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WEBCAST

WRF 5033

DEMONSTRATING THE EFFECTIVENESS OF FLUSHING FOR REDUCING THE LEVELS OF *LEGIONELLA* IN SERVICE LINES AND PREMISE PLUMBING

May 23, 2024

advancing the science of water®

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- Submit questions through the question box at any time. We will do a Q&A at the end of the presentation(s).
- Slides and a recording of the webcast will be available at www.waterrf.org.
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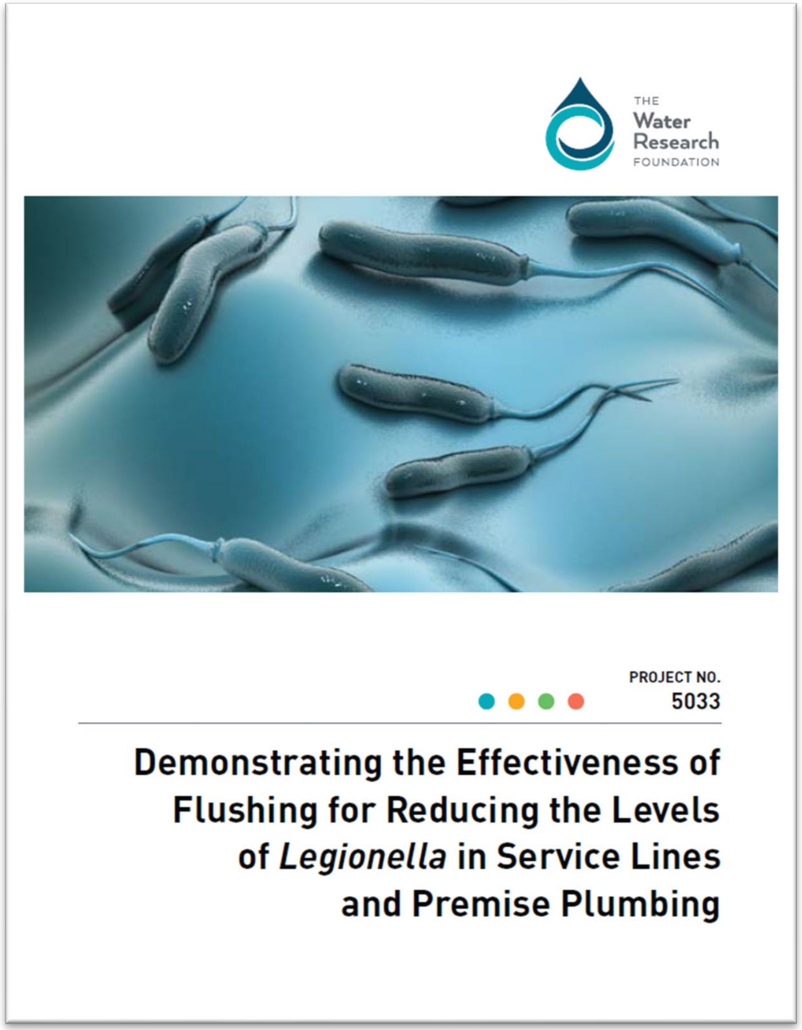
- A certificate of completion will be automatically generated after the webcast. Any questions, please contact Michelle Suazo at msuazo@waterrf.org.
- Please stay until the end to fill out a quick survey.

Final Report and Fact Sheet (5033)



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FACT SHEET

WRF 5033

Demonstrating the Effectiveness of Flushing for Reducing the Levels of *Legionella* in Service Lines and Premise Plumbing

What are *Legionella*?

Legionella are a genus of environmental bacteria commonly found in drinking water at low levels. Various species, notably *Legionella pneumophila*, can cause illnesses like severe Legionnaires' disease or influenza-like Pontiac fever. Infections are more prevalent among certain populations, with risk factors including smoking, compromised immune system, chronic lung disease, and age 50 years or older.

Why are *Legionella* Important in Service Lines and Premise Plumbing?

Legionella can persist or grow in drinking water at low levels but may flourish in building plumbing systems due to favorable factors. At higher levels, *Legionella* may become a significant public health risk. Exposure and subsequent infection may occur by inhaling contaminated aerosols from showers, faucets, or other water fixtures.

What Factors Contribute to *Legionella* Growth?

Bacterial Growth
Biofilms and amoebas that feed on biofilm play an important role in the *Legionella* life cycle.

Temperature
Legionella are active at 20 to 50°C (68 to 122°F) but grow best at 35 to 46°C (95 to 115°F). Inactivation starts at 55°C (130°F) and up.

No Disinfectant
The reduction or absence of disinfectant residual in drinking water may contribute to *Legionella* amplification.

Flushing Resets the Water Age

The factors contributing to *Legionella* growth are influenced by residence time, also known as water age. Flushing is the operation of water outlets to manage water age throughout some or all parts of a building water system, including the cold- and hot-water supplies. Flushing until the water returns to the baseline water temperature and residual disinfectant concentration (when applicable), and then an additional 5 minutes, can help manage bacterial levels and the amplification of *Legionella*. The flow rate or velocity may not be important, so long as new water replaces the old.

NTNU | Norwegian University of Science and Technology   SINTEF   University of Minnesota Driven to Discover

Demonstrating the Effectiveness of Flushing for Reducing the Levels of *Legionella* in Service Lines and Premise Plumbing   1

Today’s Presenters

Cynthia Hallé, PhD
Norwegian University of Science and Technology

Raymond M. Hozalski, PhD
University of Minnesota

Michael Waak, PhD
SINTEF

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PART I:
INTRODUCTION & BACKGROUND

Michael B. Waak, PhD
Dept. of Infrastructure, SINTEF Community

Prof. Cynthia Hallé, PhD
Norwegian University of Science & Technology

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Legionella and Legionellosis

Disease and severity

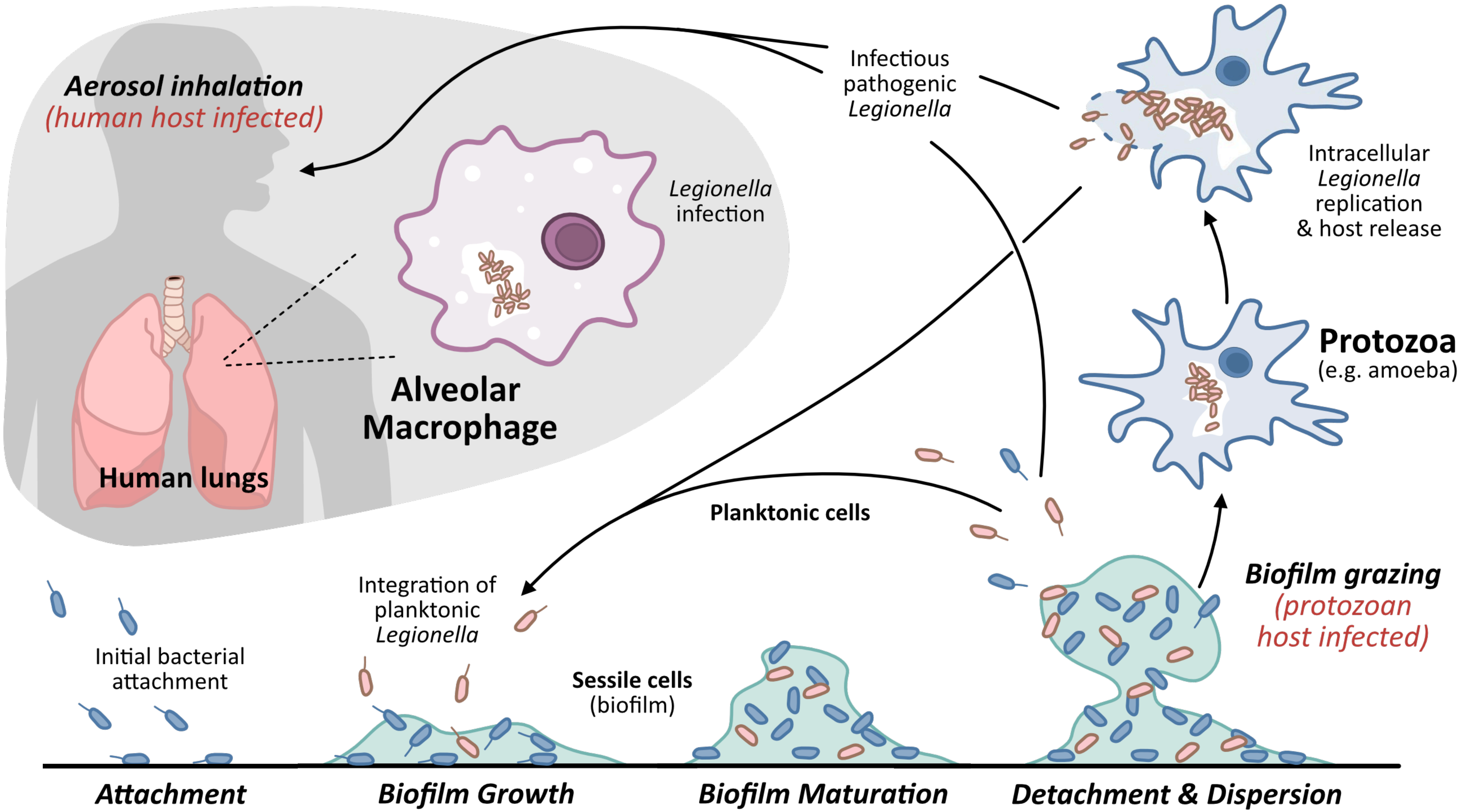
- Legionnaires' disease (severe pneumonia)
- Pontiac fever (milder, influenza-like)
- Extrapulmonary, soft tissue infections
  - Skin
  - Eyes

THE AUTHORS' POSITION

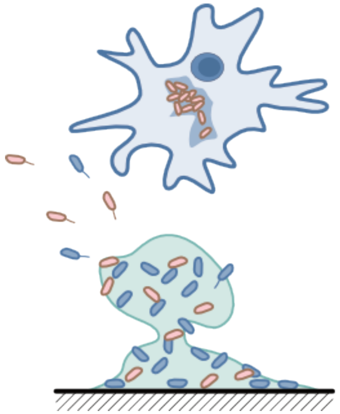
- We did not consider **infection/exposure risk**
- We assume ***Legionella* prevention** is **not** species specific (**agnostic**)

Taxonomy vs. clinical relevance

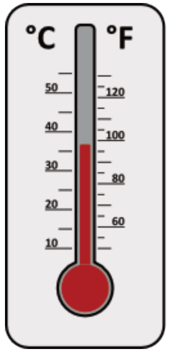
- *L. pneumophila*
  - **Serogroup 1**
  - Other serogroups (14 or more)
  - >90% of confirmed cases
- Non-*pneumophila Legionella* spp.
  - 65 (or more) species
  - 50% of these clinically observed
  - <10% of confirmed cases
- Ongoing debate concerning the focus on *L. pneumophila* vs. the genus


Aerosol inhalation
(human host infected)
Legionella
infection
Alveolar
Macrophage
Human lungs
Infectious
pathogenic
Legionella
Intracellular
Legionella
replication
& host release
Protozoa
(e.g. amoeba)
Planktonic cells
Integration of
planktonic
Legionella
Initial bacterial
attachment
Sessile cells
(biofilm)
Biofilm grazing
(protozoan
host infected)
Attachment
Biofilm Growth
Biofilm Maturation
Detachment & Dispersion

Factors benefitting *Legionella* survival and growth

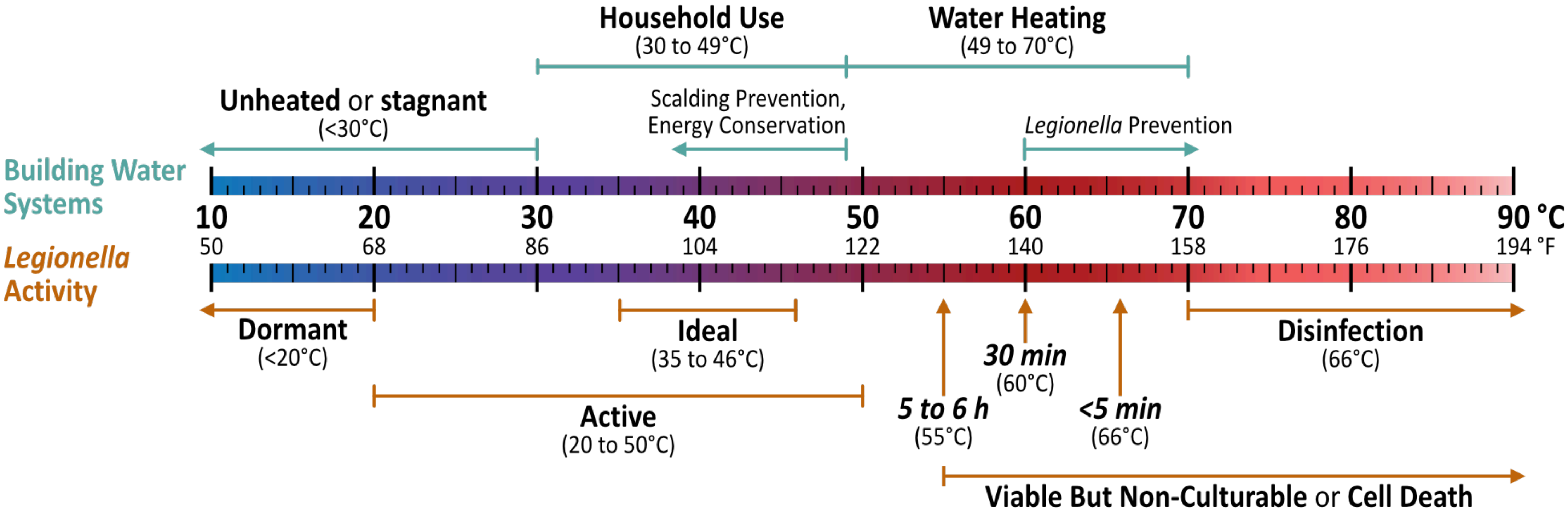


Bacterial growth
and **protozoan hosts**
(carbon & nutrients)

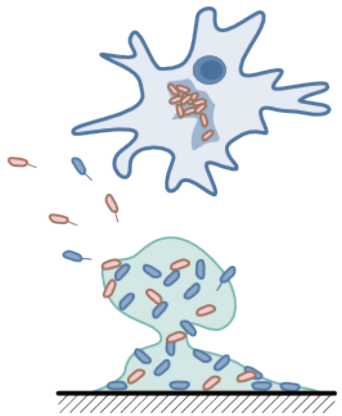


Water temperature
20 to 50 °C (70 to 120 °F)

Water temperature vs. *Legionella* activity



Factors benefitting *Legionella* survival and growth



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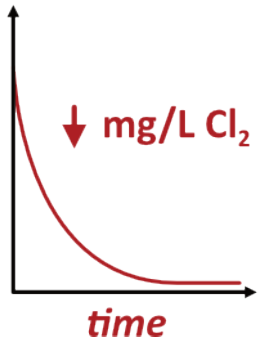
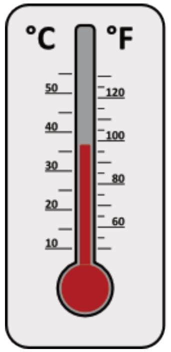


Loss or absence of
residual disinfectant



Water temperature
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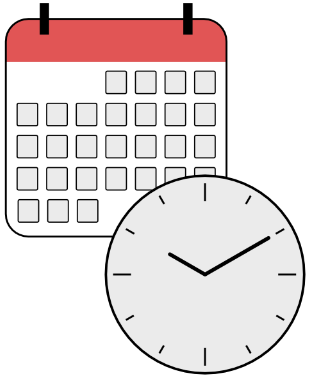
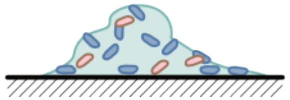
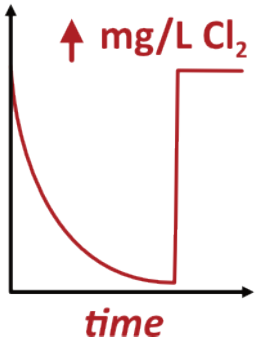


Residence time
(water age)

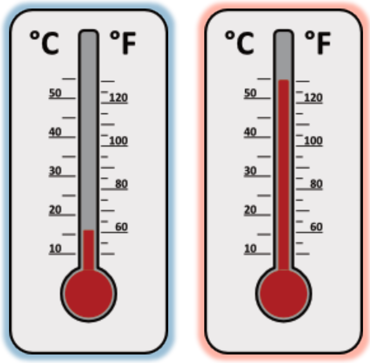
The role of flushing



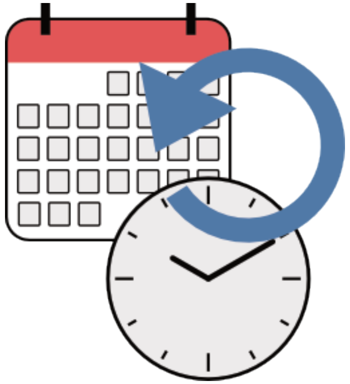
Expel accumulated biomass



Replenish residual disinfectant



Regulate water temperature
<20 or >50 °C



Reset water age

WRF 5033 Project Objectives

- Assess flushing for its potential as a **corrective action** and ongoing control strategy to reduce *Legionella* levels in **service lines and premise water systems**

- Use a combination of **laboratory experiments** and **real-world case studies** to generate **novel, hypothesis-driven data**

- Provide **evidence-based recommendations** to a broad audience of potential stakeholders regarding the **efficacy of flushing for *Legionella* control**

PART II:
FLUSHING RECOMMENDATIONS

Prof. Raymond M. Hozalski, PhD
University of Minnesota, Twin Cities

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Defining the Problem & Corrective Action

- *Legionella* bacteria and especially *L. pneumophila* can cause severe illness
- Naturally present in water, leading to exposure risk in buildings
- Factors affecting *Legionella* growth
  - Presence of bioavailable carbon
  - Temperature at 20 to 50 °C (70 to 120 °F)
  - No disinfectant residual
- Flushing resets the **water age**

Before Flushing

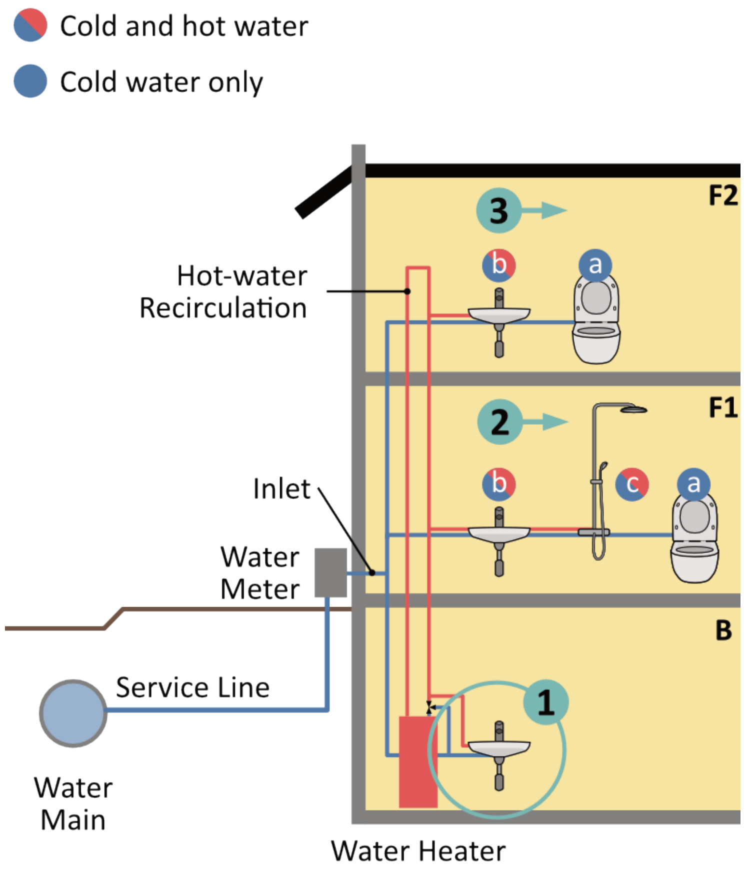
- Know the design and operation of the building water system

- Understand the baseline water quality, especially **water temperature** and **residual disinfectant** in both **cold water** and **hot water**

- Identify the scope of flushing (i.e., where is water age a problem?)
  - **Whole-building flushing** (e.g., after prolonged closure or low occupancy)
  - **Targeted flushing** (e.g., typical occupancy, with unused outlets or “dead legs”)

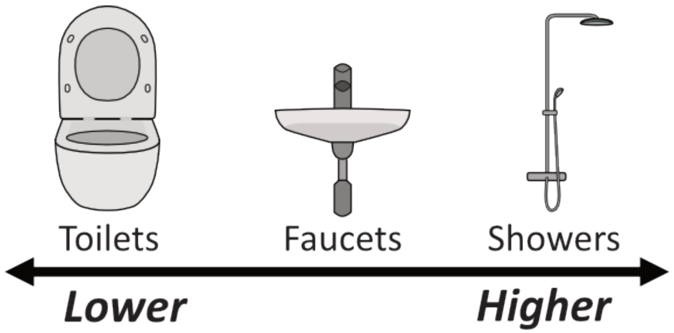
General Flushing Recommendations (1 of 2)

