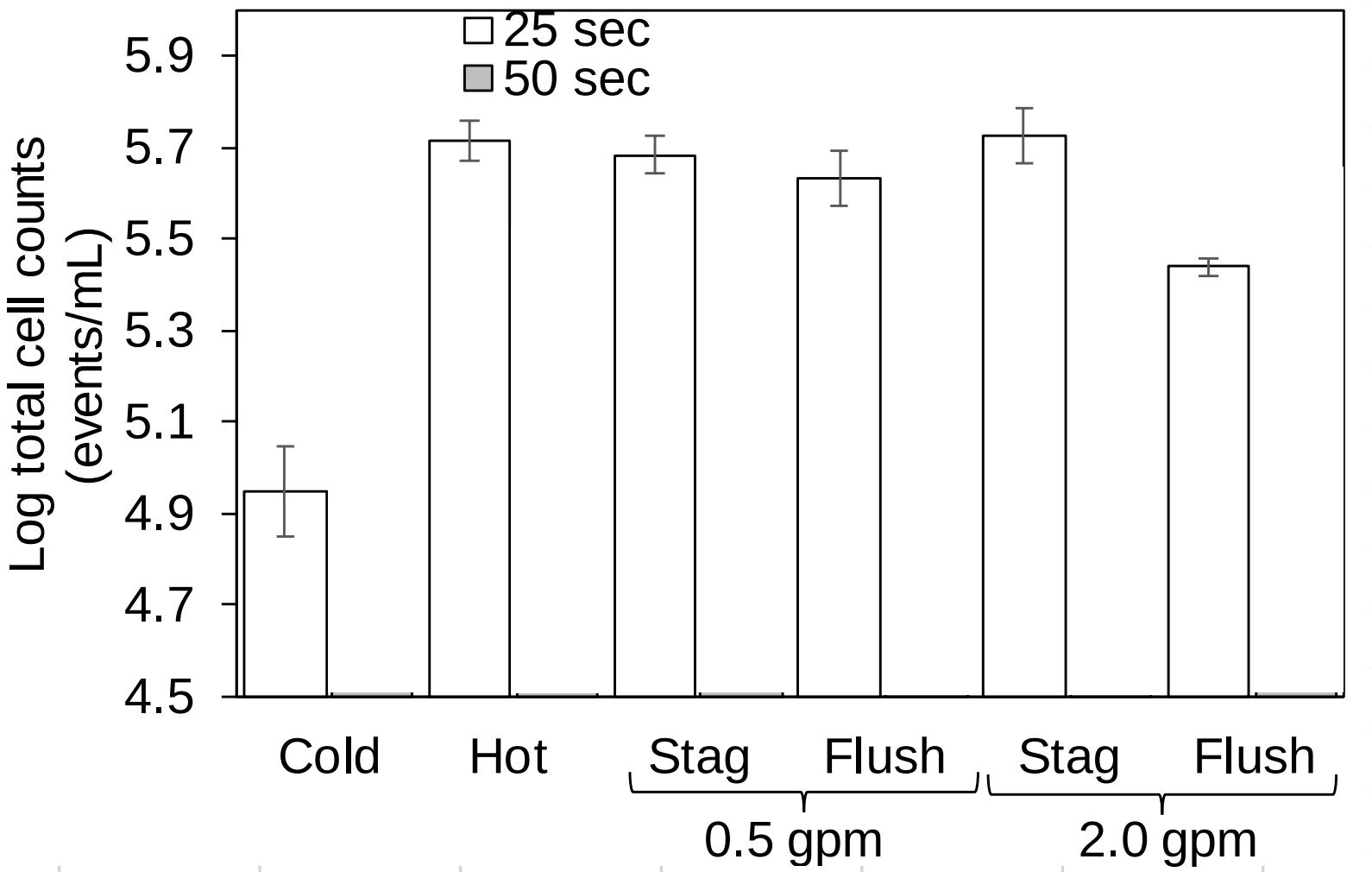
Completed: Constant draw duration

- **25 second water draw**
- **50 second water draw**

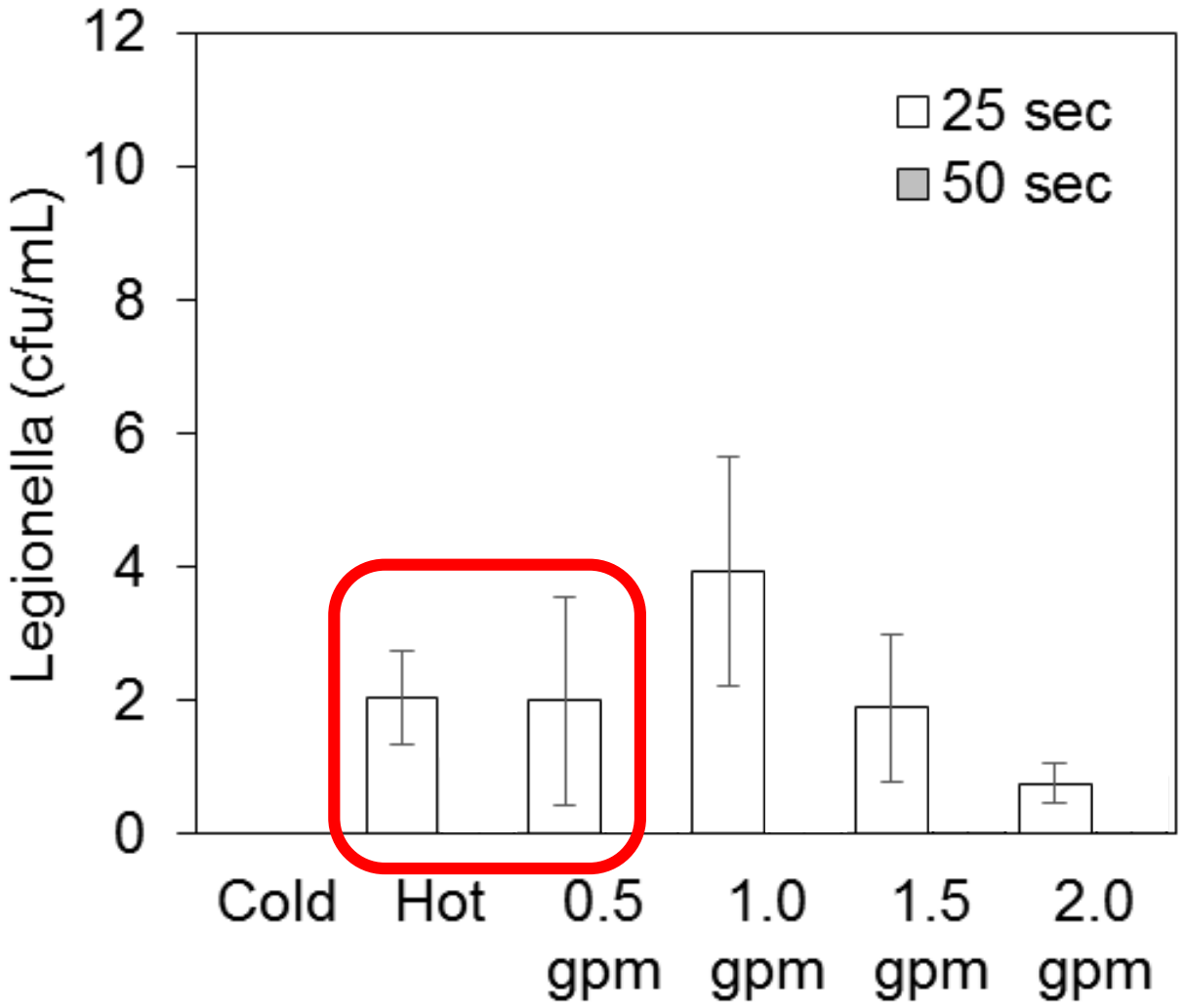
Approximate hot water pipe volumes replaced during flow

Flow Rate	25 sec	50 sec
0.5 gpm	0.68	1.73
1.0 gpm	1.36	3.46
1.5 gpm	2.04	5.20
2.2 gpm	3.00	7.63

Total cell counts (flow cytometry)



