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

William Rhoads

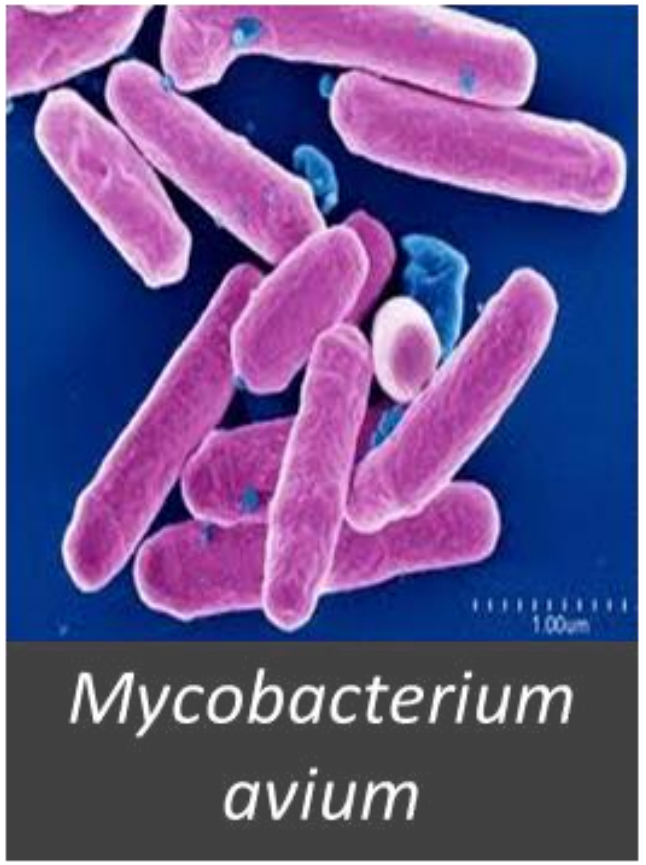
Amy Pruden

Marc Edwards


💧Water INTERFace
IGEP at VT

# Opportunistic pathogens (OPs)-
## infect (mainly) immunosuppressed individuals

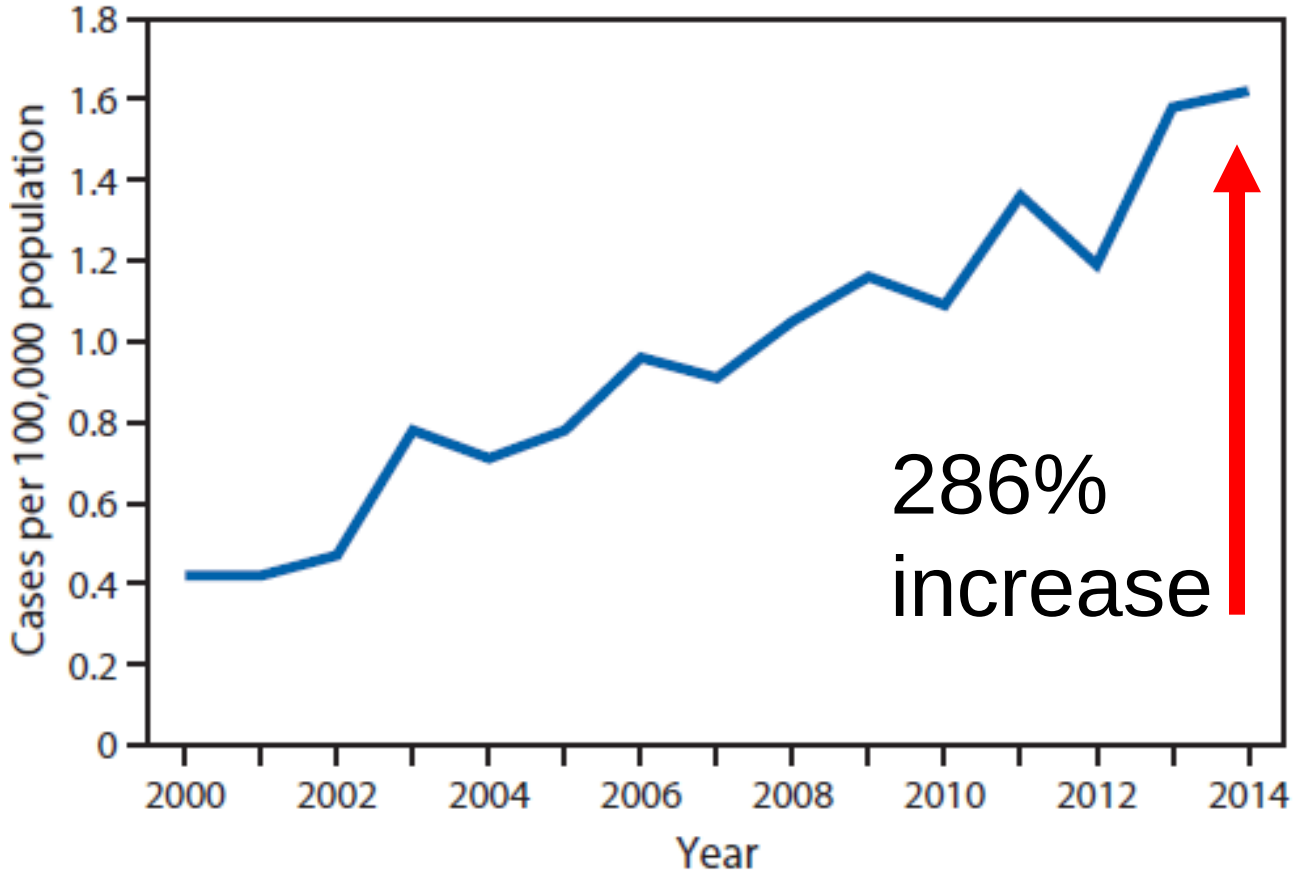

- **8k-18k cases/yr**
- **$430M/yr**
- Caused all 31 reported respiratory waterborne disease outbreaks 2007-10