- Prime the **cold**- and **hot**-water systems with **fresh municipal water**
  - Start near the inlet(s) to flush out the service line(s)
  - Flush between the inlet and hot-water system
  - **Note** the baseline temp. and/or disinfectant
- Flush nearest the inlet and progress farther into the building
  - Flush until water quality resembles baseline temperature and/or disinfectant
  - Flush an additional 5 minutes

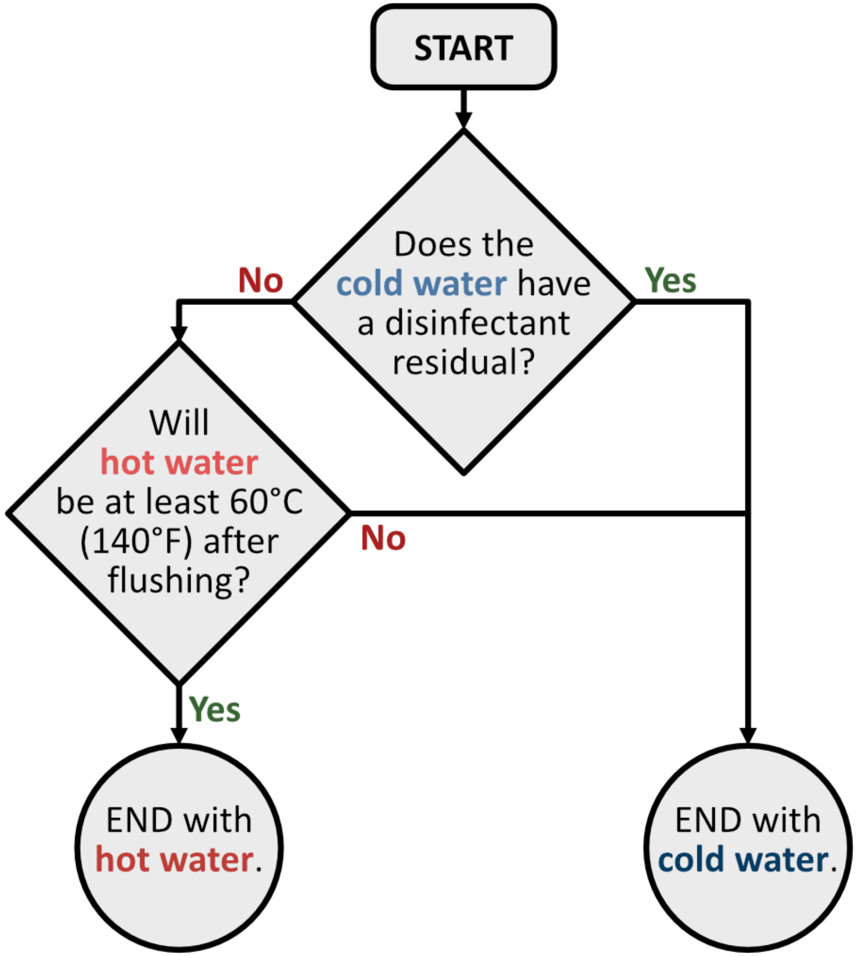


General Flushing Recommendations (2 of 2)

- Prioritize flushing low-aerosol outlets prior to high-aerosol outlets

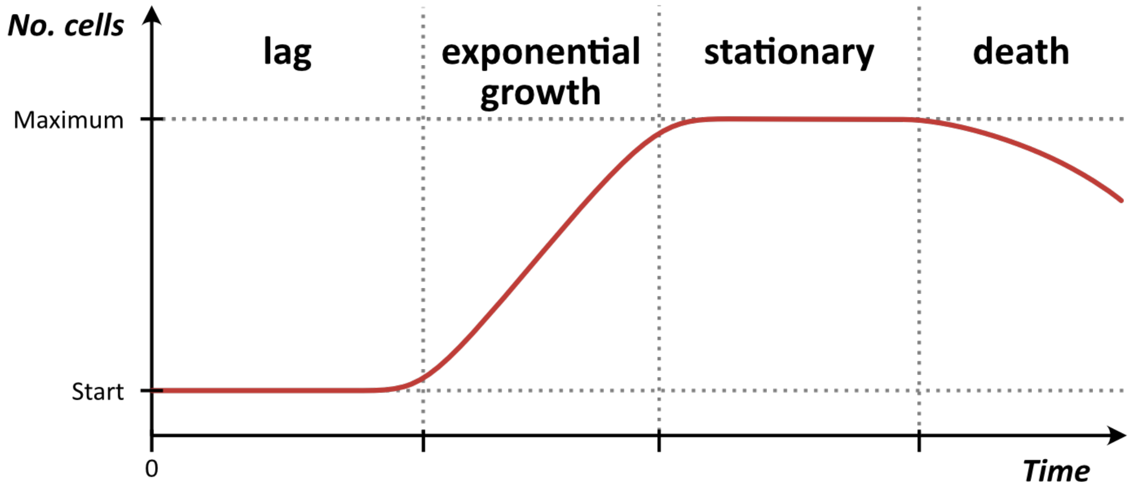


- Leave the outlet with water **most hostile** to bacterial growth (temperature, disinfectant residual)



Additonal considerations

- *How often should I flush?*
  - **Residual disinfectant** present?
    Max. water age = 7 days
  - **No** residual disinfectant?
    Max. water age = 3 days
- *When should I flush?*
  - Before water users could be exposed
  - Outside normal or peak hours to minimize hazards for water users



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PART III:
METHODS

Michael B. Waak, PhD
Dept. of Infrastructure, SINTEF Community

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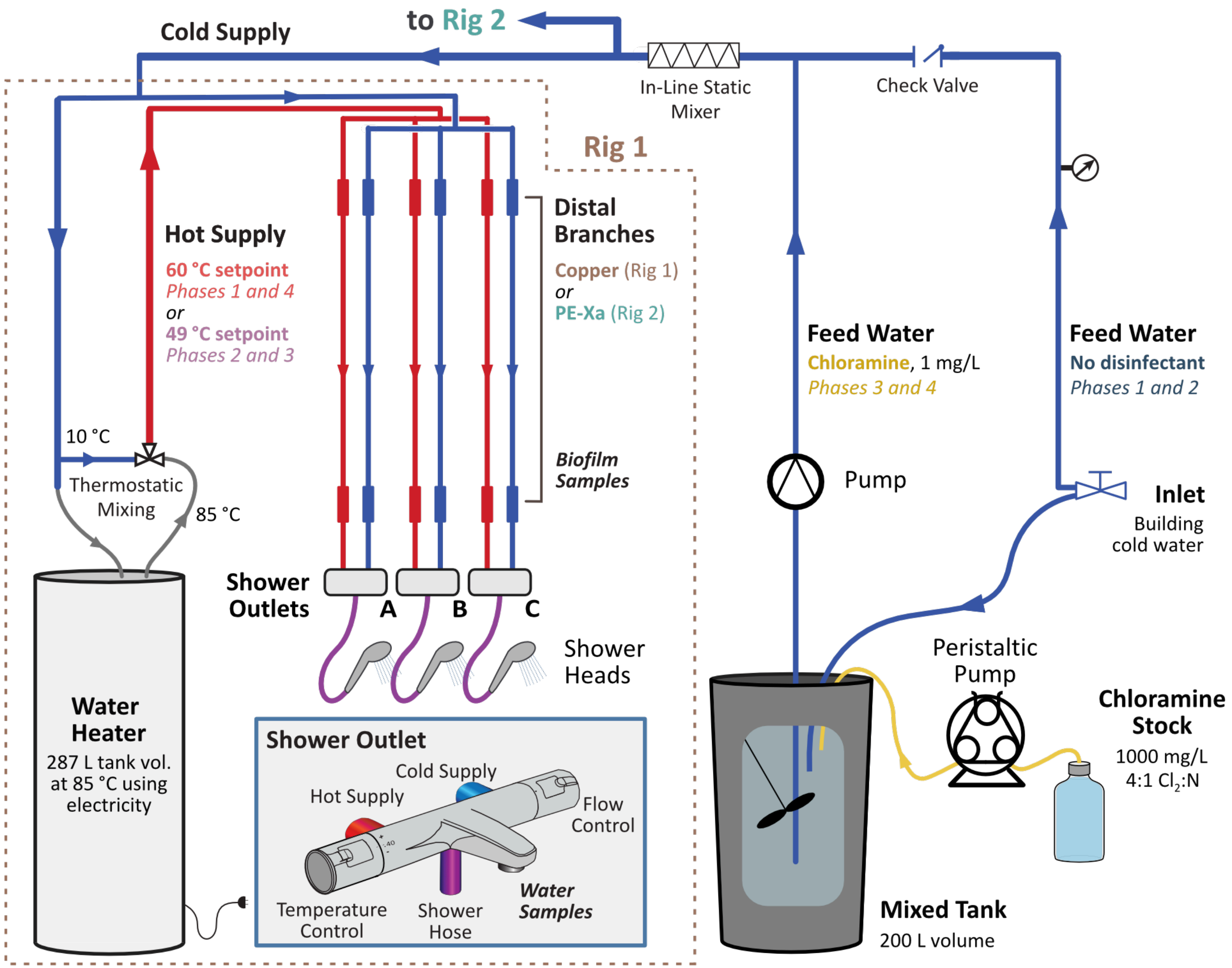
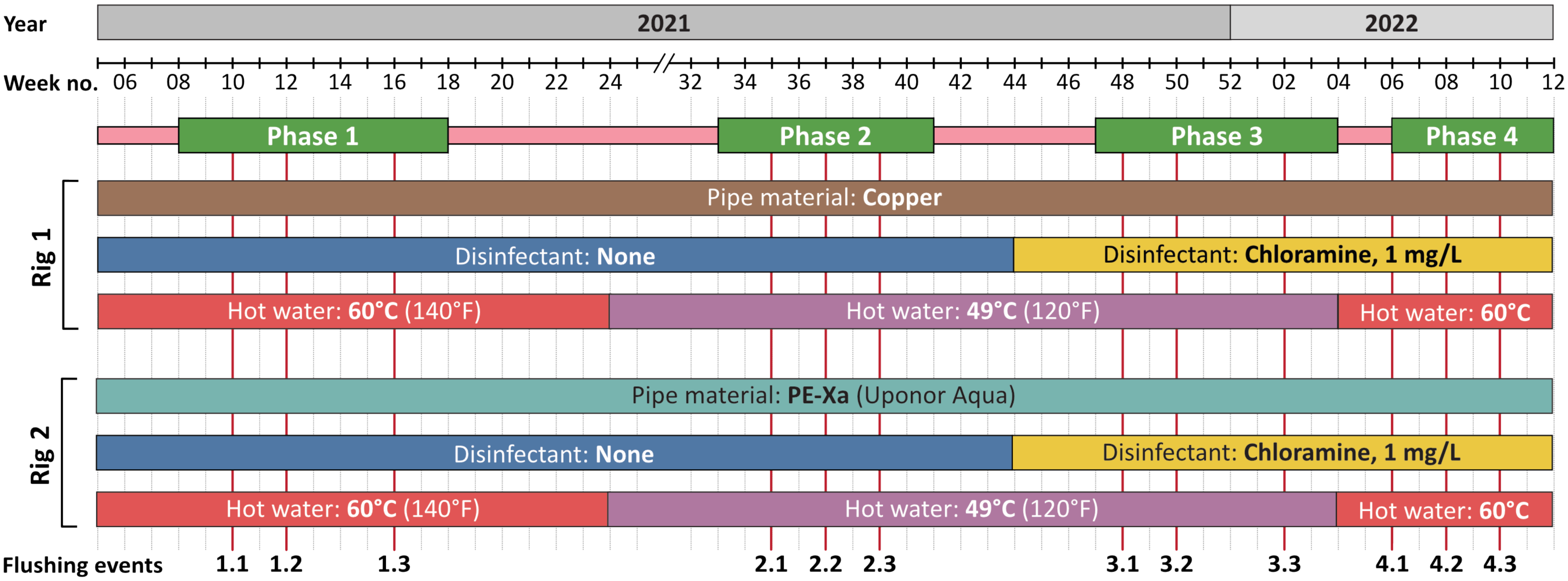
Pilot-scale Premise Plumbing System

- **Intervention (flow rate)**
  - Flushing (max. flow, 5 min)
  - None (simulated shower)
- **Residual Disinfectant**
  - None
  - Chloramine, 1 mg/L Cl_2
- **Pipe Material**
  - Copper
  - Uponor Aqua PE-Xa
- **Temperature Setpoint** (mixing valve)
  - 49 °C (120 °F) [1:1 C/H]
  - 60 °C (140 °F) [3:7 C/H]



Experimental Operation of the Pilot



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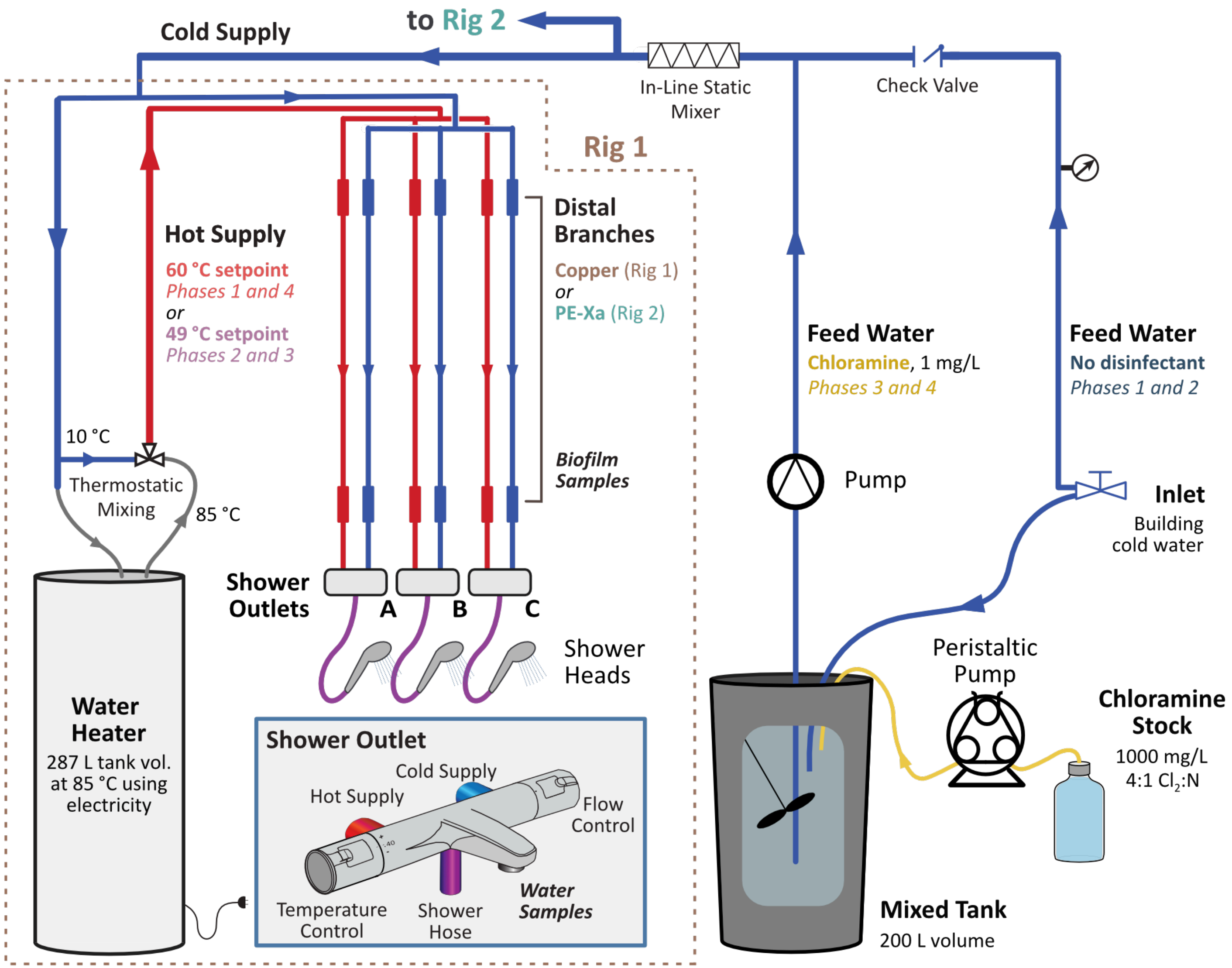
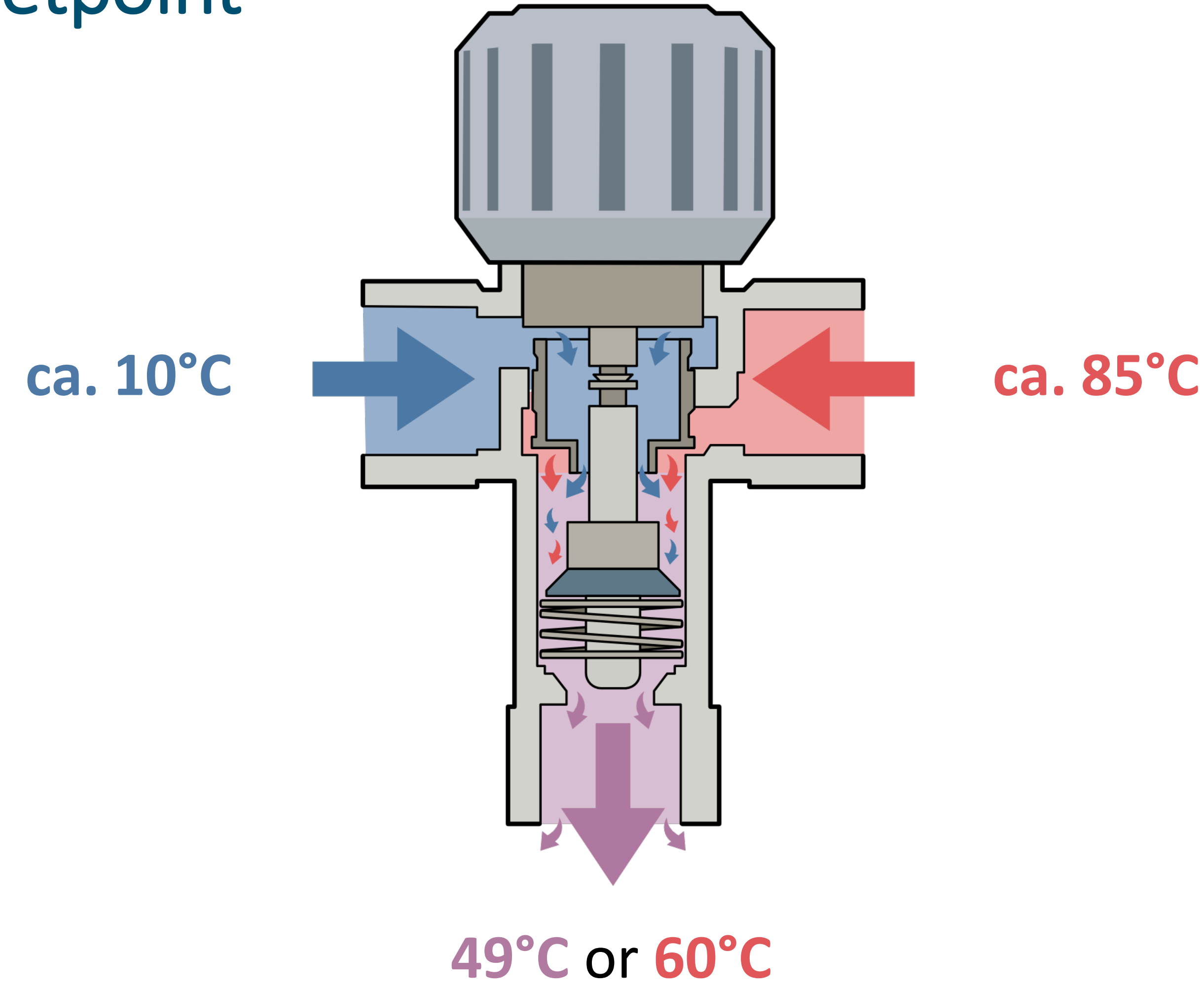
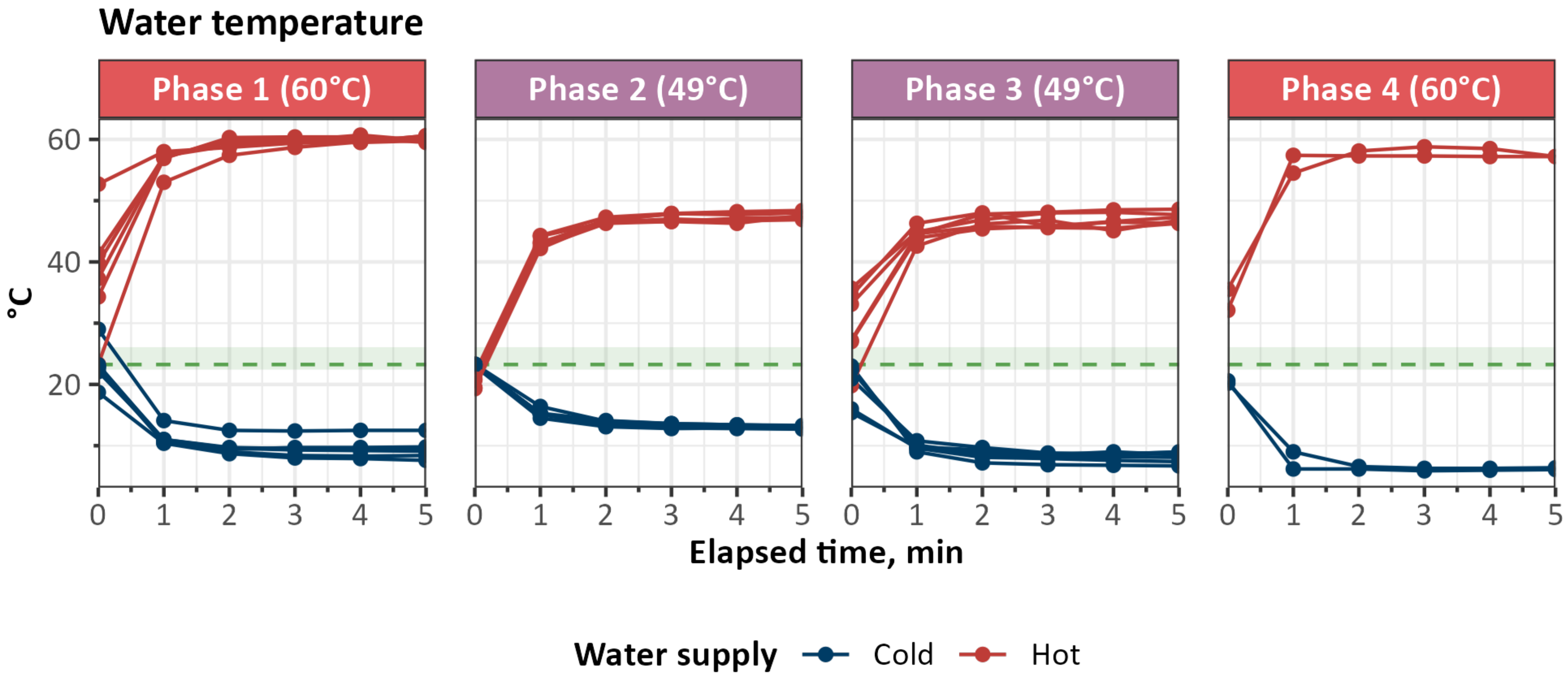