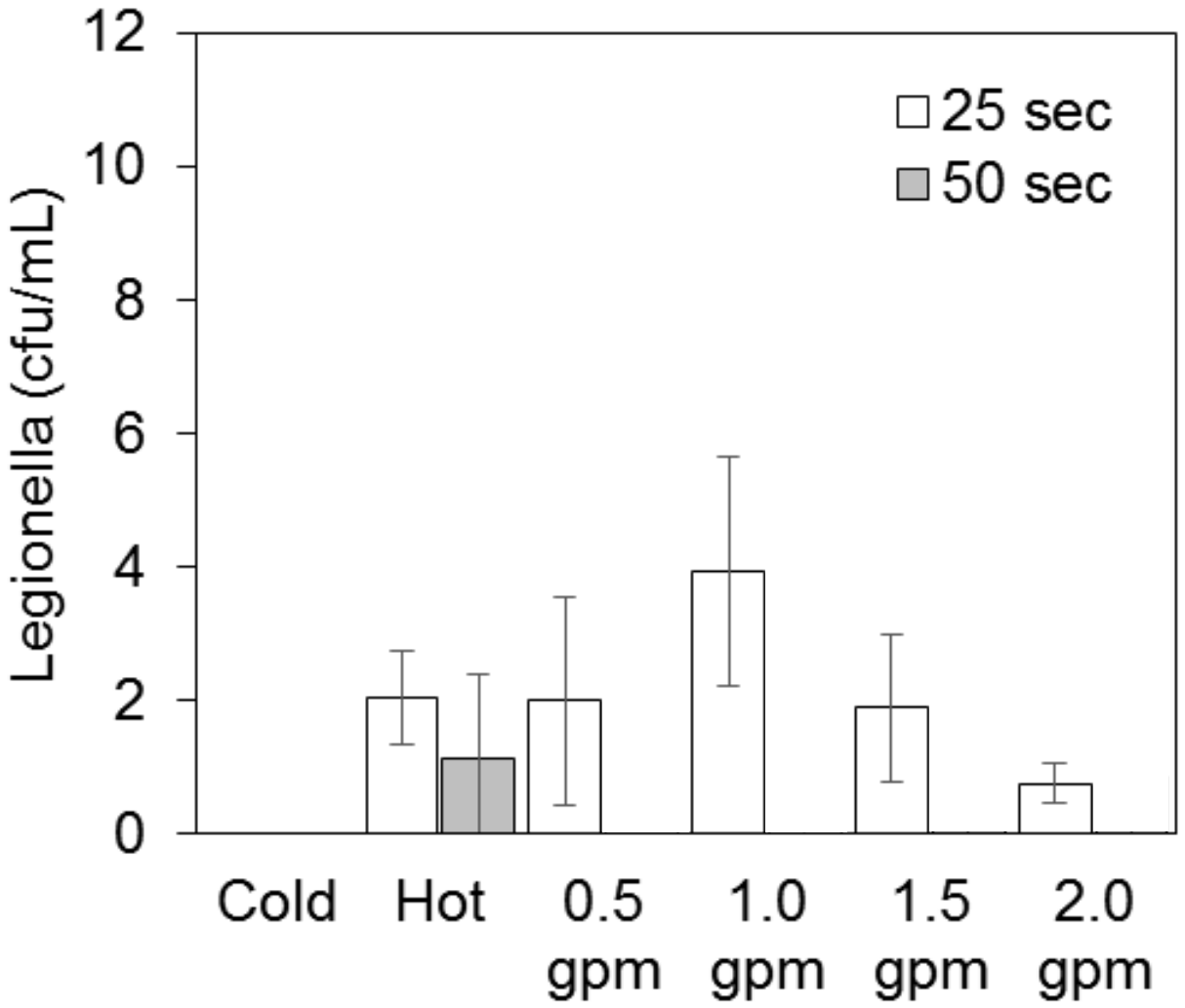
Legionella growth (by culture)



25 second flush duration

Flow Rate	Log Growth	Max. Hot Temp.
0.5 gpm	0.29	28.0 °C
1.0 gpm	0.59	42.9 °C
1.5 gpm	0.27	45.4 °C
2.0 gpm	-0.14	49.0 °C

Legionella growth (by culture)



50 second flush duration

Flow Rate	Log Growth	Max. Hot Temp.
0.5 gpm	0.91	48.7 °C
1.0 gpm	0.24	49.2 °C
1.5 gpm	-0.33	49.0 °C
2.0 gpm	0.07	49.4 °C

Future conditions to study

- Account for tank turn over/dilution
- Effect of tank temperature setting
- Constant volume draw from each faucet
- Determine effect of insulation

Quickly reiterate

Lower flow rates may…

- Increase water age at individual taps
- Decrease delivery of disinfectant/corrosion control

Flow rate doesn’t act alone

- Conditions delivered by the flow to the distal tap
- How frequently those conditions are delivered
- How the system is designed

Questions? Comments?

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