- **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**

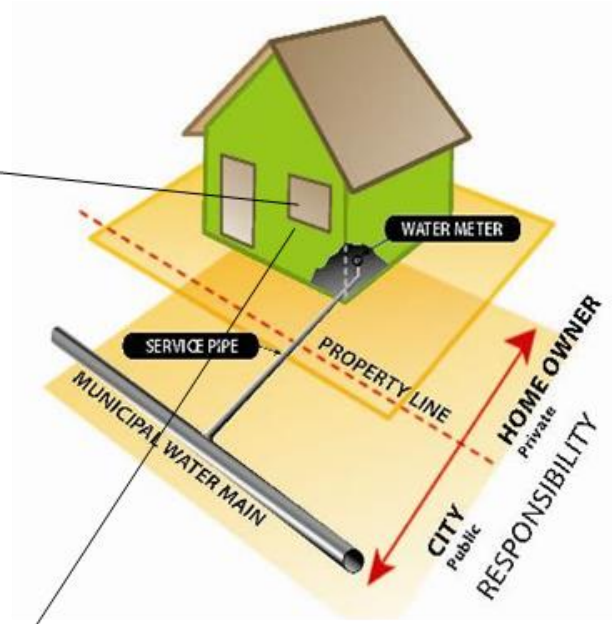
- Water use pattern
- Material selection
- In-building treatment

**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

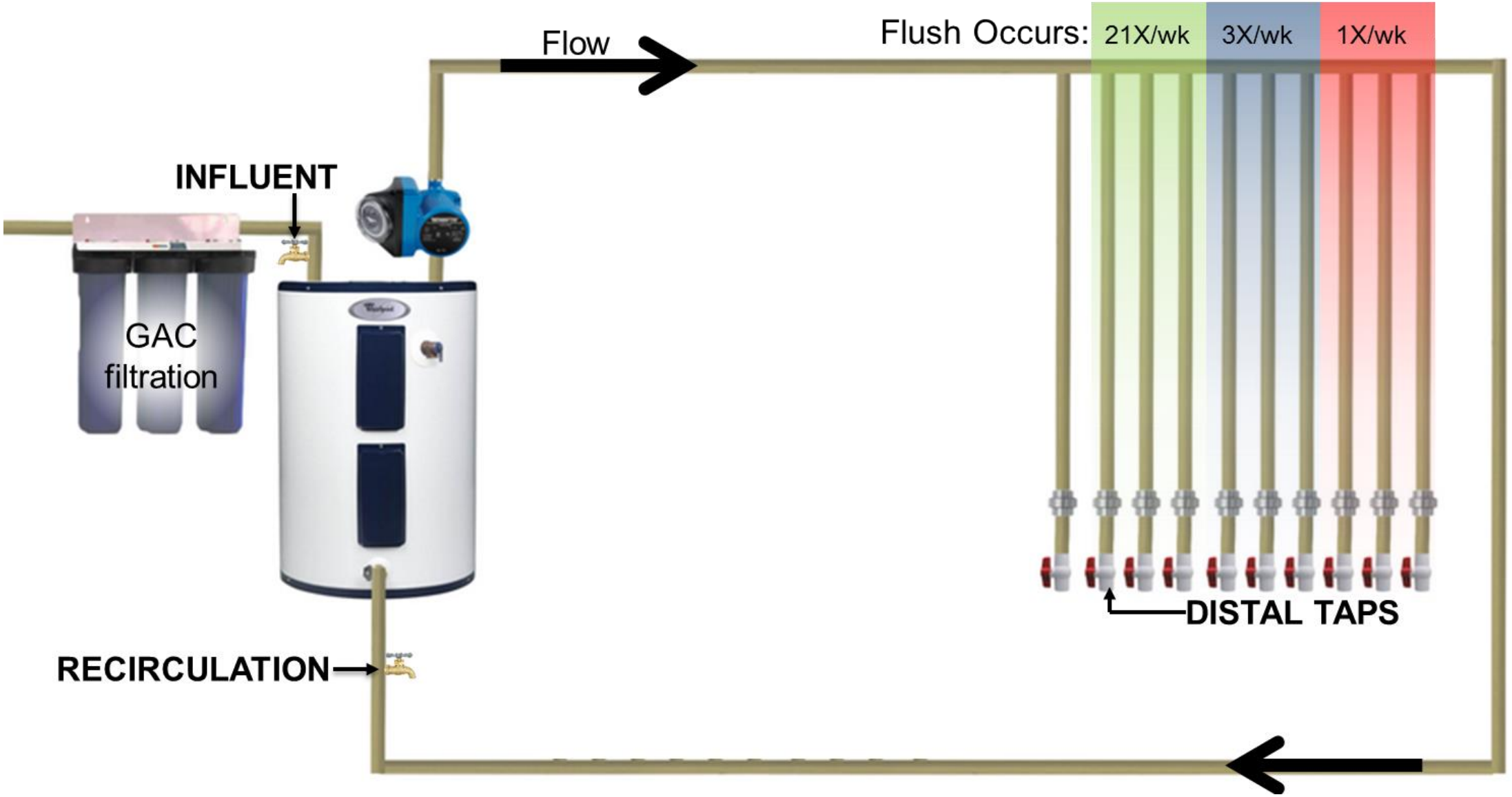
- When flow deliverers high temperature or chemical disinfectant to taps