Temperature Setpoint



Water Temperature during Pilot Operation



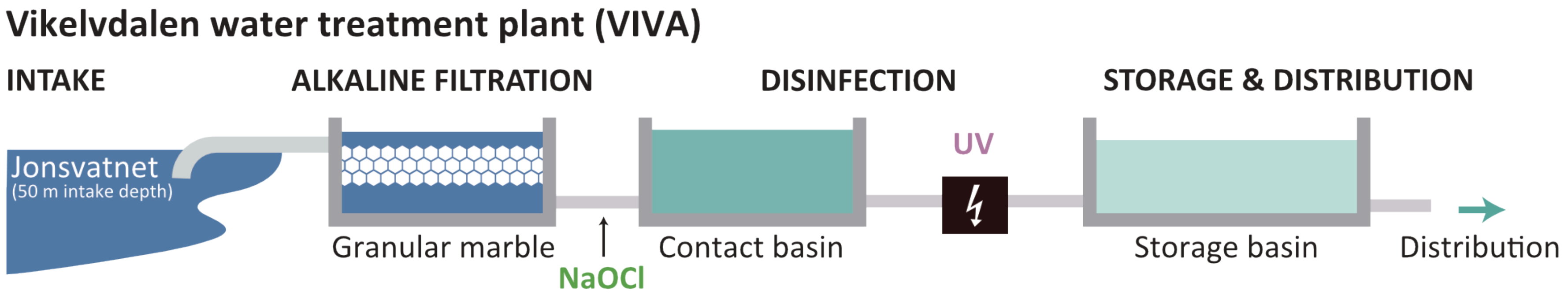
Pipe Material

- **Copper**
  - 5/8 in. external diameter
  - 16 mm internal diameter

- **Uponor Aqua PE-Xa**
  - 5/8 in. external diameter
  - 12.5 mm internal diameter

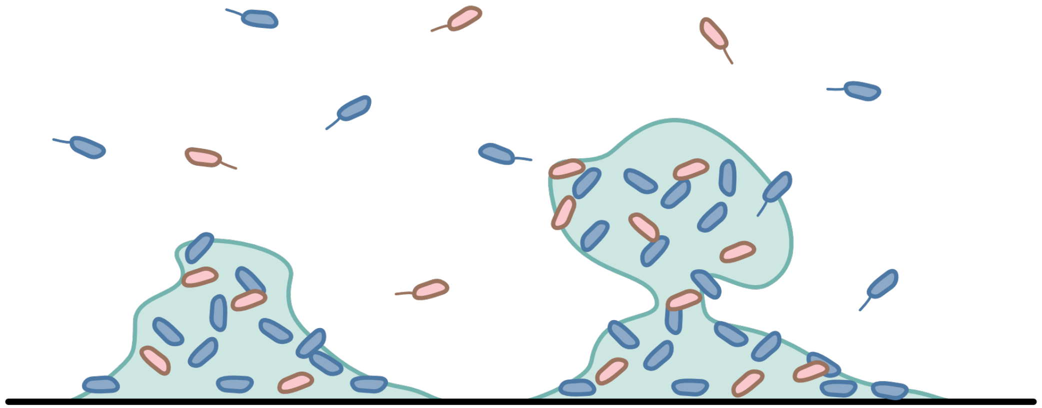
Feed Water

Parameter	Values
Temperature, °C	**10.0** [7.6, 13.6]
pH	**8.0** [7.7, 8.3]
Hardness, mg/L $CaCO_3$	**54** [53, 55]
TOC, mg/L C	**2.7** [2.5, 3.0]
AOC, µg/L C	**96** [28, 244]
Total chlorine, mg/L Cl_2	**<0.02**

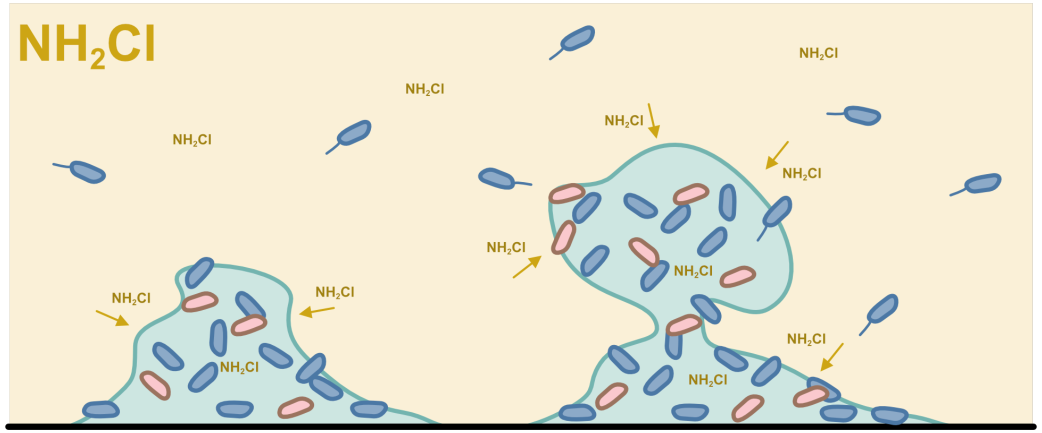


No Residual vs. Residual Disinfectant

- **No Residual**
  - Unaltered municipal tap water



- **Chloramine (NH_2Cl)**
  - Relatively common municipal disinfectant
  - Potentially more stable than HOCl
  - Better at penetrating biofilm than HOCl
  - Target dose = 1 mg/L Cl_2

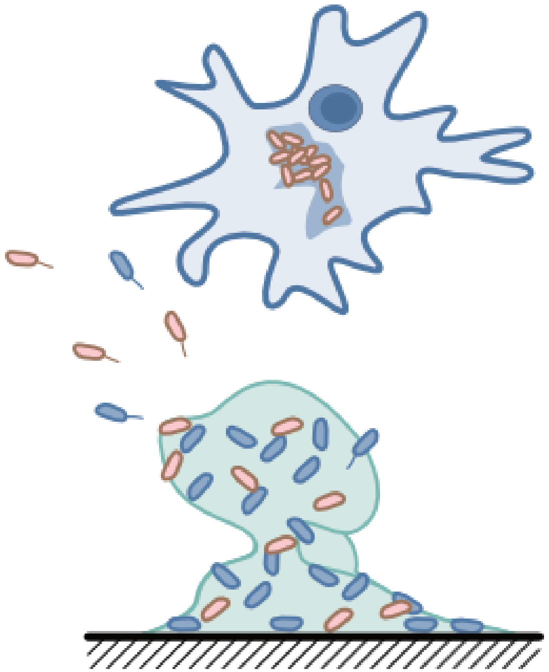


Flushing vs. No Flushing

- Are there flushing benefits beyond resetting water age?
  - Shear stress vs. biofilms?
  - Synergy with thermal, chemical strategies

- Should operators put in extra effort to maximize flow rate?*

*to the extent possible

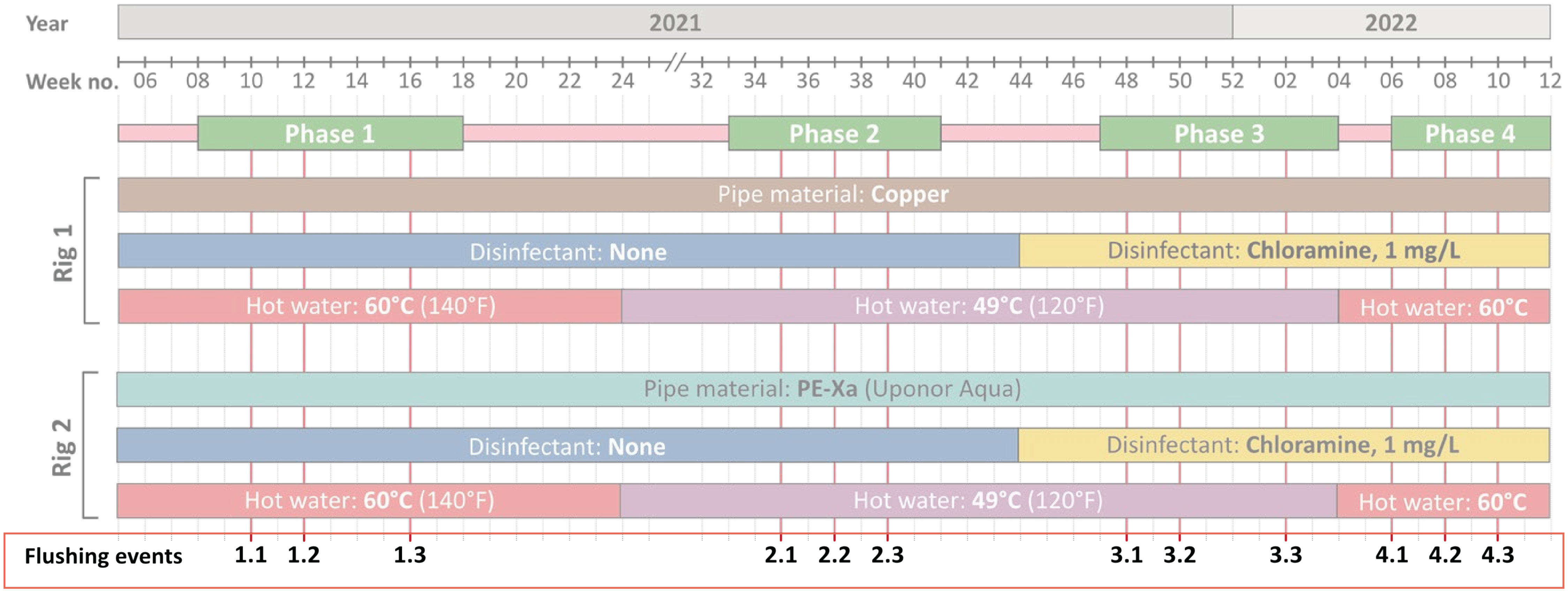


Outlet Operation

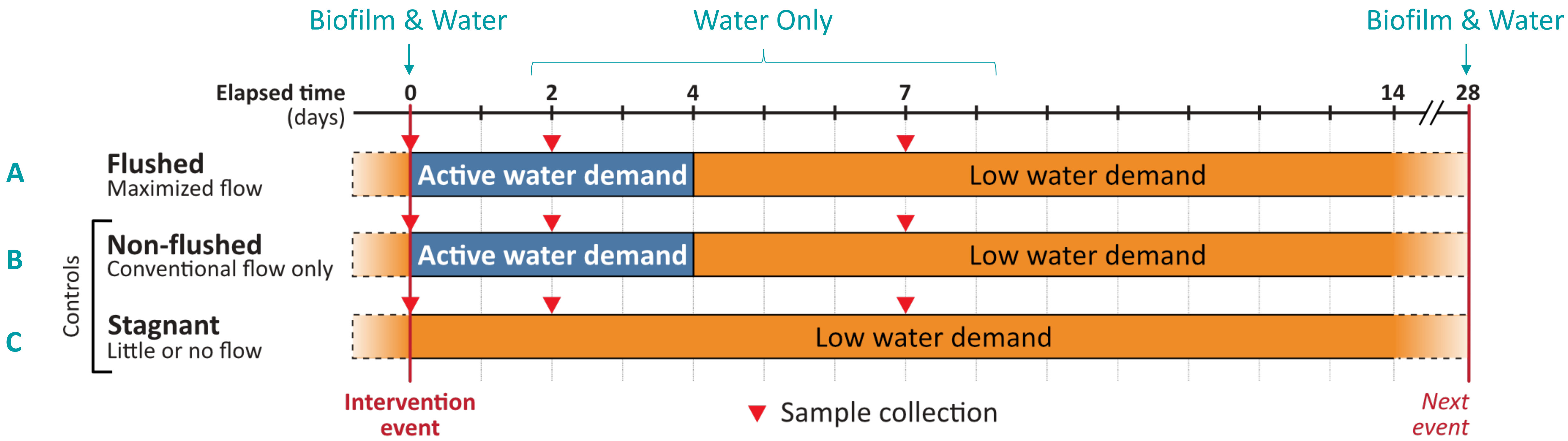
Parameter	**Flushing** (max. flow)	**Shower** (conventional flow)
Shower hose & head	Removed	Connected
Duration	5 min	8 min
Temperature	Full cold or hot	40°C (104°F)
Flow rate	15.7 to 17.5 L/min (4.2 to 4.6 gpm)	7.2 L/min (1.9 gpm)
Flow velocity (5/8 in.)	1.9 to 2.6 m/s (6.2 to 8.5 ft/s)	< 1.0 m/s (< 3.3 ft/s)
Flow profile	Turbulent	Laminar to Turbulent

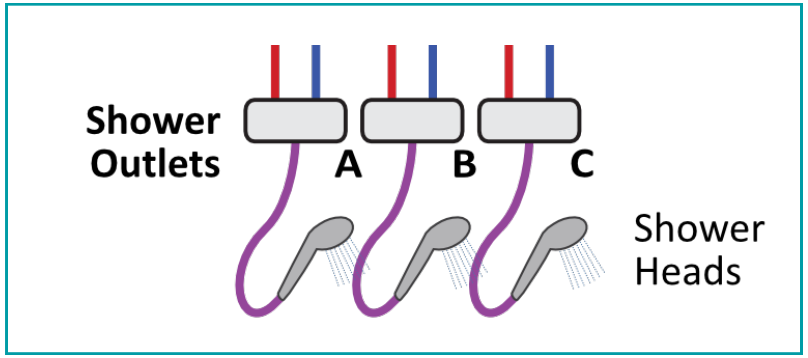
Photo: Ahlsell AS,
A-collection Azur shower battery

Experimental Operation of the Pilot



Operation/sampling cycle (flushing event plus follow-up)





Water Samples

- Pre-/Post-flush = 1000 mL
- Follow-up = ca. 100 mL

- MCE membrane filters
  - 0.2 µm pore size
  - 47 mm diameter

Photo (above): Nasco Whirl-Pak Stand-up Bags, via www.adventureprozone.ca

Photos (left and above): Sigma-Aldrich.com, Millipore EZ-Stream system with Microfil manifold

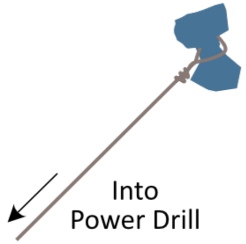
Biofilm Sample Collection

1

POLYWIPE Sponge

Pre-moistened with sterile, non-inhibitory diluent

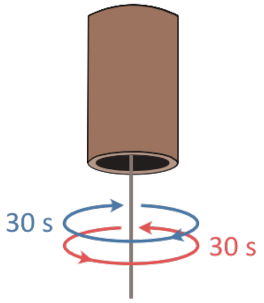
2



Loop/Sponge Assembly

Sponge affixed to autoclave-sterilized steel wire via loop

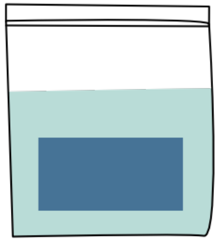
3



Biofilm Collection

Loop/sponge assembly rotated for 30 s clockwise and then counterclockwise

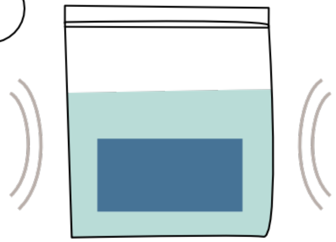
4



Submersion 1

Sponge submerged in 50 mL elution solution

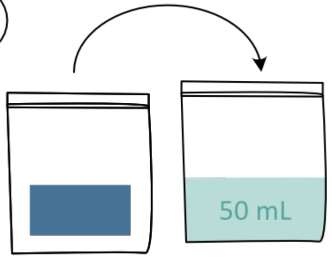
5



Sonication

2 min ultrasonic bath to suspend biofilm

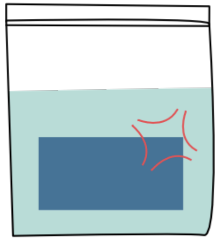
6



Elution 1

Elution solution with suspended biofilm transferred to new bag

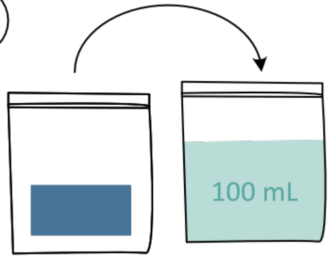
7



Submersion 2

Sponge submerged in fresh 50 mL elution solution and squeeze-massaged

8

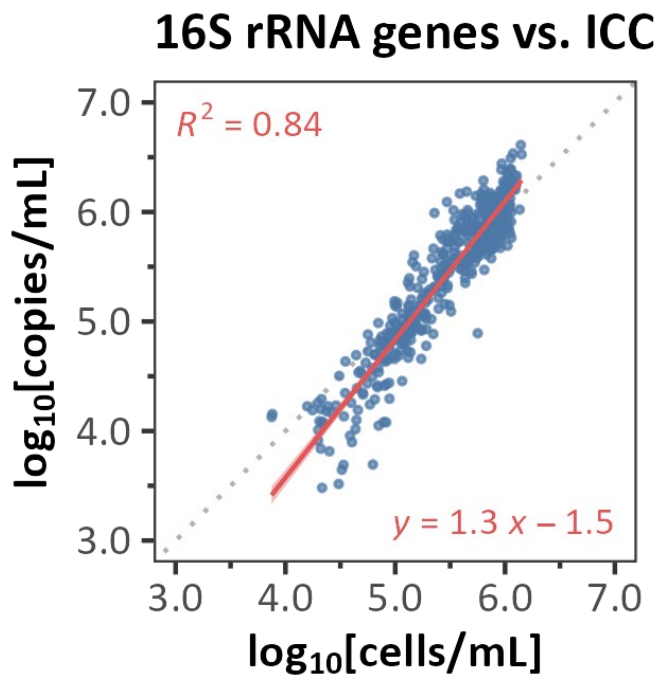


Elution 2

Second solution transferred and combined with first solution

Sample Analysis

- Quantitative PCR (qPCR)
  - Total bacteria (16S rRNA genes)
  - *Legionella* spp. (*ssrA*)
  - *L. pneumophila* (*mip*)
  - *Vermamoeba vermiformis* (18S rRNA gene)
- Flow cytometry
  - Total Cell Count (TCC)
  - Intact Cell Count (ICC)
- Cultivation
  - IDEXX Legiolert
  - Heterotrophic plate count (HPC) (R2A agar, 29°C)



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PART IV:

RESULTS – FLUSHING WITHOUT RESIDUAL DISINFECTANT

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Norwegian University of Science & Technology

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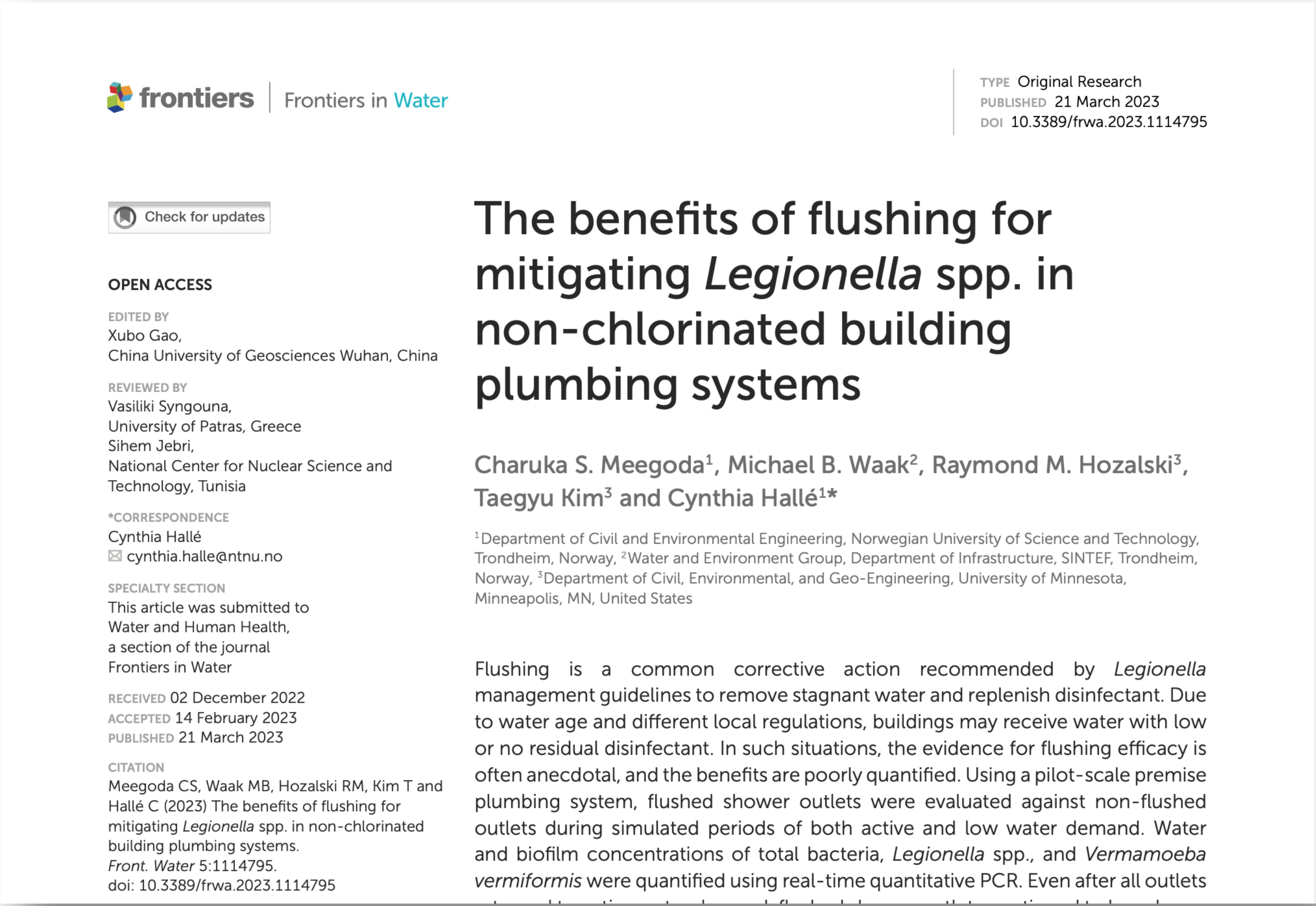
frontiers | Frontiers in Water

TYPE Original Research
PUBLISHED 21 March 2023
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Check for updates

The benefits of flushing for mitigating *Legionella* spp. in non-chlorinated building plumbing systems

Charuka S. Meegoda[1], Michael B. Waak[2], Raymond M. Hozalski[3], Taegyu Kim[3] and Cynthia Hallé[1]*

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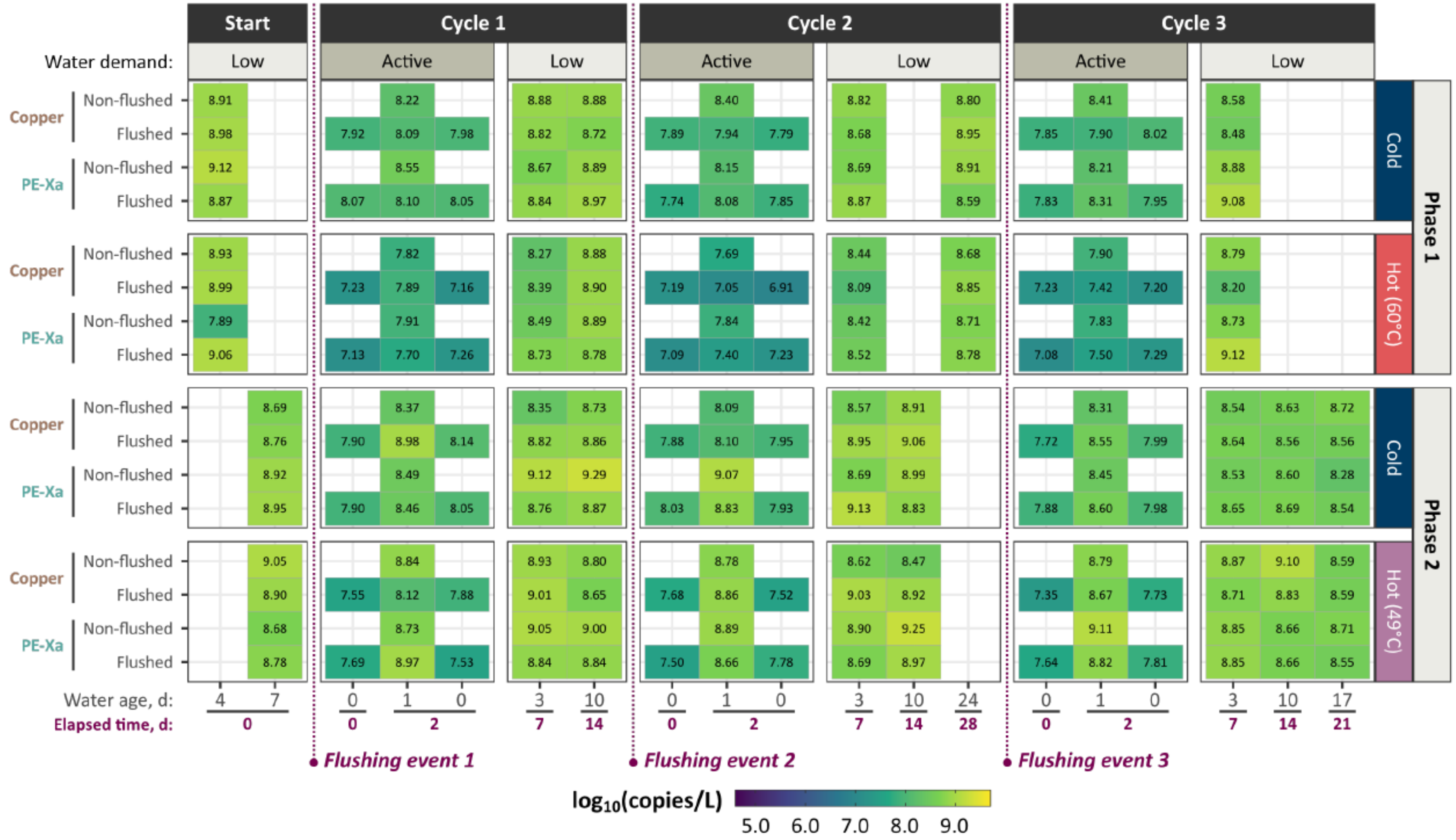
Meegoda CS, Waak MB, Hozalski RM, Kim T and Hallé C (2023) The benefits of flushing for mitigating *Legionella* spp. in non-chlorinated building plumbing systems.
Front. Water 5:1114795.
doi: 10.3389/frwa.2023.1114795

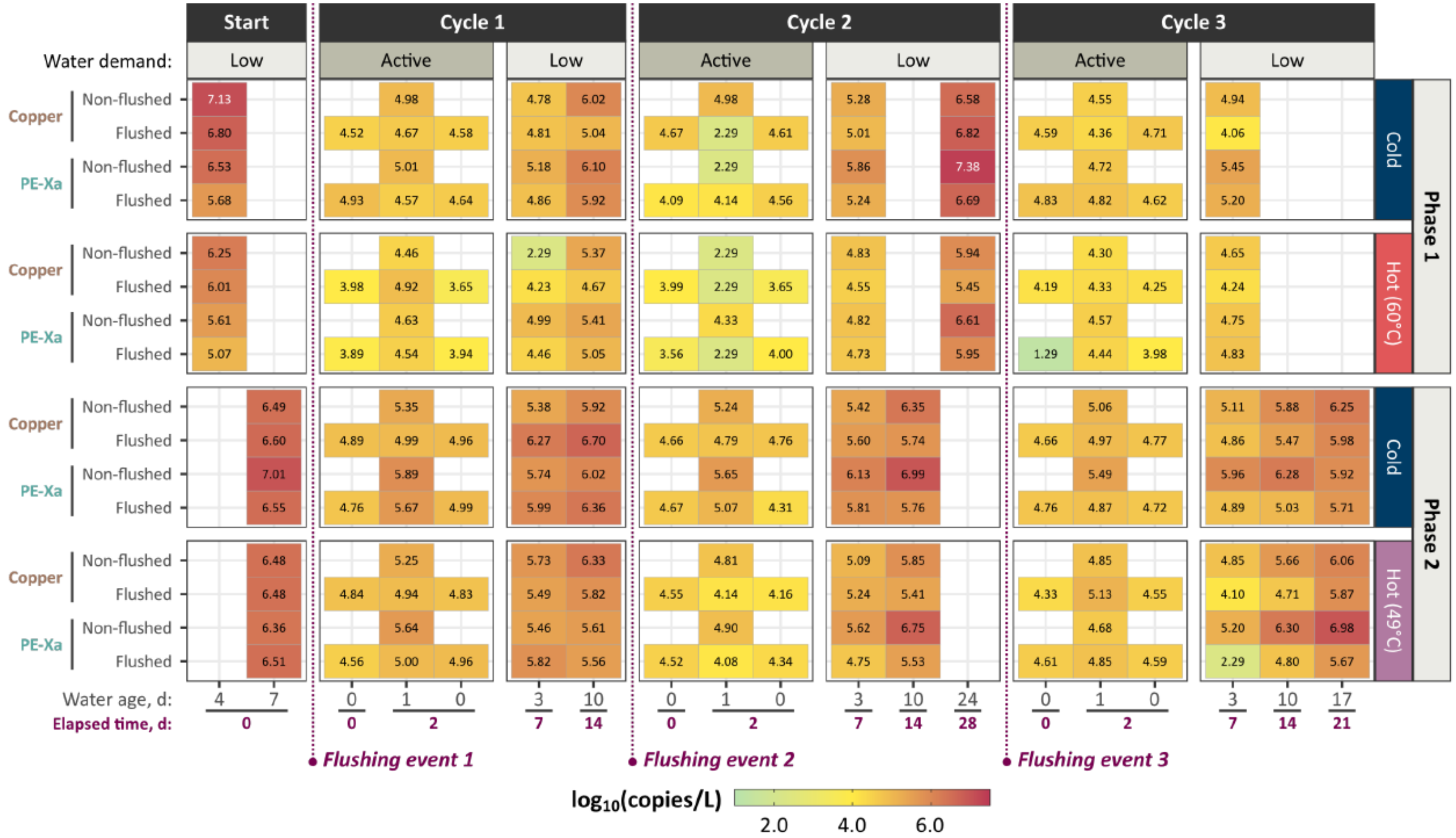
Flushing is a common corrective action recommended by *Legionella* management guidelines to remove stagnant water and replenish disinfectant. Due to water age and different local regulations, buildings may receive water with low or no residual disinfectant. In such situations, the evidence for flushing efficacy is often anecdotal, and the benefits are poorly quantified. Using a pilot-scale premise plumbing system, flushed shower outlets were evaluated against non-flushed outlets during simulated periods of both active and low water demand. Water and biofilm concentrations of total bacteria, *Legionella* spp., and *Vermamoeba vermiformis* were quantified using real-time quantitative PCR. Even after all outlets

Meegoda CS, Waak MB, Hozalski RM, Kim T, Hallé C. 2023. The benefits of flushing for mitigating *Legionella* spp. in non-chlorinated building plumbing systems. *Front Water*. 5:1114795. doi:10.3389/frwa.2023.1114795

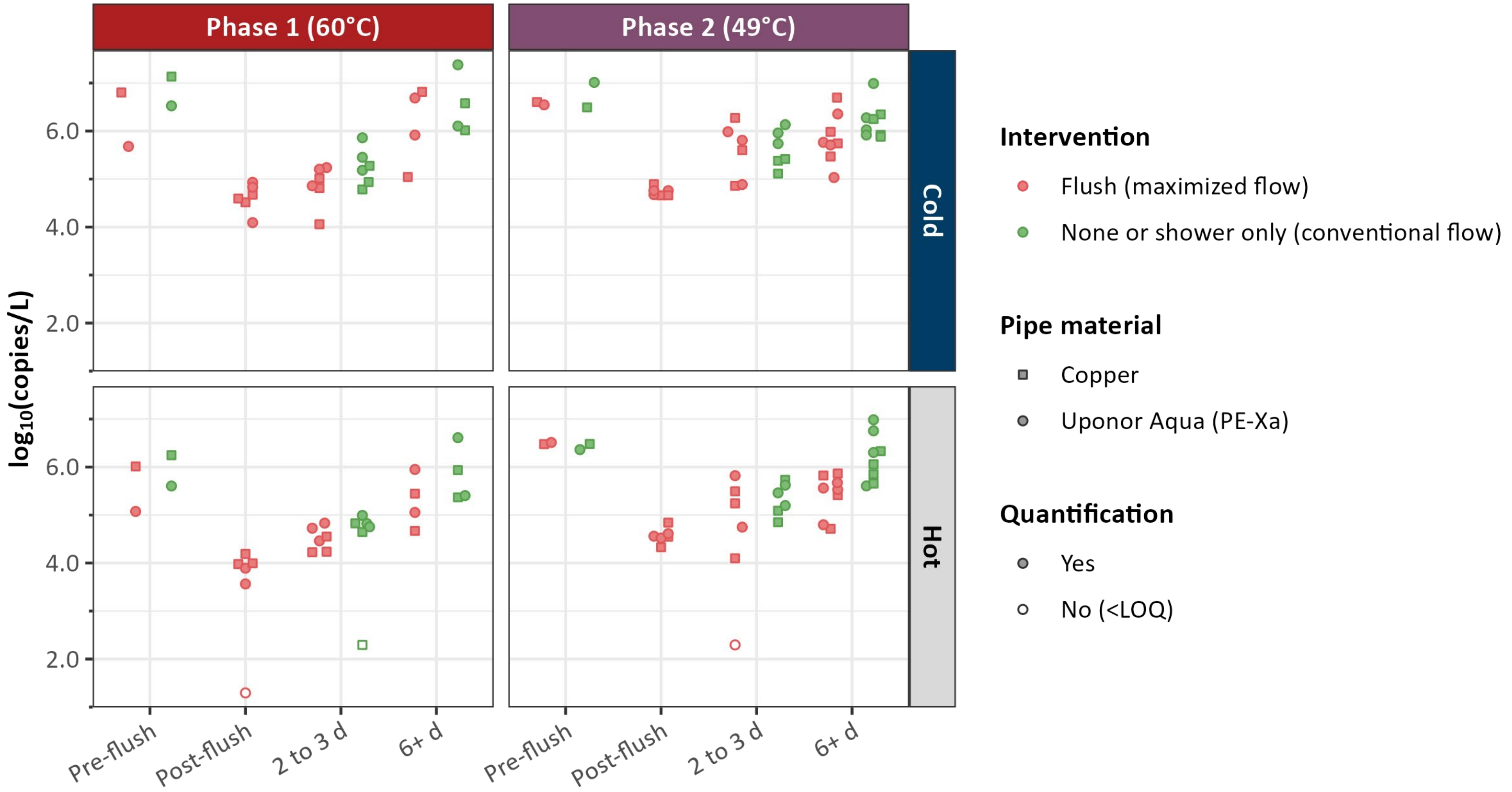
Suspended Total Bacteria at Varying Water Age
Without residual chlorine



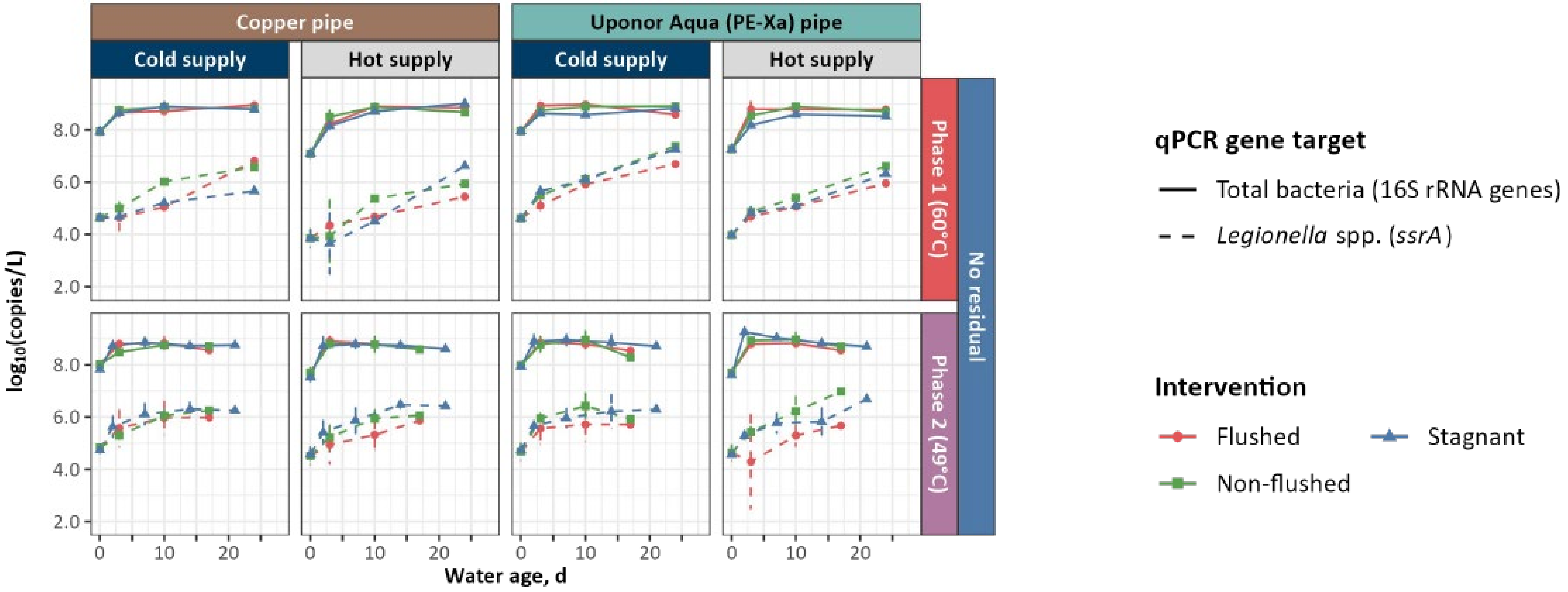
Suspended *Legionella* spp. at Varying Water Age without residual chlorine



Short-term benefits of flushing *Legionella* spp. (*ssrA* via qPCR)



Long-term benefits of flushing



Key Findings

- Immediate reduction of total bacteria and *Legionella* spp.in water (range 90 to 99%) from flushing or typical shower flow rates were similar
  - Higher flow rate during flushing may accelerate the turnover of old water
- Flushing is effective to reset total bacterial levels, with significant reductions observed within approximately 3 days after flushing.
  - This short-term effect may be insufficient for controlling Legionella growth, which is influenced by various factors.
- In bulk water, there is insufficient evidence to support a difference in log reduction between pipe materials.