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

## Contrary to wisdom: Flow is worse

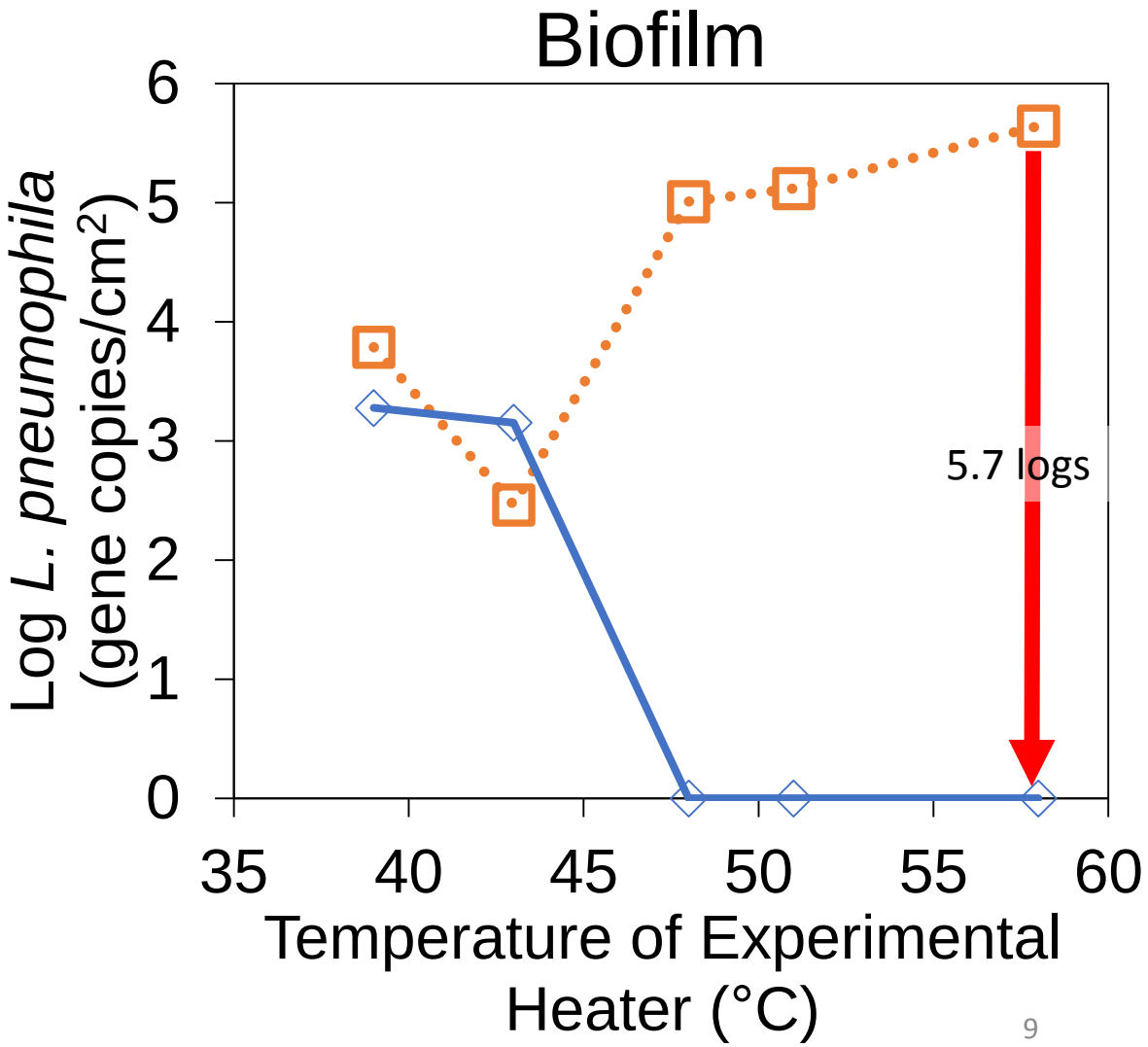
- When flow delivers ideal growth temperatures and nutrients