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PART V:

RESULTS – FLUSHING WITH RESIDUAL CHLORAMINE

Michael B. Waak, PhD
Dept. of Infrastructure, SINTEF Community

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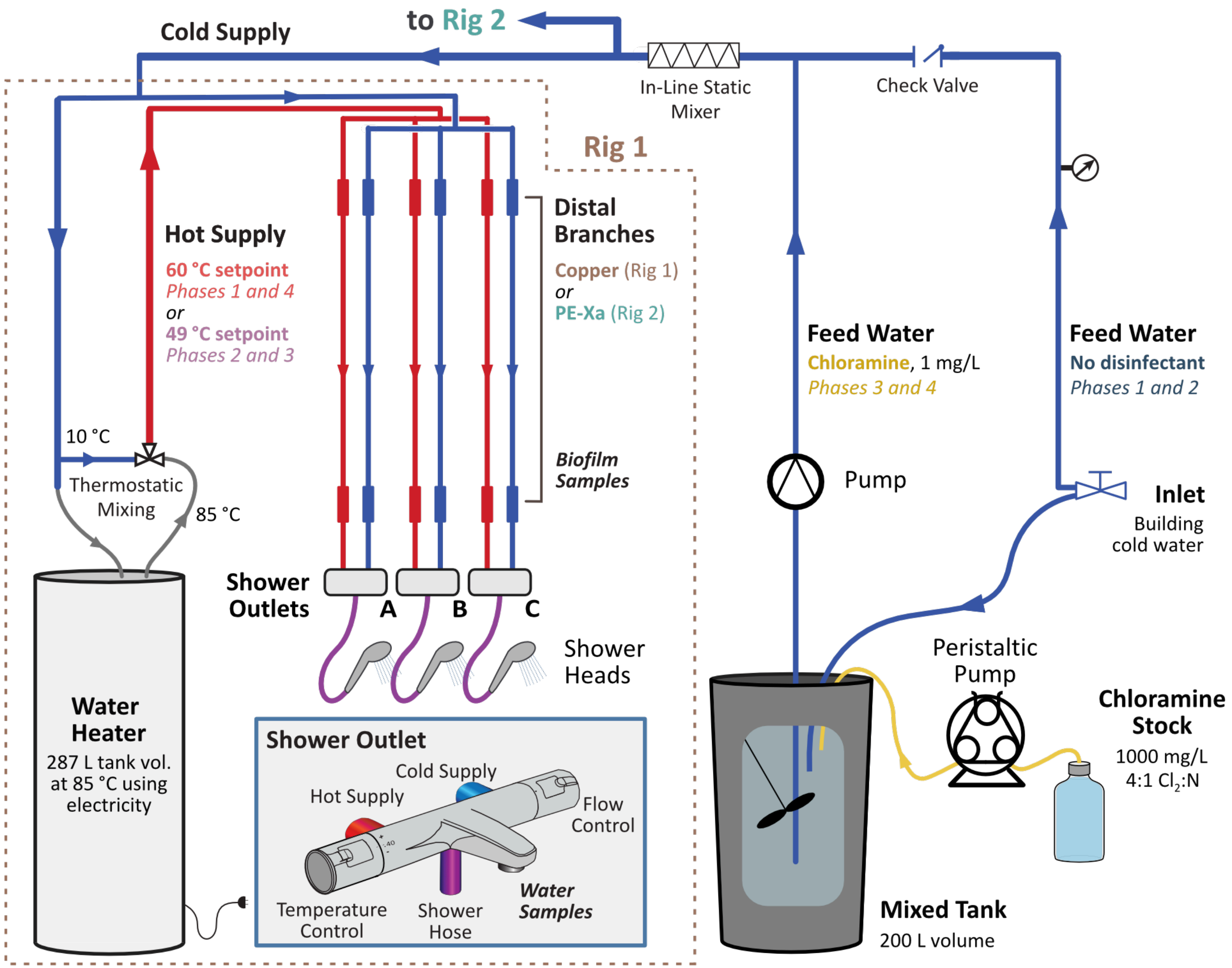
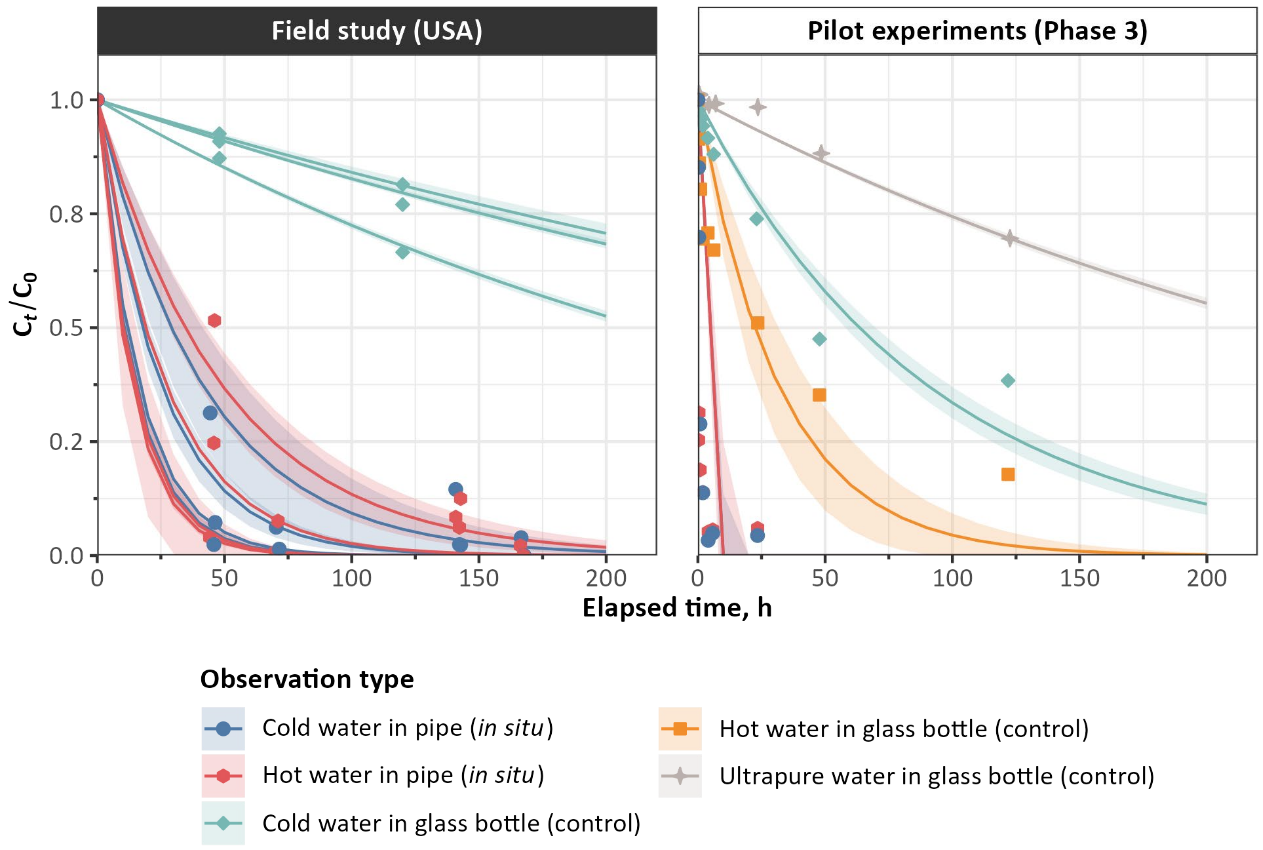
Pilot-scale Premise Plumbing System

- **Intervention (flow rate)**
  - None (simulated shower)
  - Flushing (max. flow, 5 min)
- **Residual Disinfectant**
  - None
  - Chloramine, 1 mg/L Cl_2
- **Pipe Material**
  - Copper
  - Uponor Aqua PE-Xa
- **Temperature Setpoint**
  - 49 °C (120 °F)
  - 60 °C (140 °F)



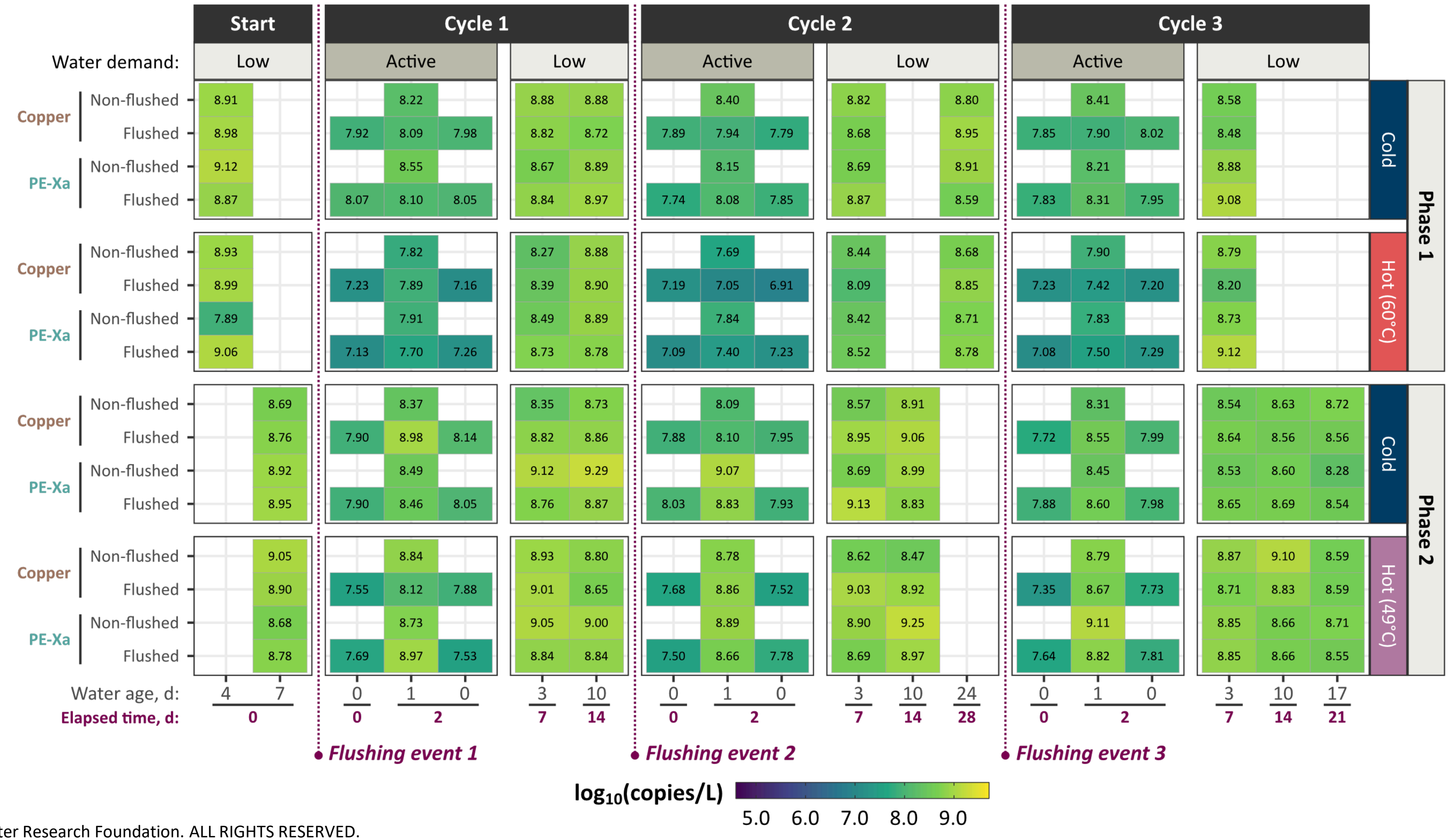
Chloramination

- Stock chloramine (EPA method 127)
  - 1000 mg/L Cl_2
  - 4:1 Cl_2:N (by mass)
- Mixed tank
  - Final dose **0.9 ± 0.1 mg/L Cl_2**
- CT values
  - **Cold:** 3.6 mg·min/L
  - **Hot:** 6.4 mg·min/L



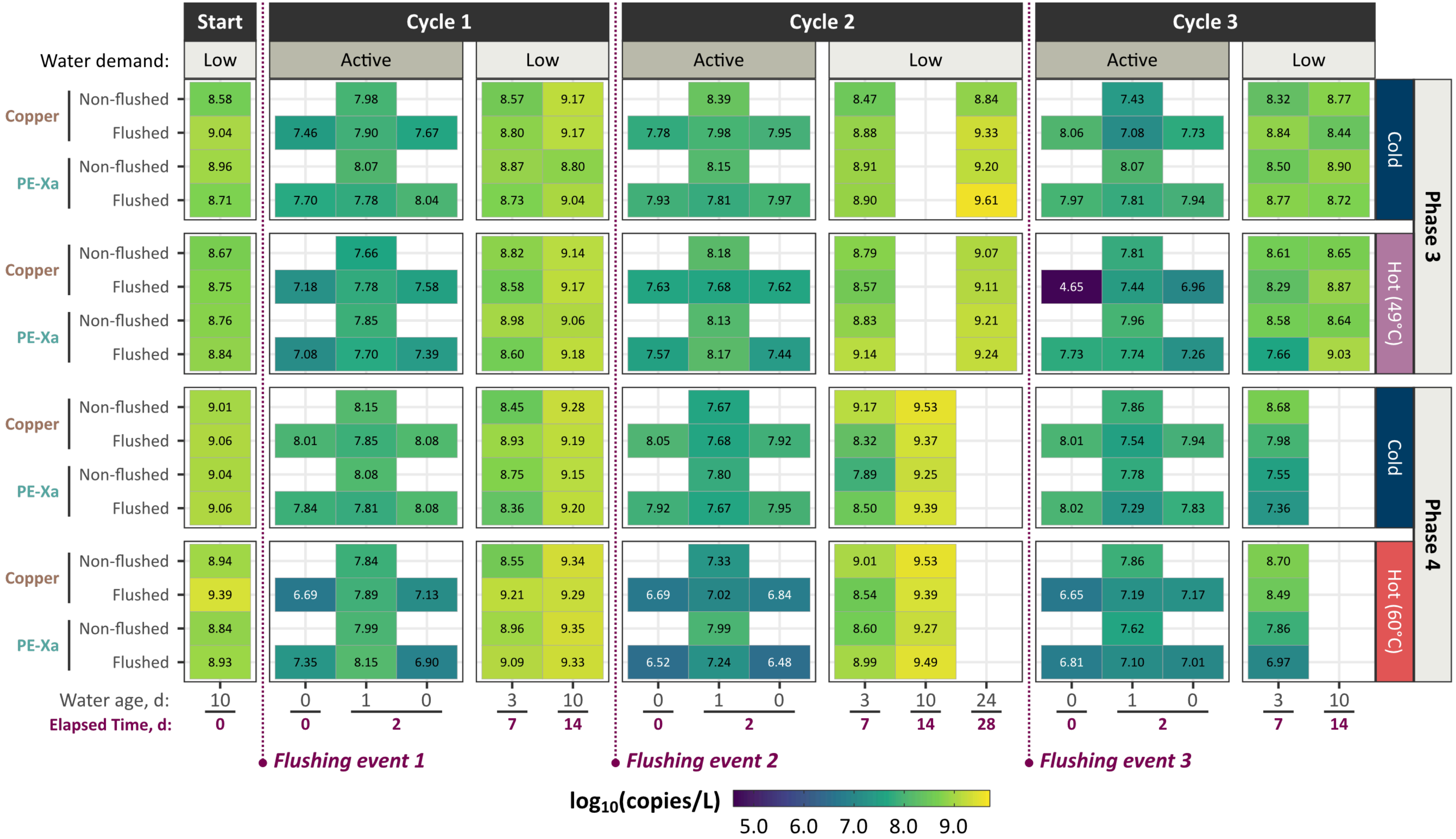
Total Bacteria (16S rRNA genes via qPCR)

No Residual

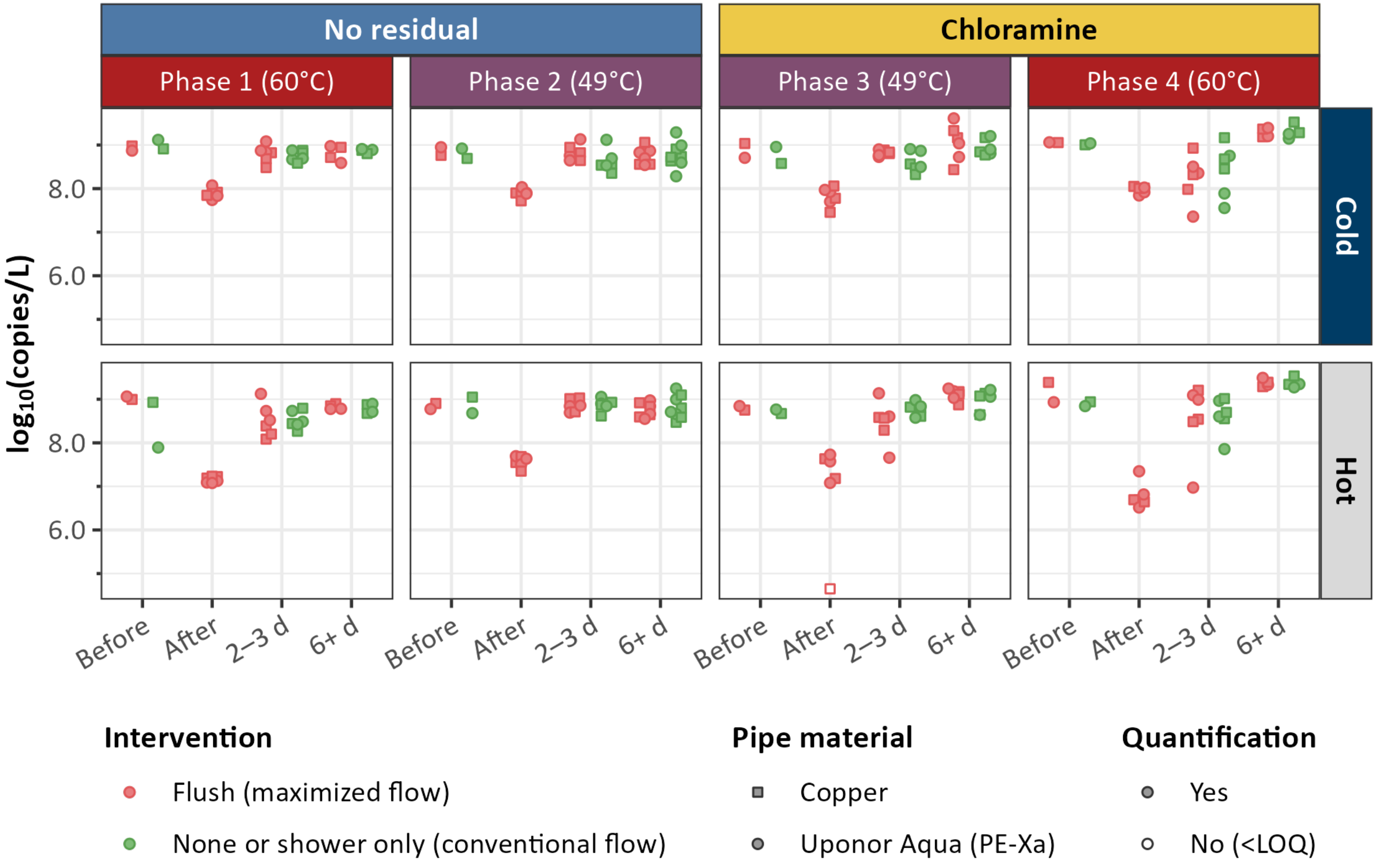


Total Bacteria (16S rRNA genes via qPCR)

Chloramine

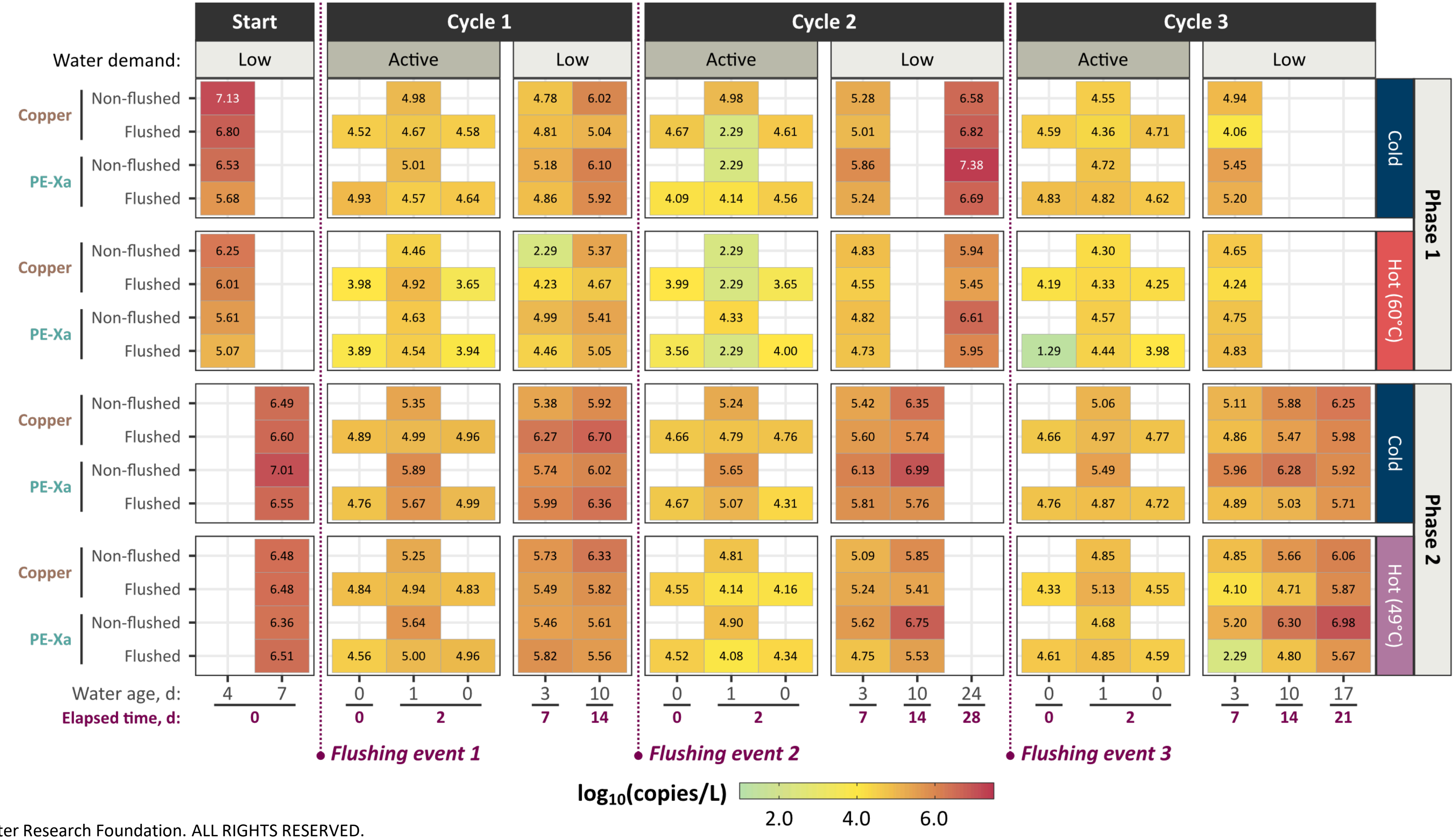


Total bacteria (16S rRNA genes via qPCR)