Liu et al., 2006



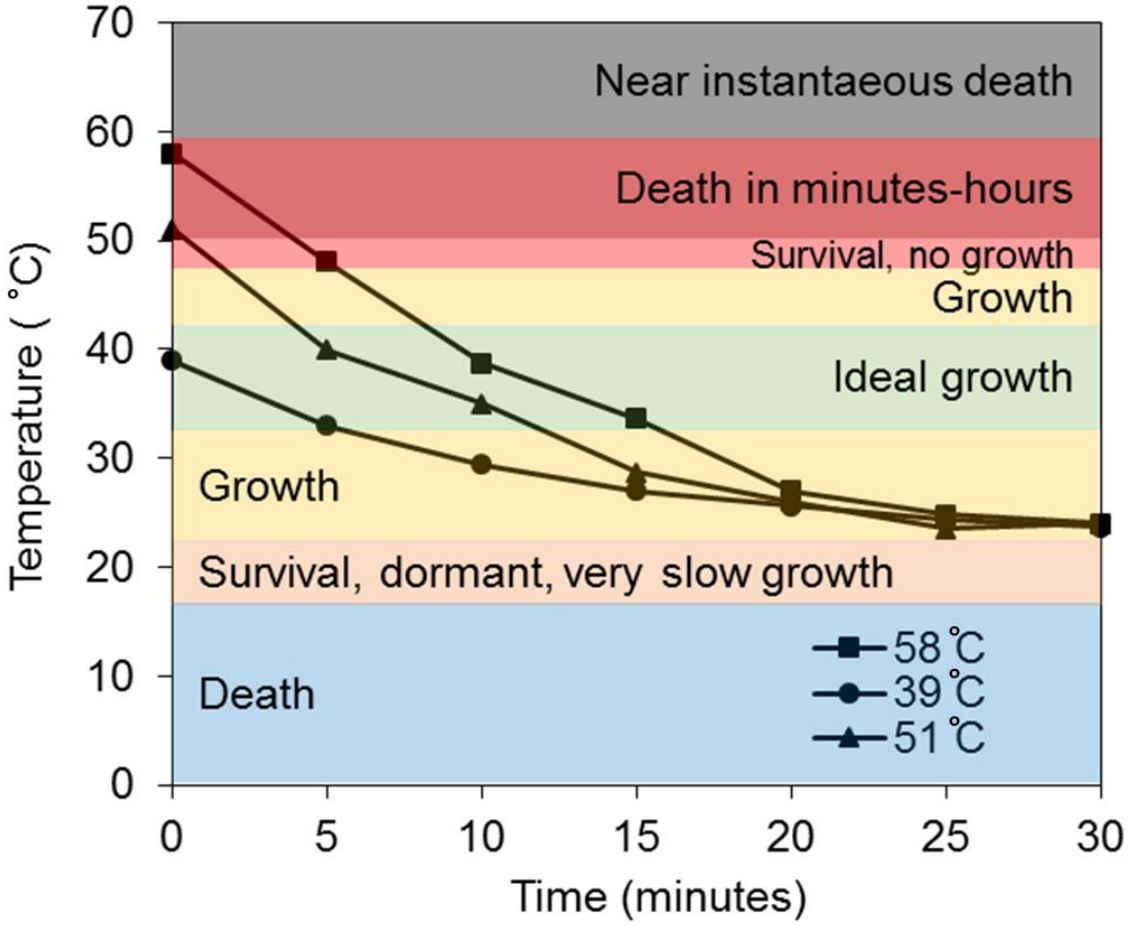

Two identical systems: 40° C vs Variable T (40-60 ° C)
Three use frequencies (water age in distal pipes): High, Med, Low
No disinfectant residual.

# Growth dependent on conditions delivered by flow



# Growth dependent on frequency of flow

Temp. profiles after use



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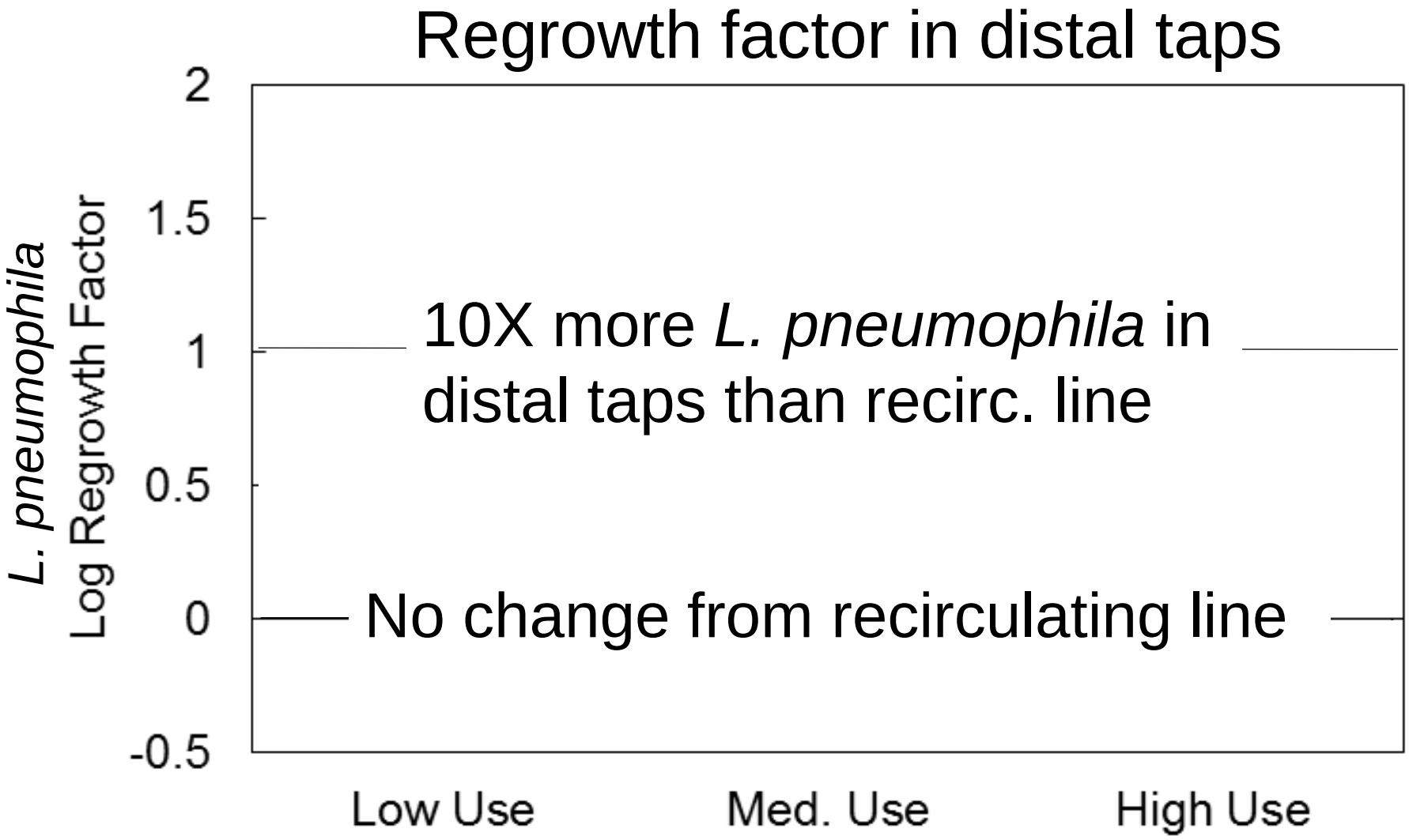