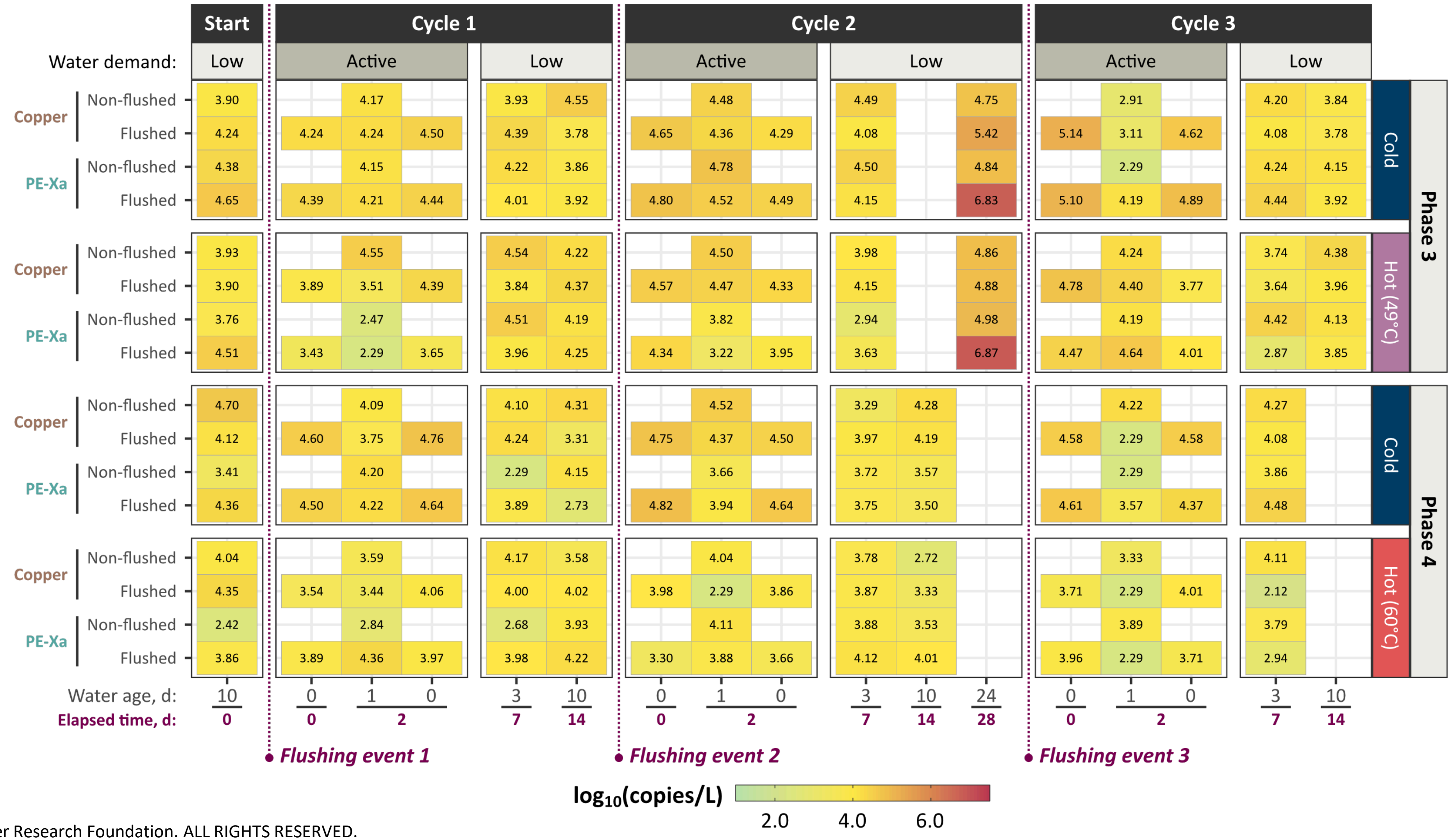
Legionella spp. (*ssrA* via qPCR)

No Residual

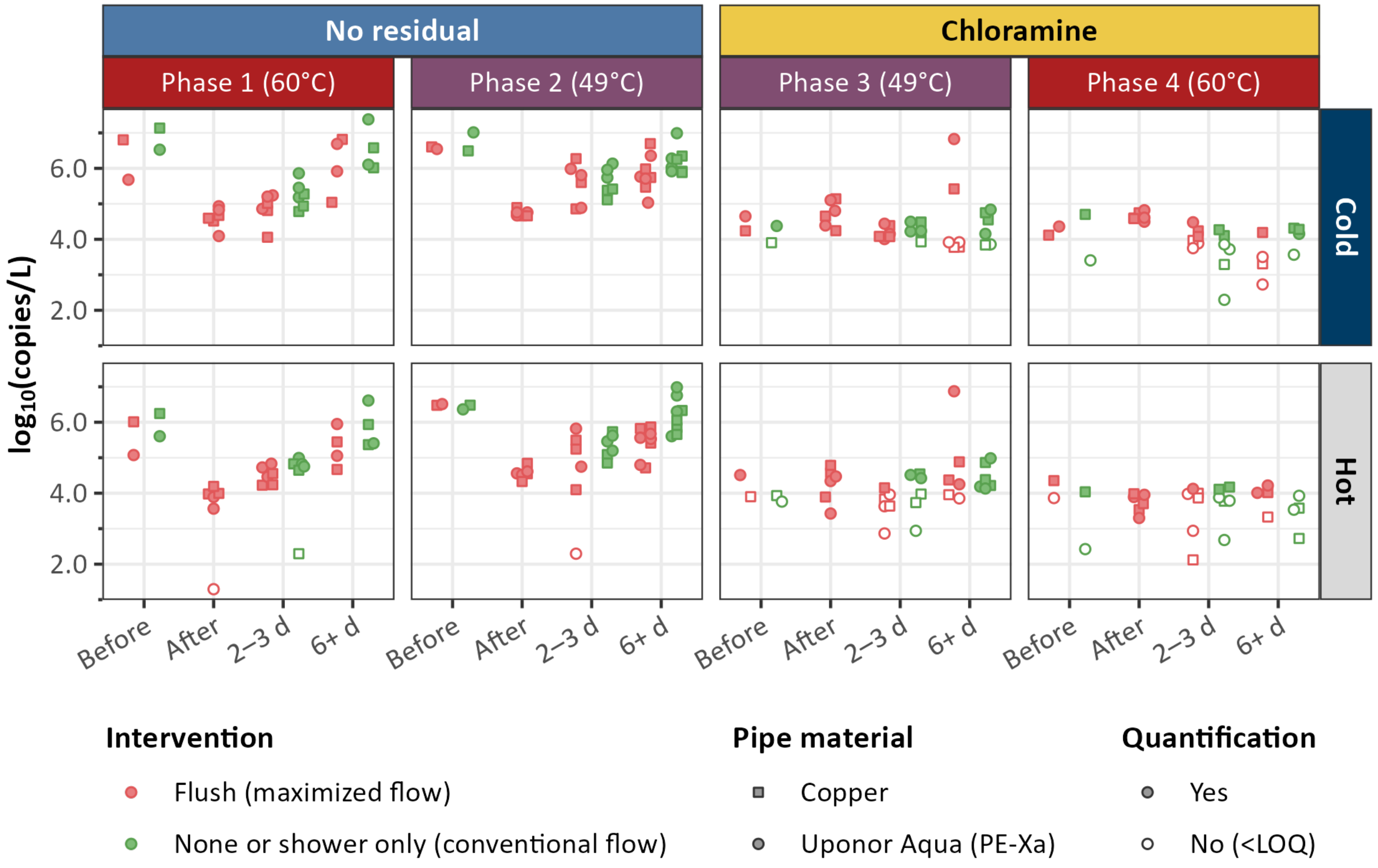


Legionella spp. (*ssrA* via qPCR)

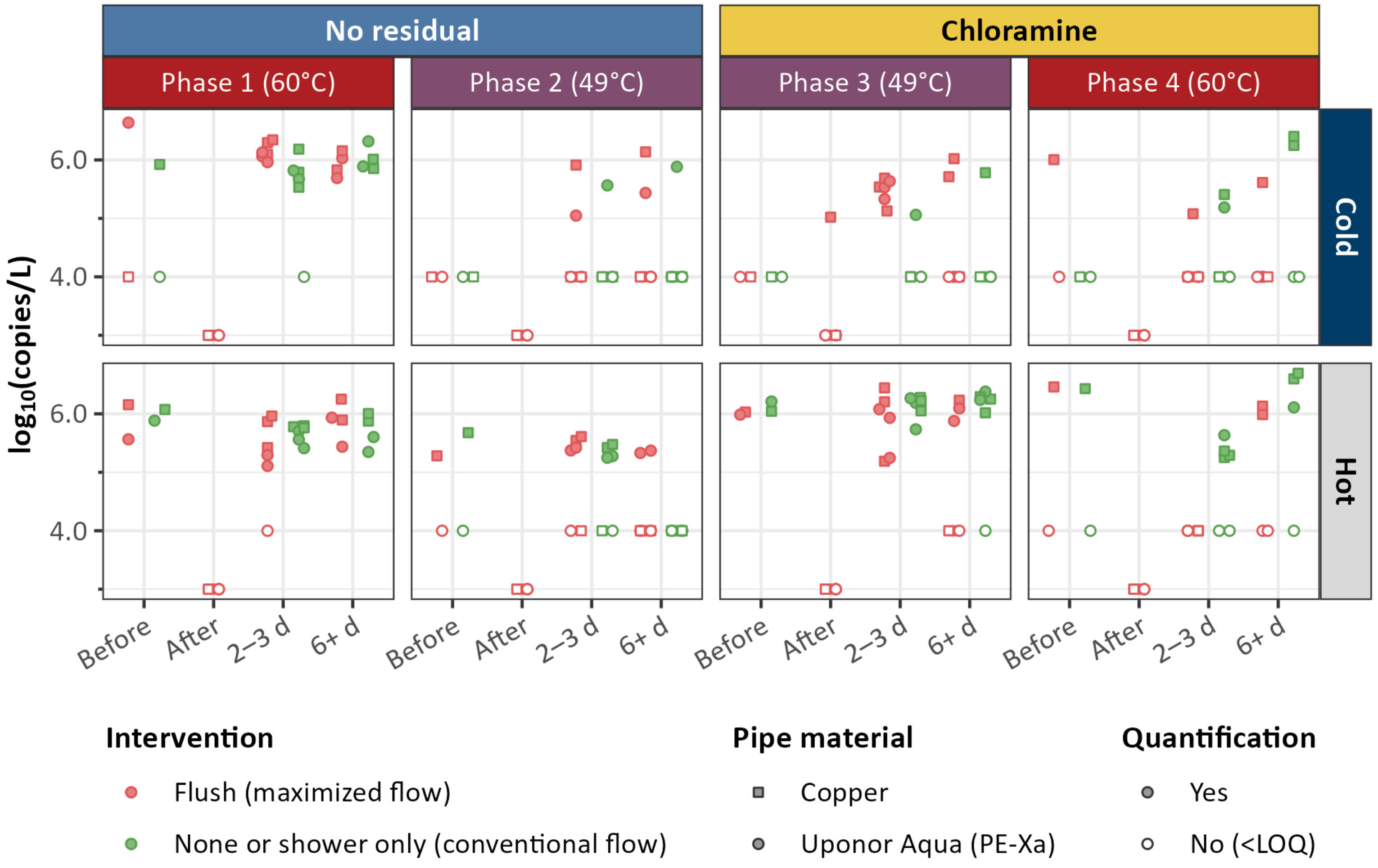
Chloramine



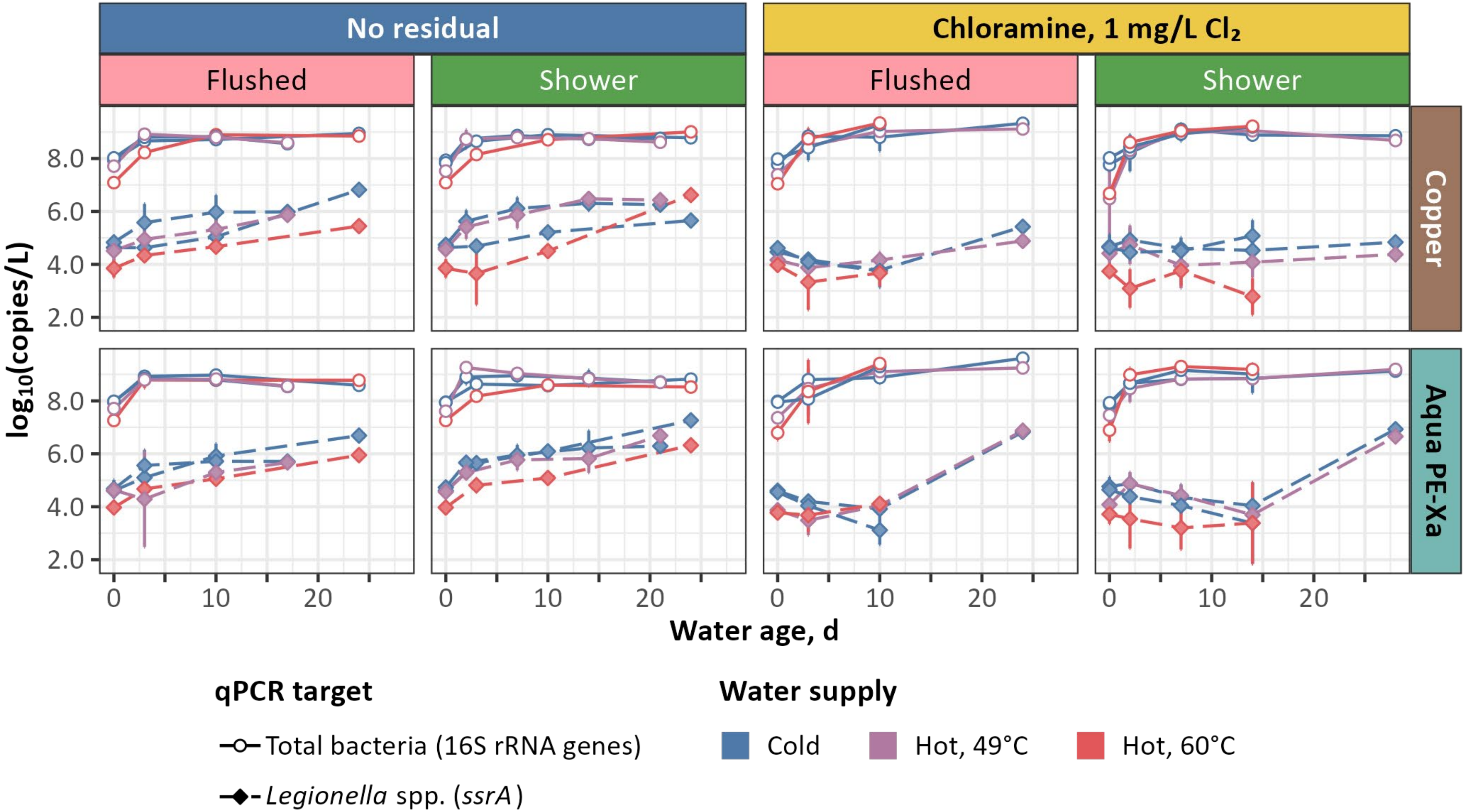
Legionella spp. (*ssrA* via qPCR)



Vermamoeba vermiformis (18S rRNA genes via qPCR)



Growth vs. Water Age (Stagnation)



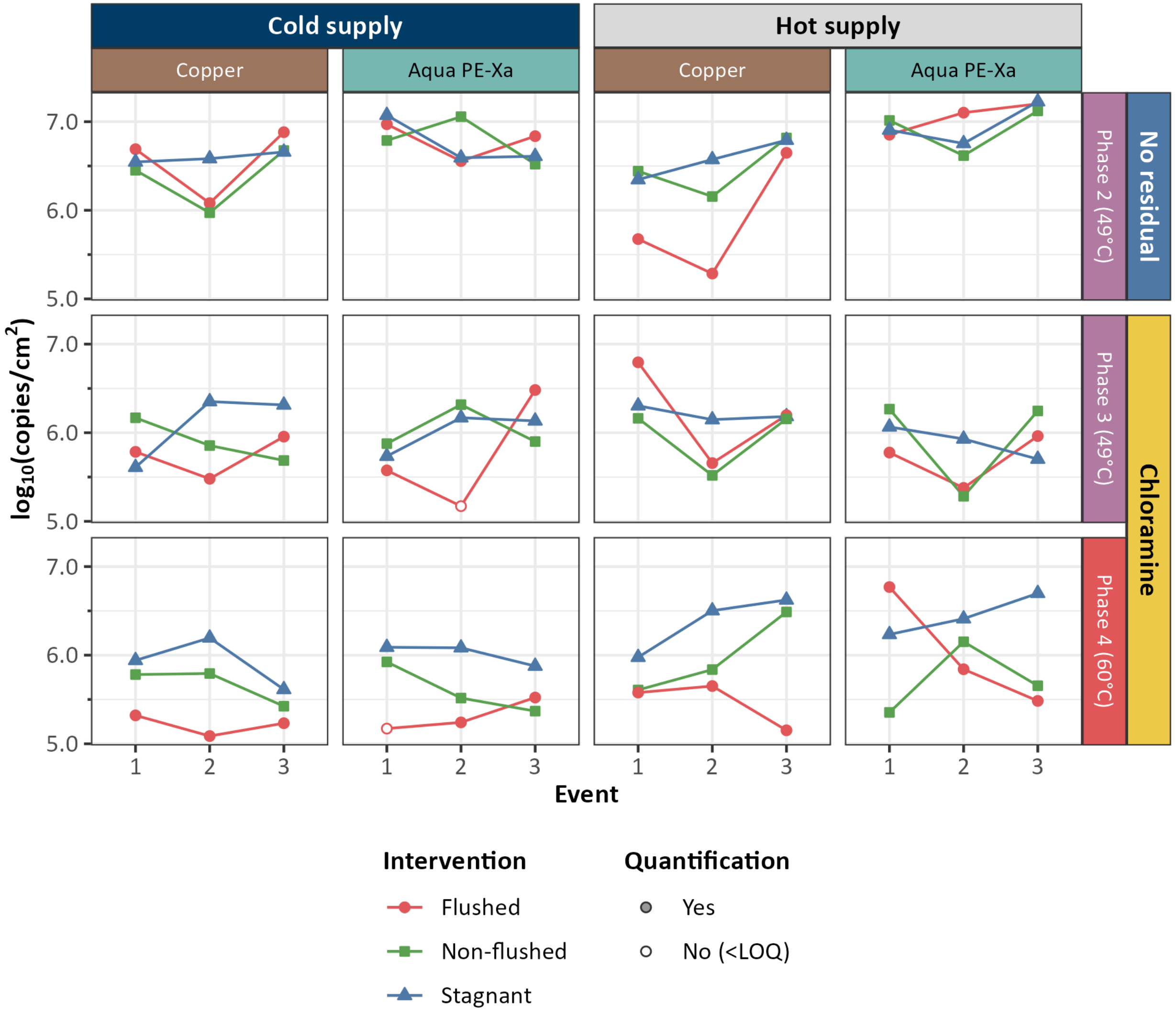
Key Findings:

Effect of Flushing on **Water-Phase** Bacteria

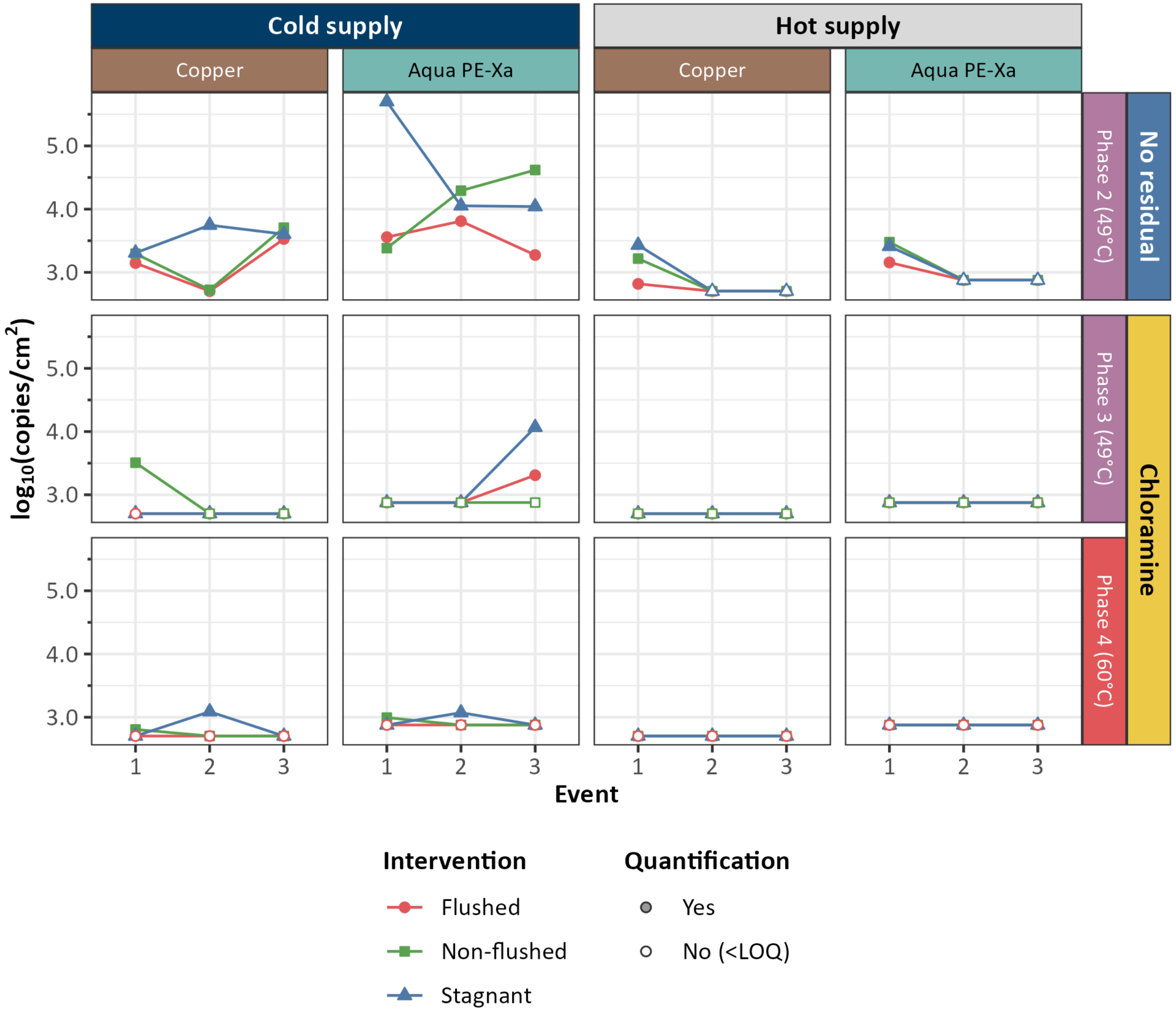
- Limited effect of chloramine vs. total bacteria
  - May even be stimulated (confounded by time, however)
- Stable *Legionella* concentration post-chloramination (induced lag phase?)
- *Vermamoeba vermiformis* present at low levels with higher **water age** (hit or miss)
- The beneficial mechanism of flushing differs:
  - **No residual**
    - Bacteria growth (incl. *Legionella*) is **not** under control; flushing expels accumulated biomass
  - **Chloramine**
    - *Legionella* growth is suppressed
    - Flushing resets the disinfectant residual and expels total bacteria
- Presence and growth of *Legionella* spp. is not limited to the hot water (it's the cold water too!)

Biofilm

Total bacteria (16S rRNA genes)



Legionella spp. (*ssrA*)



Key Findings:
Effect of Flushing on **Biofilm-Phase** Bacteria

- No clear (or at least consistent) effect of pipe material with regard to biomass

- Similar total bacteria between cold and hot water, but less *Legionella* in hot water versus cold water

- Chloramine helps reduce biofilm *Legionella* vs. no disinfectant residual
  - There will still be growth in the water phase if *Legionella* come in with the municipal water

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PART VI:
RESULTS – FIELD STUDIES IN THE UNITED STATES AND NORWAY

Prof. Raymond M. Hozalski, PhD
University of Minnesota, Twin Cities

Prof. Cynthia Hallé, PhD
Norwegian University of Science & Technology

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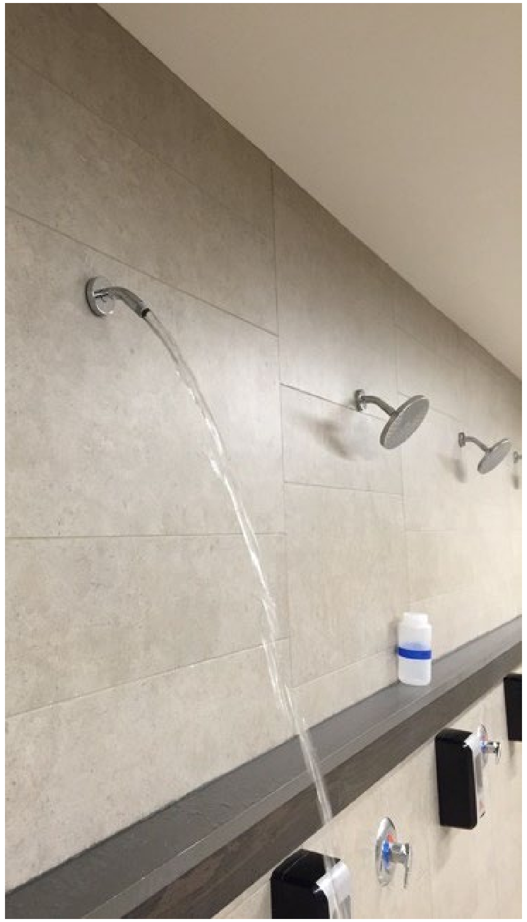
Field Study in Minnesota (U.S.)

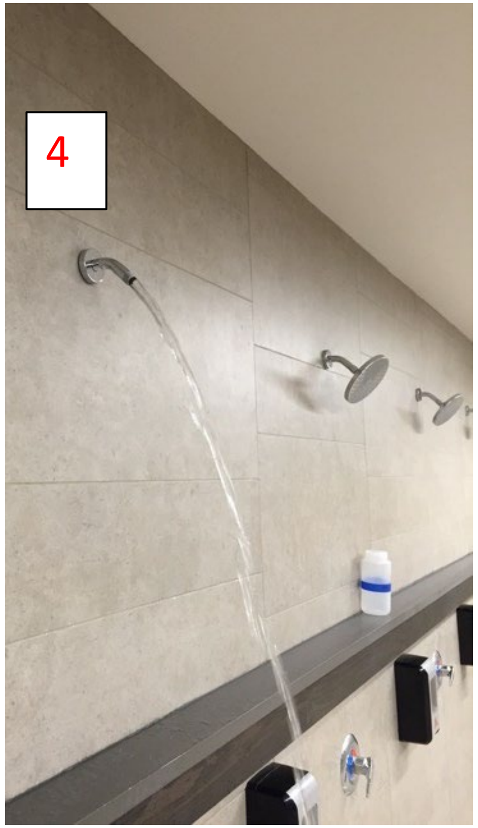
Photo Credit: Visit Saint Paul Official Convention & Visitors Bureau
https://www.visitsaintpaul.com/directory/university-of-minnesota-conference-event-services/ [accessed 2024-05-21]

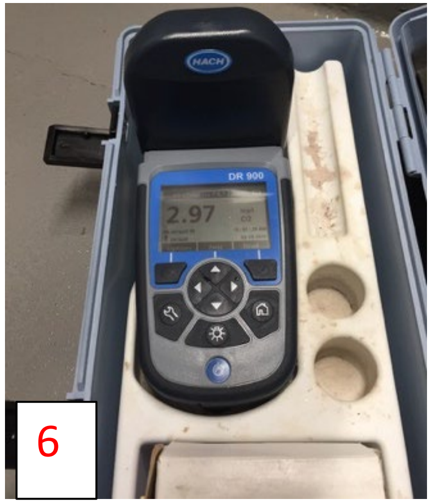
Sampling Sites

- 5 university buildings (U. of Minnesota)
  - 4 on Minneapolis campus (A, B, C, and D)
    - Surface water with chloramines
  - 1 on St. Paul campus (E)
    - Surface water with chloramines
- Suburban high school
    - Groundwater with free chlorine
- 3 buildings at a youth camp
    - Groundwater (3 separate wells)

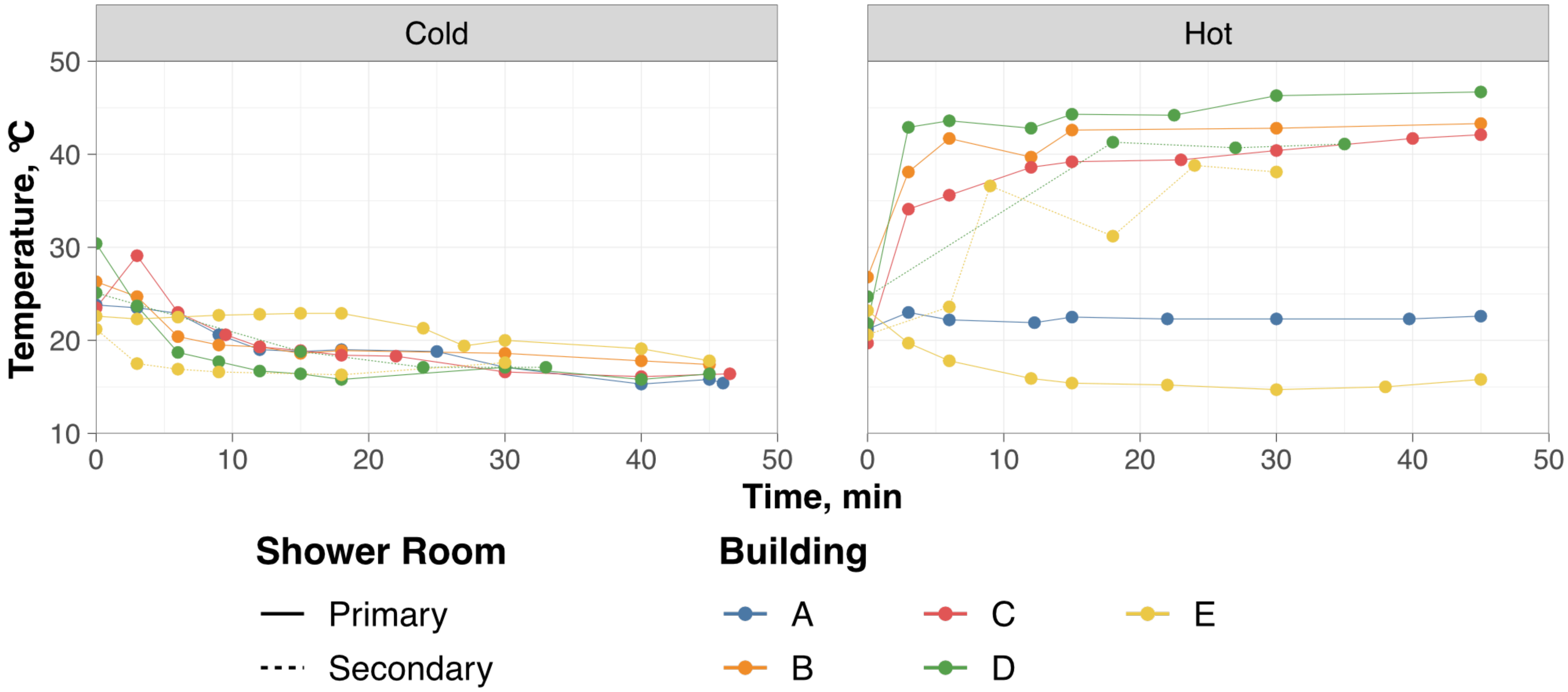


Approach



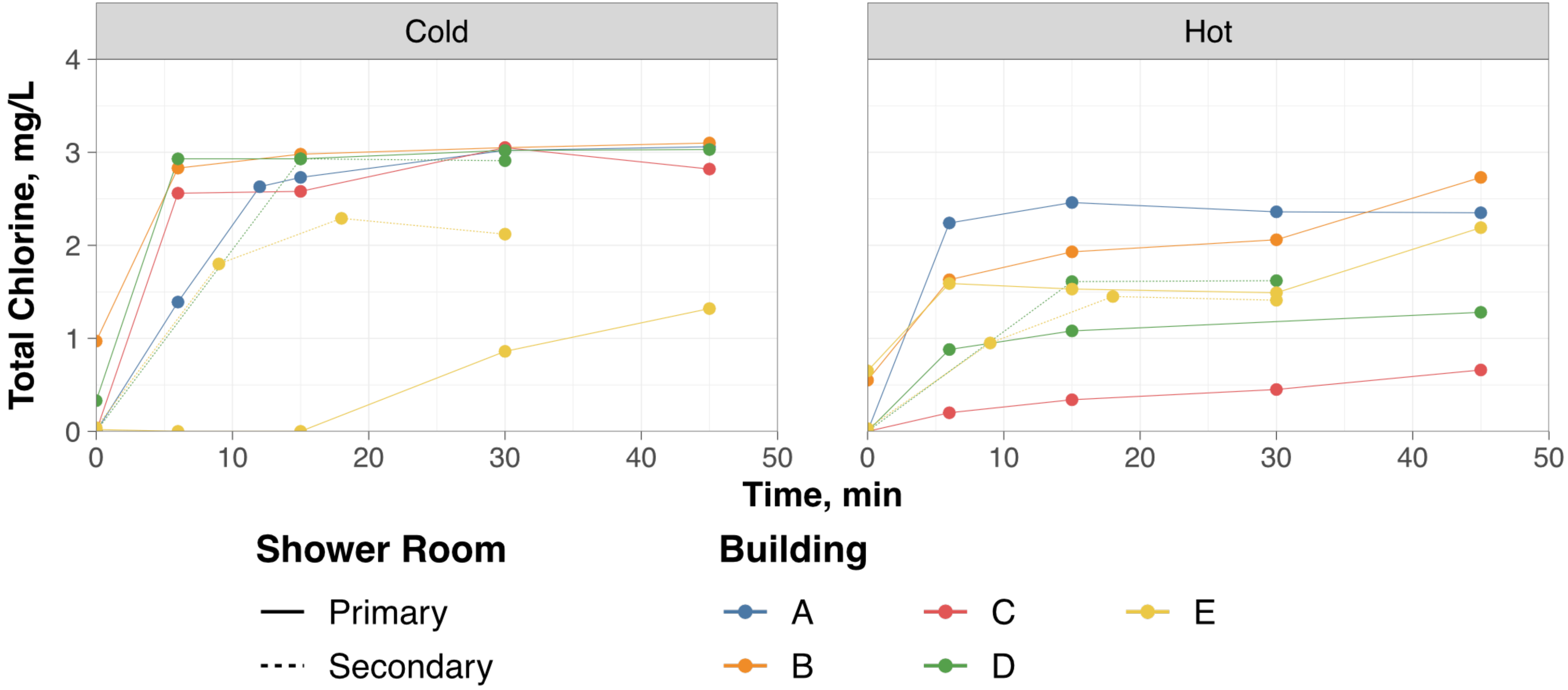


Temperature (U. of Minnesota)

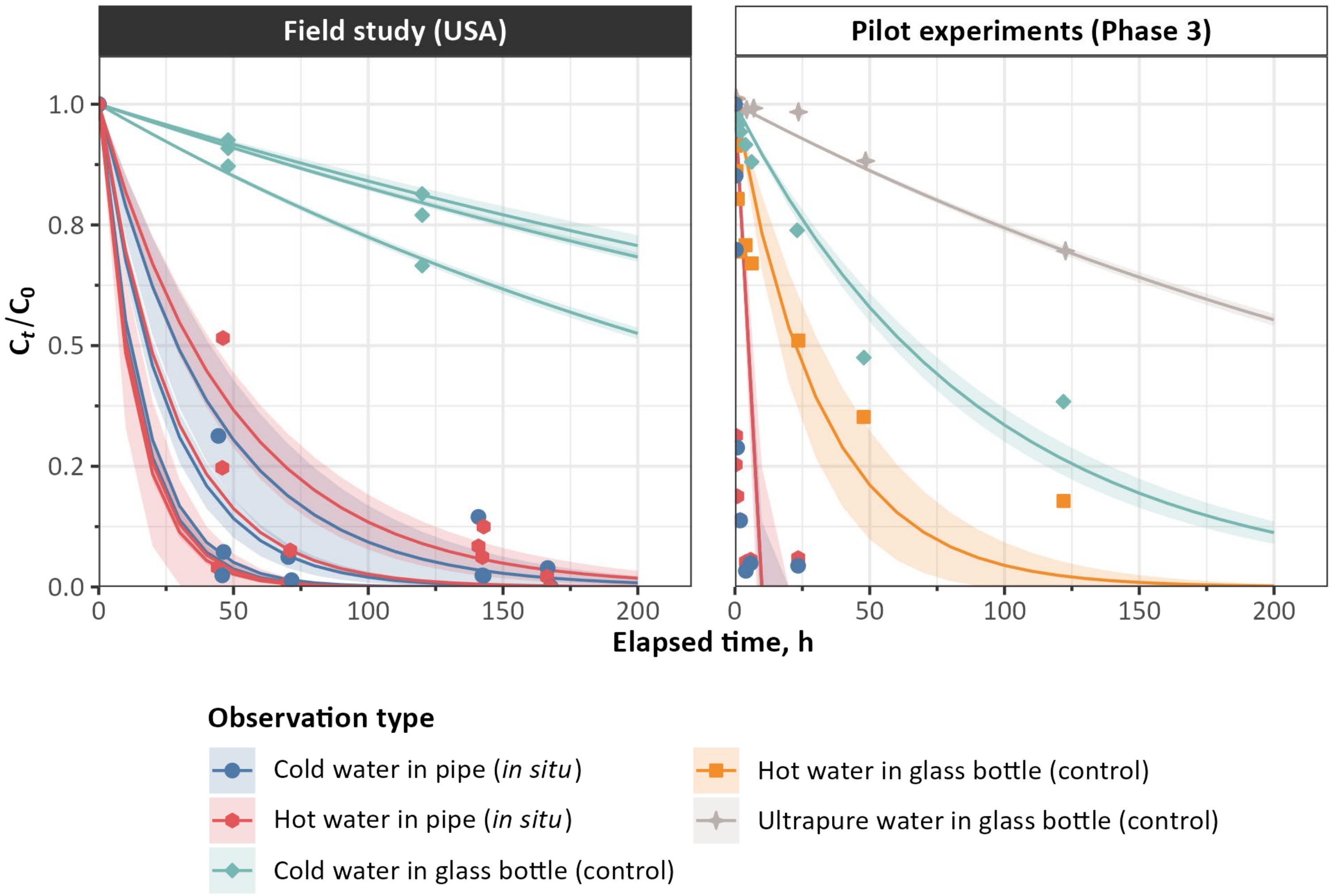


pH = 8.5 - 9.5

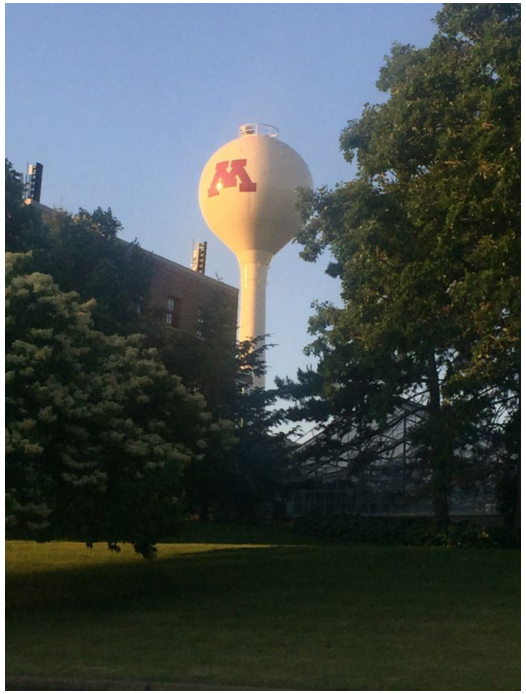
Total Chlorine (U. of Minnesota)