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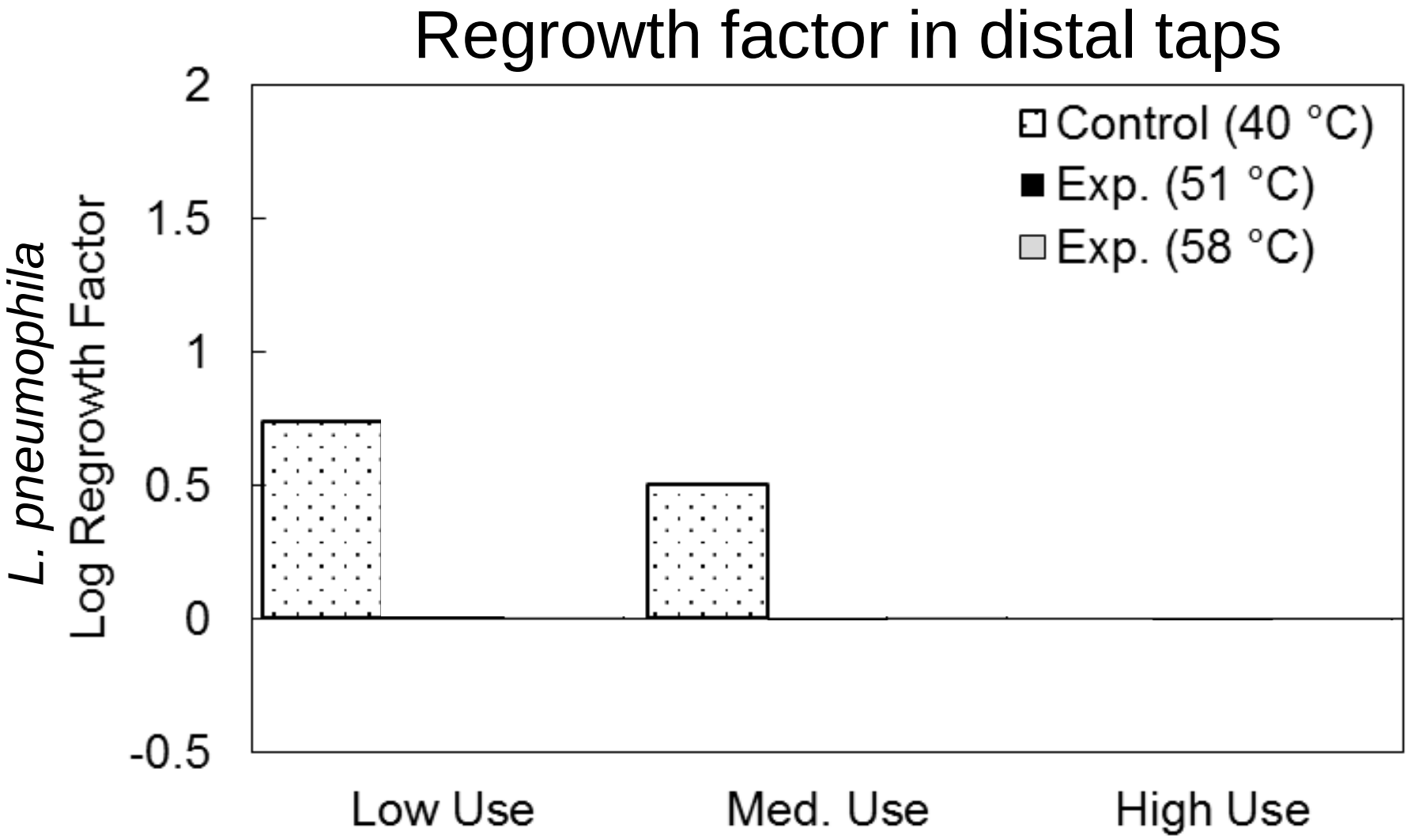


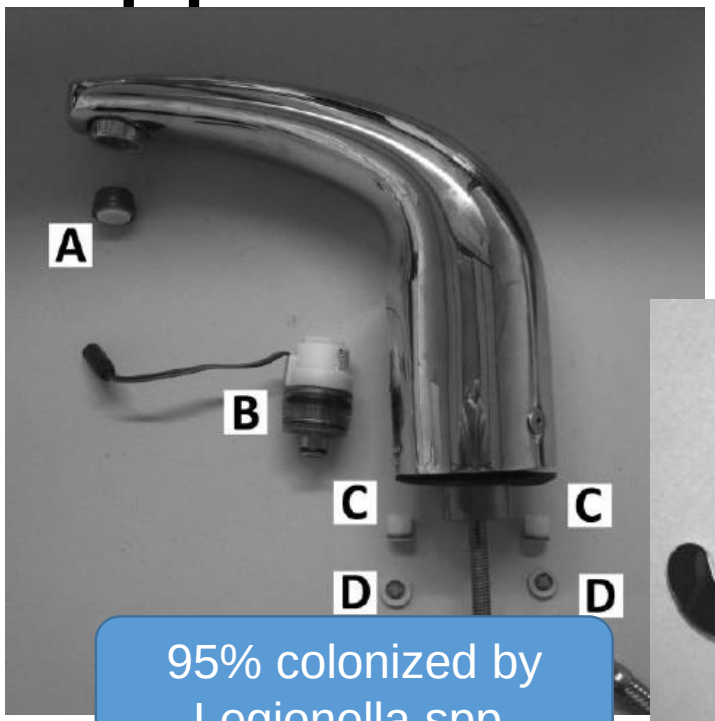
# Growth dependent on how pipes are designed

50 sec flush through ¾” pipes

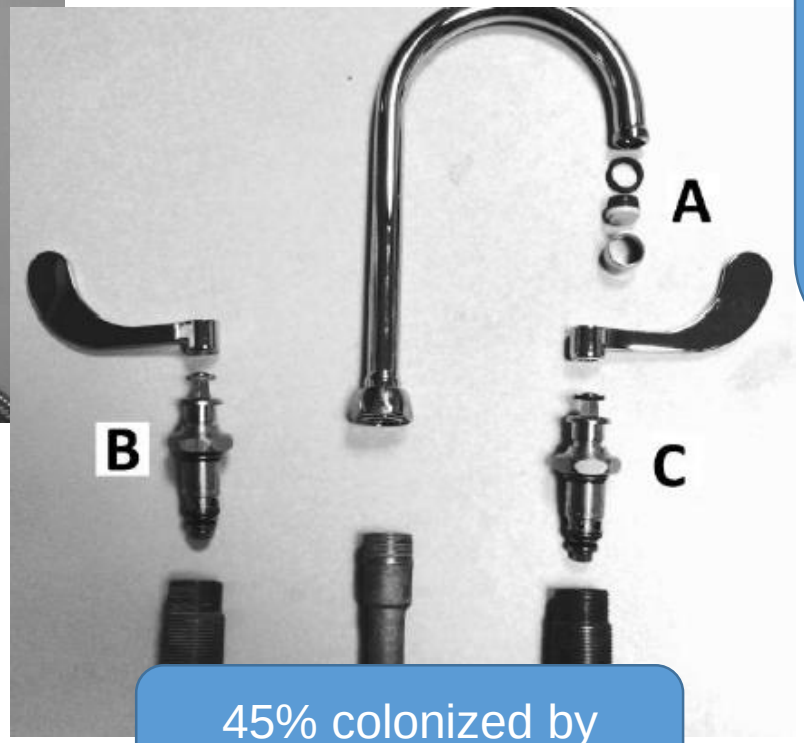
- $T_{cold}$ = 10 °C; $T_{hot}$ = 40 °C; $T_{mix}$ = 37 °C
  - @0.5 gpm – 0.38 gallons hot water used – 16 ft of pipe
  - @2.2 gpm – 1.65 gallons hot water used – 71 ft of pipe
- $T_{cold}$ = 30 °C; $T_{hot}$ = 60 °C; $T_{mix}$ = 37 °C
  - @0.5 gpm – 0.1 gallons hot water used – 4.2 ft of pipe
  - @2.2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

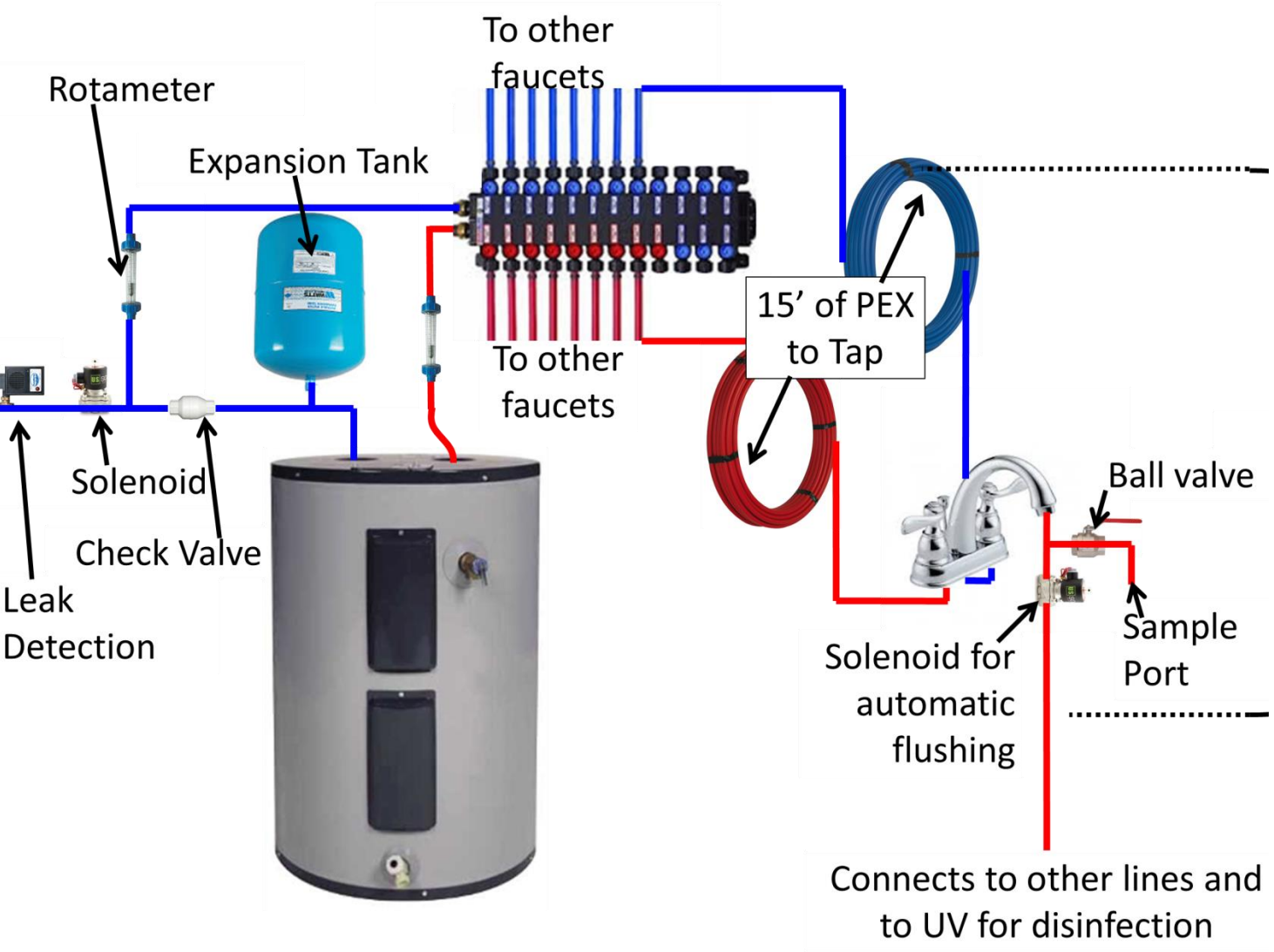
Clear PVC seeded with organics at very low flow

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

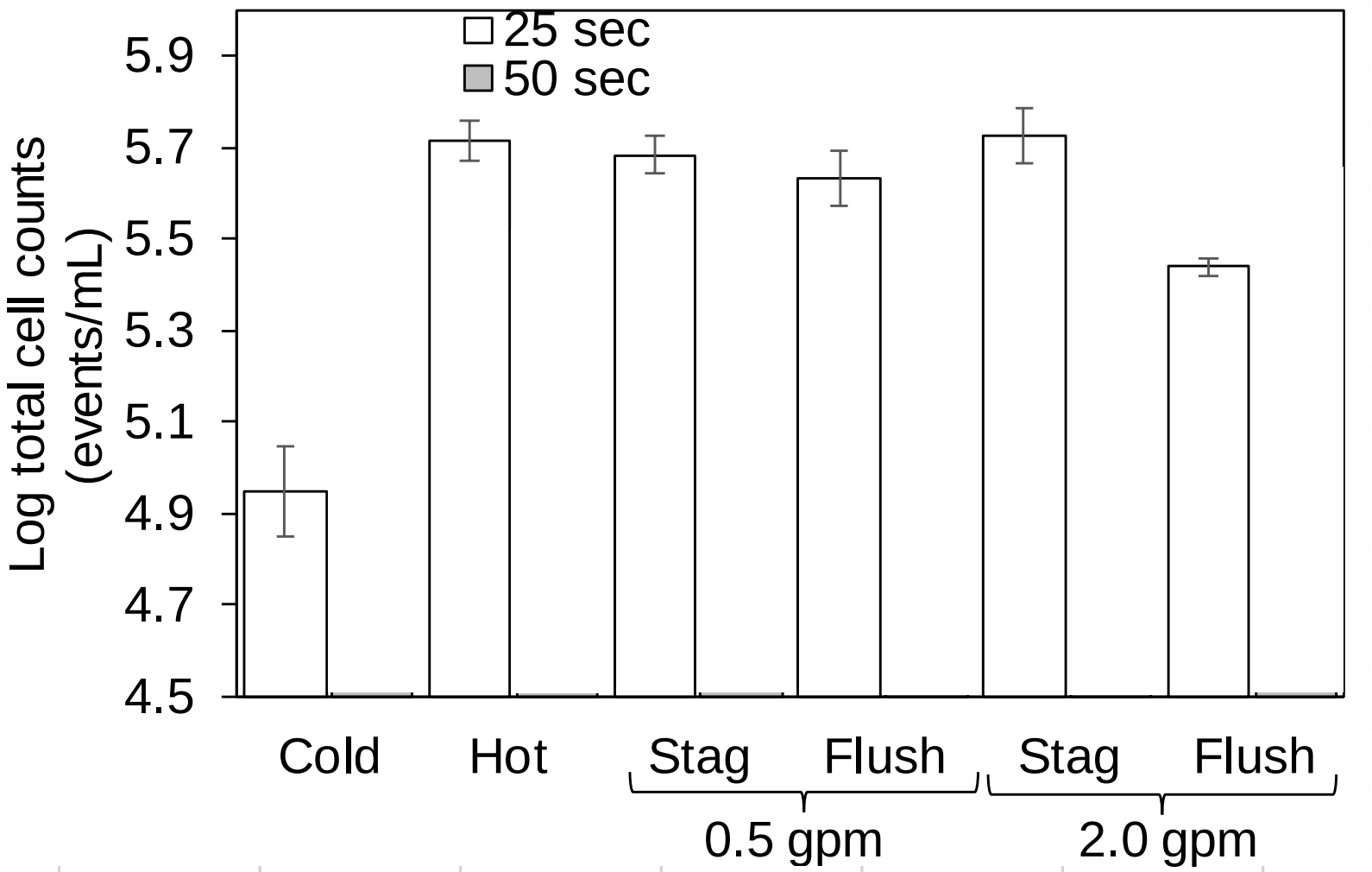
Completed: Constant draw duration

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

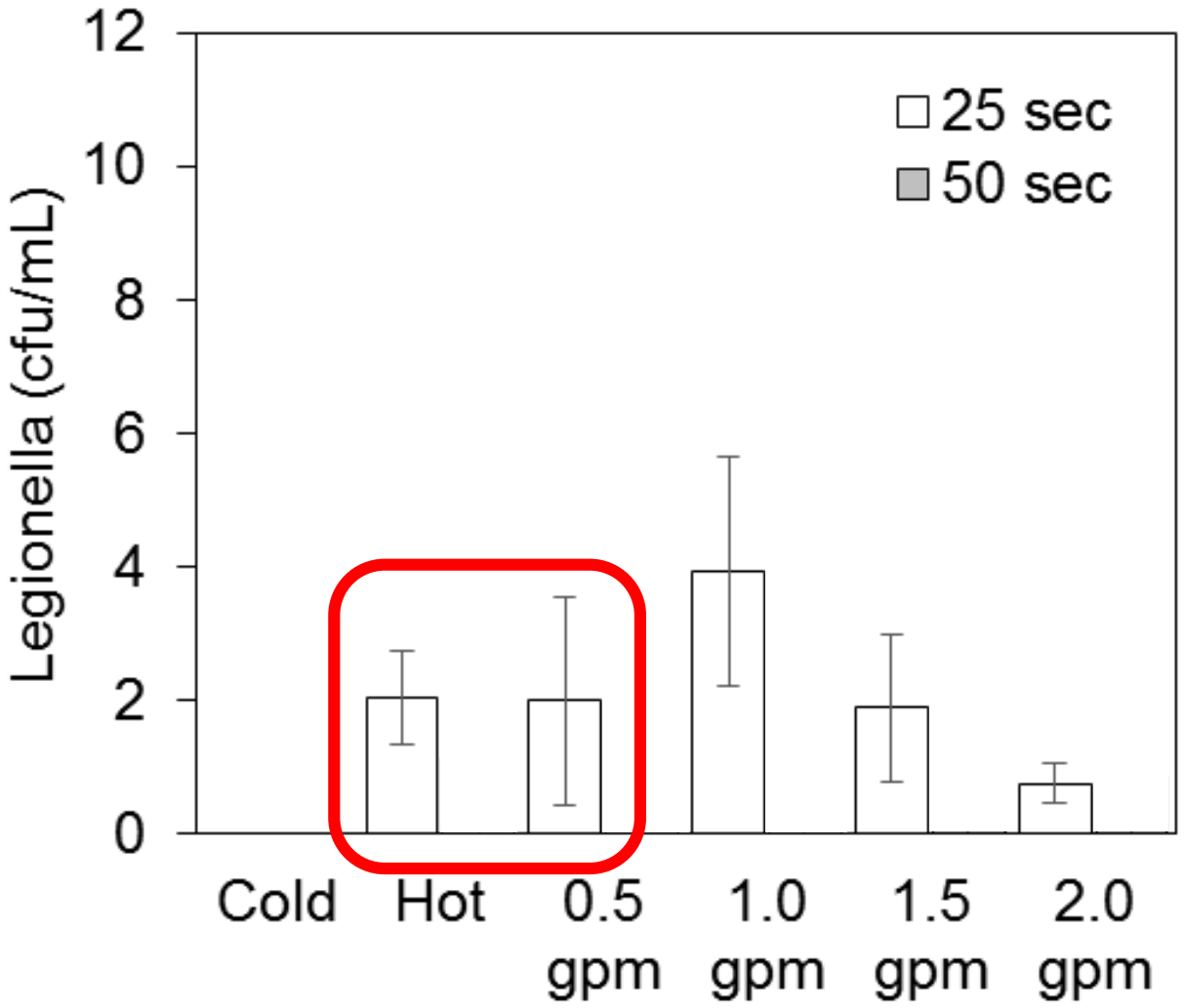
Approximate hot water pipe volumes replaced during flow

| 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)



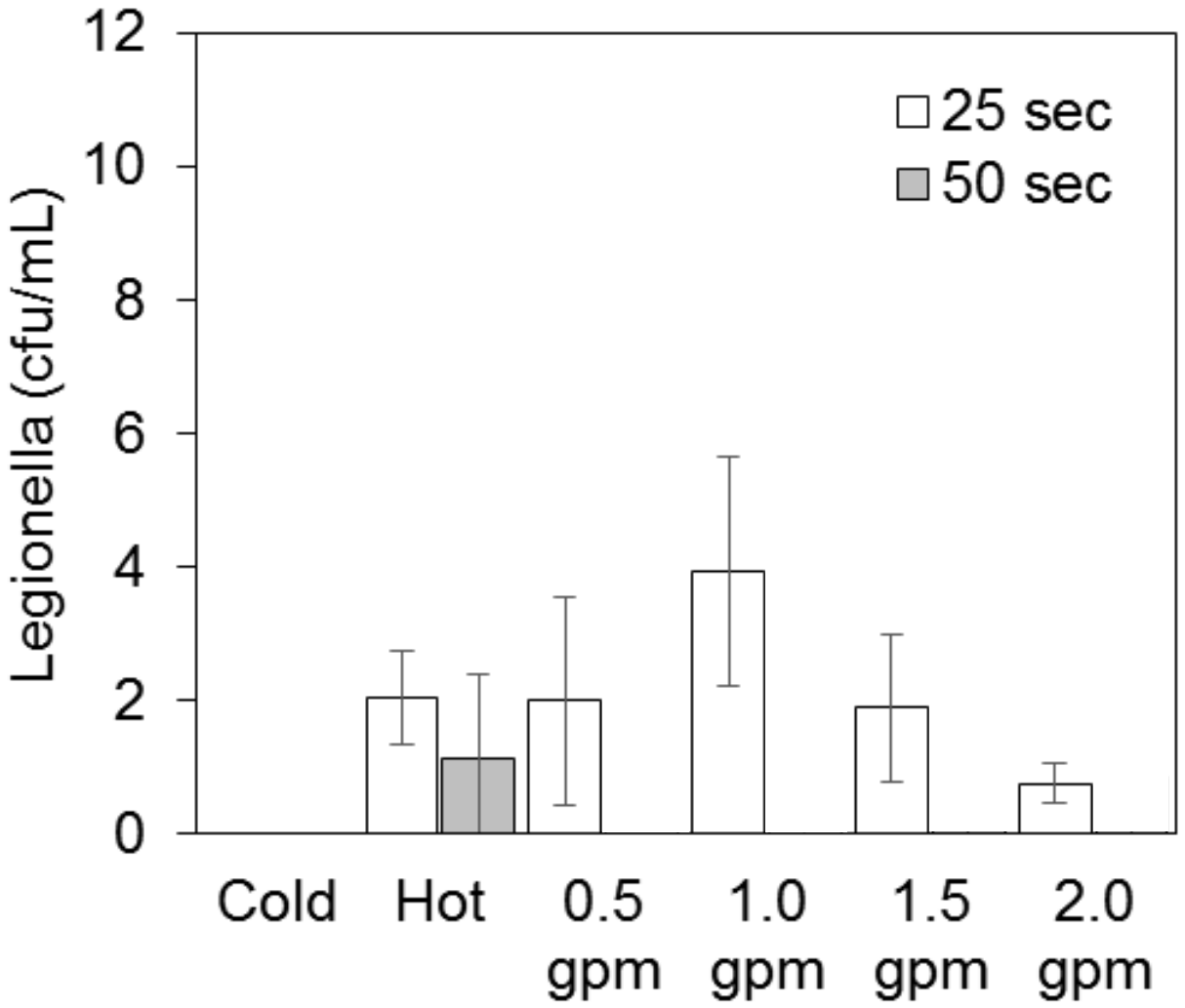
# Legionella growth (by culture)




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?

William Rhoads – wrhoads@vt.edu - @wjrhoads
Marc Edwards – edwardsm@vt.edu
Amy Pruden – apruden@vt.edu