Chloramine Decay



Results: Total Bacteria (U. of Minnesota)



Total *Bacteria* (16S rRNA genes)

Site			Inlet	Flushing: Pre-flush	6	15	30	45 min	Follow-up: 2 to 4 d	6 or 7 d
A		Cold	4.79	6.95	≤ 3.49	≤ 3.60	≤ 3.37	≤ 3.29	4.75	6.27
A		Hot*		5.92	4.00	≤ 3.70	≤ 3.38	≤ 3.54	5.08	6.84
B		Cold	3.90	5.58	≤ 3.44	≤ 3.15	≤ 3.07	≤ 3.42	4.14	5.80
B		Hot		6.20	≤ 3.28	≤ 3.23	≤ 3.17	≤ 3.29	5.24	5.49
C		Cold	≤ 3.32	6.74	≤ 3.58	≤ 3.29	≤ 3.45	≤ 3.61	5.51	6.80
C		Hot		7.60	4.63	4.62	≤ 3.59	3.97	6.03	7.72
D	1	Cold	≤ 3.59	6.88	≤ 3.38	≤ 3.42	≤ 3.42		5.83	6.54
D	1	Hot		5.56	≤ 3.54	≤ 3.21	≤ 3.17	≤ 3.54	4.38	5.68
D	2	Cold		7.20			≤ 3.62		4.27	5.98
D	2	Hot		6.70			≤ 3.35		4.38	4.80
E	1	Cold	5.37	7.19	6.07	6.18	6.17	5.49	6.10	6.26
E	1	Hot*		6.80	4.98	5.05	4.88	4.65	6.40	6.07
E	2	Cold		6.20			5.59		6.24	6.01
E	2	Hot		7.24			6.67		6.72	6.03

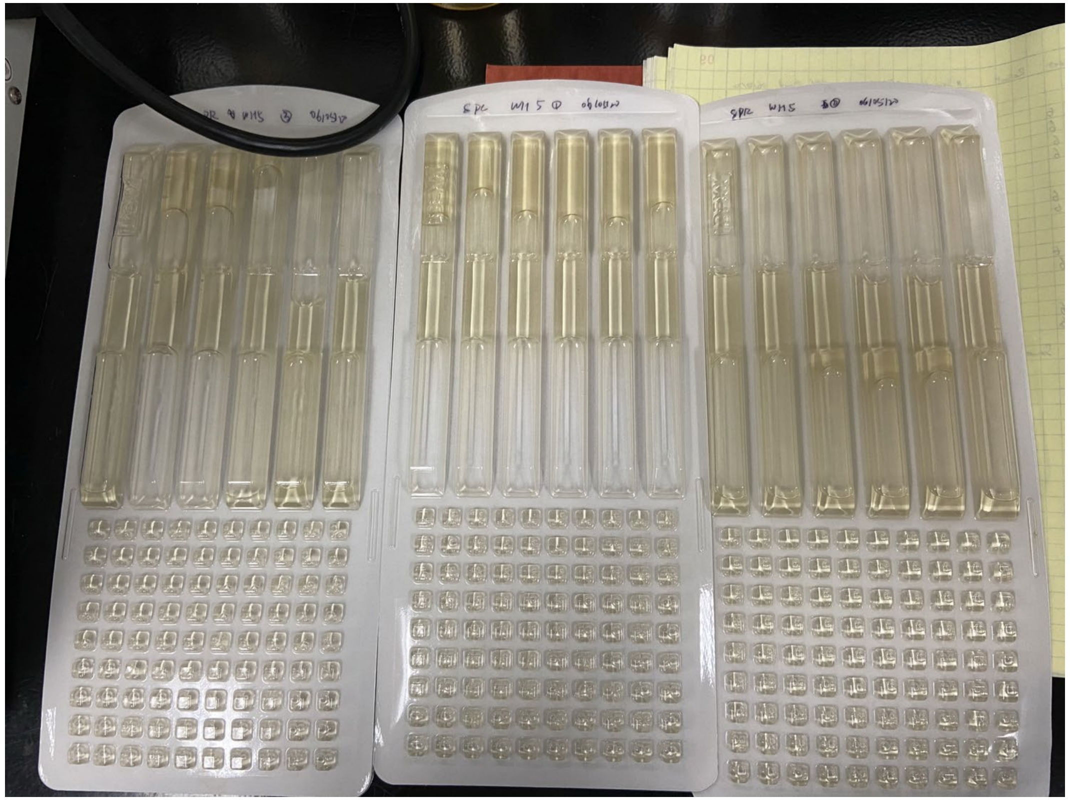
log$_{10}$(copies/L): 3 4 5 6 7 8

qPCR amplification

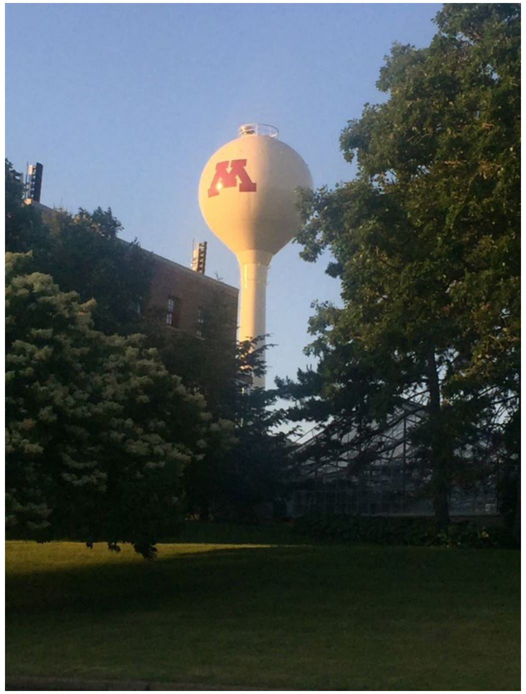
- 123 (red) Similar to negative controls (≤ observed quantity)
- 123 Above 99.9% conf. limit of mean negative control

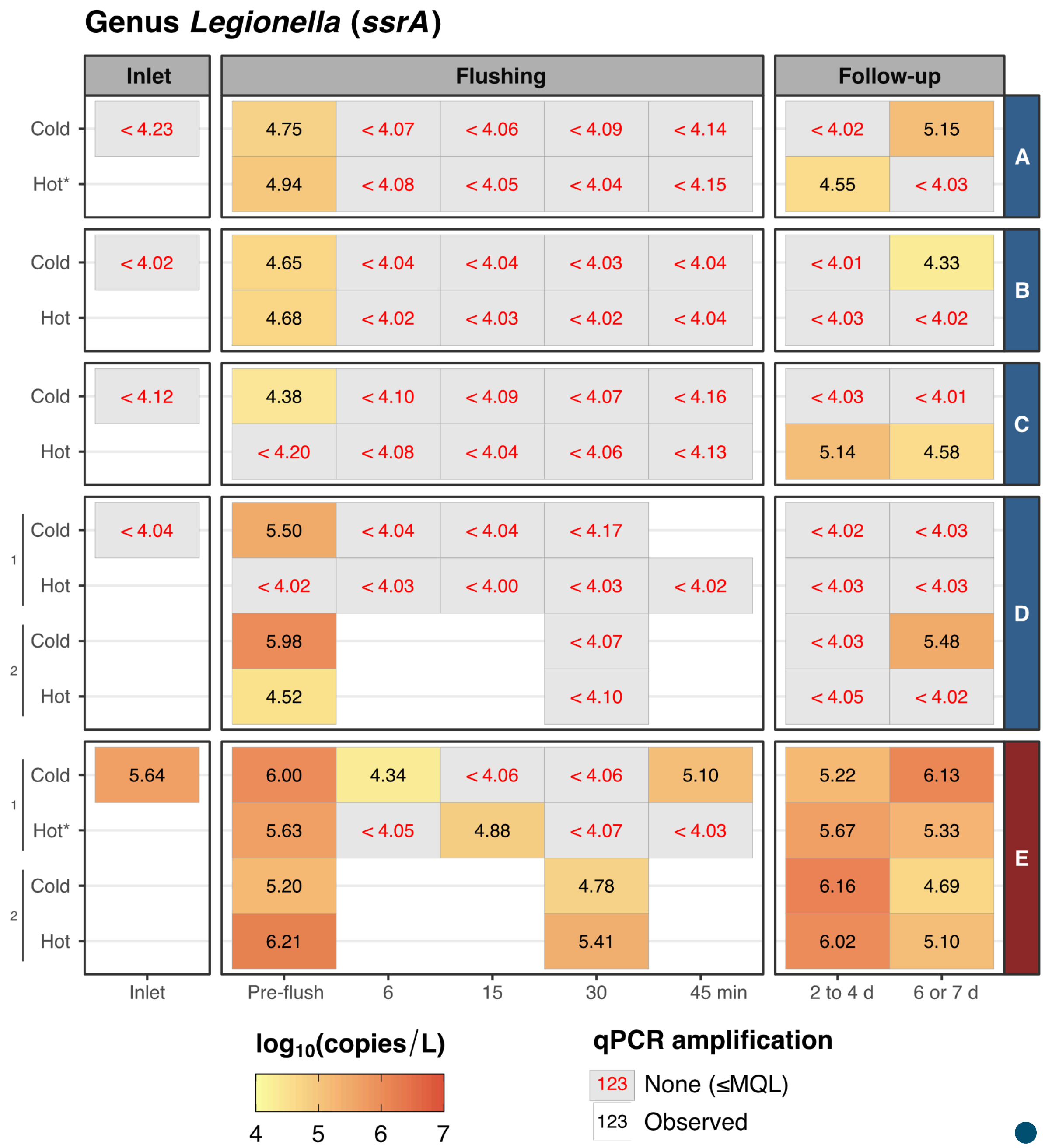
Legionella pneumophila

- Not detected via Legiolert testing
- Not detected via qPCR targeting mip gene

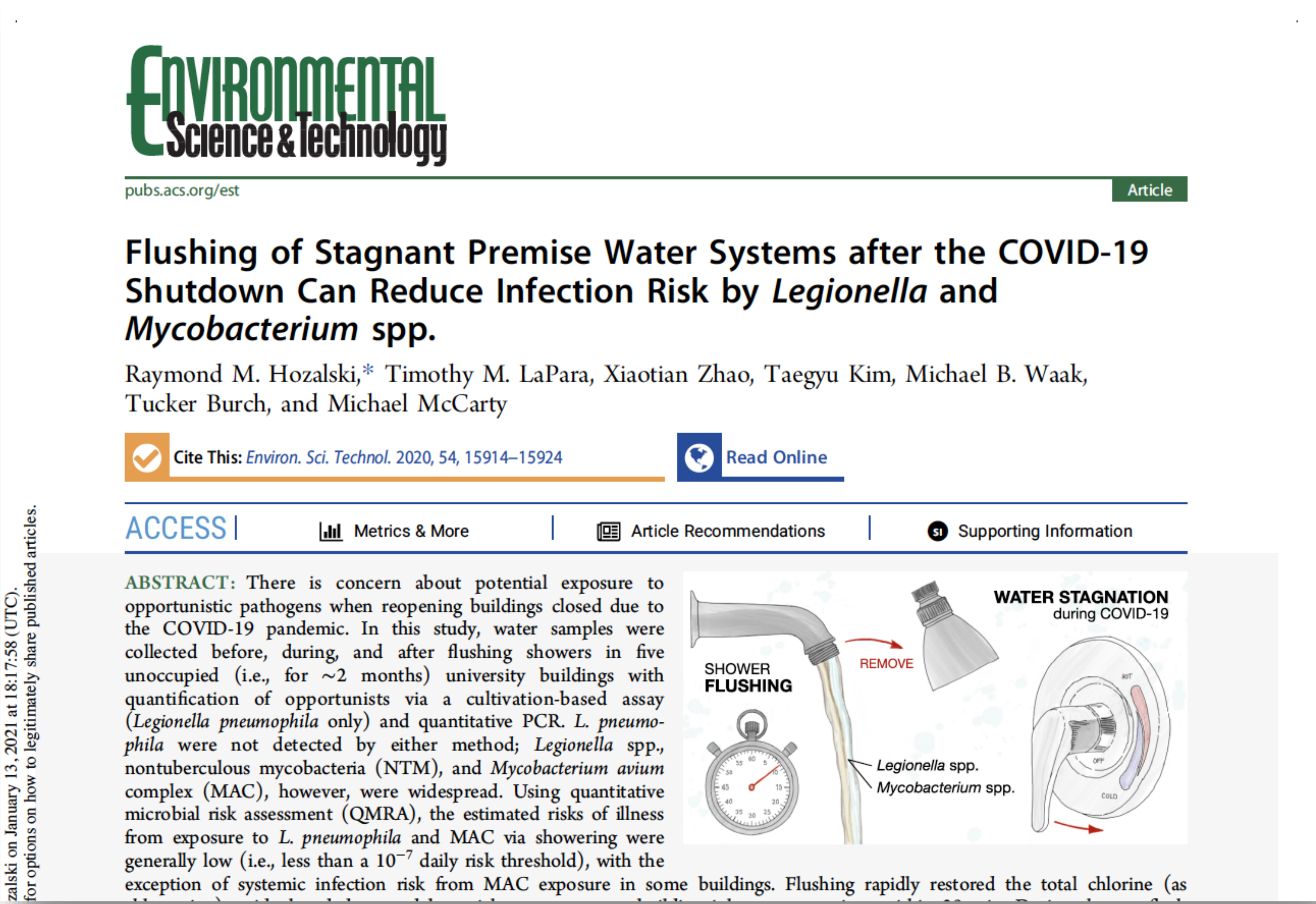


Results: *Legionella* spp. (U. of Minnesota)





Hozalski RM, LaPara TM, Zhao X, Kim T, Waak MB, Burch T, McCarty M. 2020. Flushing of stagnant premise water systems after the COVID-19 shutdown can reduce infection risk by *Legionella* and *Mycobacterium* spp. *Environ Sci Technol*. 54(24):15914–15924. doi:10.1021/acs.est.0c06357



Environmental Science & Technology
pubs.acs.org/est
Article

Flushing of Stagnant Premise Water Systems after the COVID-19 Shutdown Can Reduce Infection Risk by *Legionella* and *Mycobacterium* spp.

Raymond M. Hozalski,* Timothy M. LaPara, Xiaotian Zhao, Taegyu Kim, Michael B. Waak, Tucker Burch, and Michael McCarty

Cite This: *Environ. Sci. Technol.* 2020, 54, 15914–15924

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ABSTRACT: There is concern about potential exposure to opportunistic pathogens when reopening buildings closed due to the COVID-19 pandemic. In this study, water samples were collected before, during, and after flushing showers in five unoccupied (i.e., for ~2 months) university buildings with quantification of opportunists via a cultivation-based assay (*Legionella pneumophila* only) and quantitative PCR. *L. pneumophila* were not detected by either method; *Legionella* spp., nontuberculous mycobacteria (NTM), and *Mycobacterium avium* complex (MAC), however, were widespread. Using quantitative microbial risk assessment (QMRA), the estimated risks of illness from exposure to *L. pneumophila* and MAC via showering were generally low (i.e., less than a 10^{-7} daily risk threshold), with the exception of systemic infection risk from MAC exposure in some buildings. Flushing rapidly restored the total chlorine (as

Take-home messages

- Chloramine appears to limit the colonization of premise plumbing systems by *L. pneumophila*, decreasing likelihood of problems from building closures & stagnation
    - Other concerning populations were observed (*Legionella* spp. and MAC)
    - Negligible risk of serious illness (e.g., Legionnaires disease)
- Flushing with chloraminated water improves biological water quality, but only temporarily
- GW systems were less likely to have opportunistic pathogens
- Flushing GW systems with water containing little or no disinfectant had little impact on biological water quality

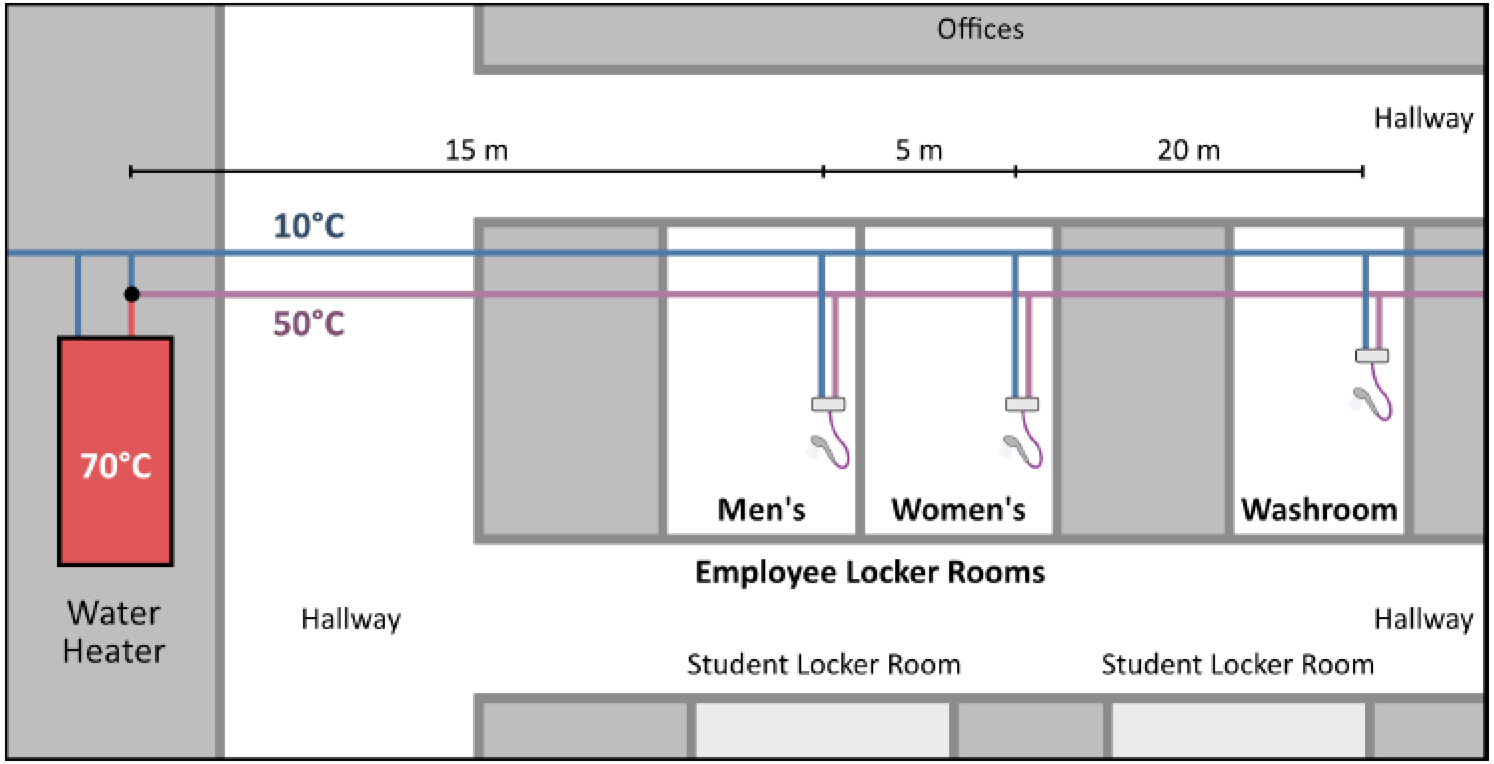
Field Study in Norway

Photo Credit: Betonmast SS
https://www.betonmast.no/prosjekter/lade-skole/[accessed 2024-05-21]

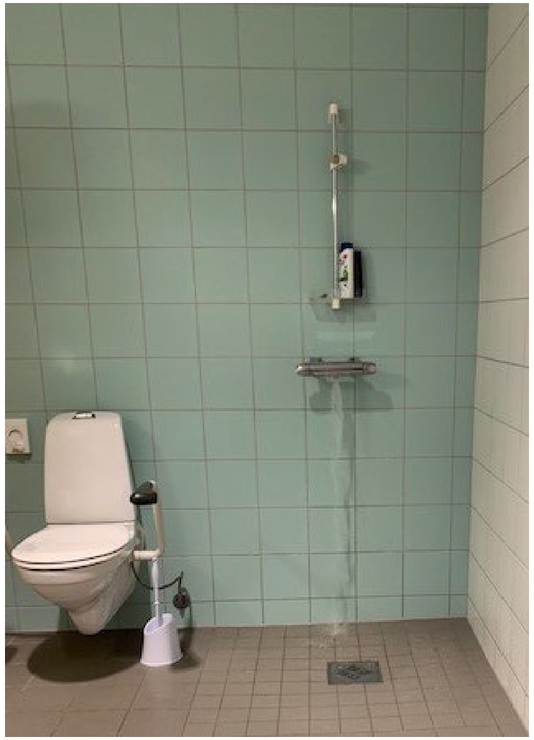
Sampling Sites

- Location: Lade Skole
- Primary school with ca. 700 students
- Renovated in 2018
- Area 10930 m^2
- Flushing study conducted in April 2022
- Drinking water source is Jonsvatnet
- Hot water heater set at 70°C and blended to 50°C for distribution

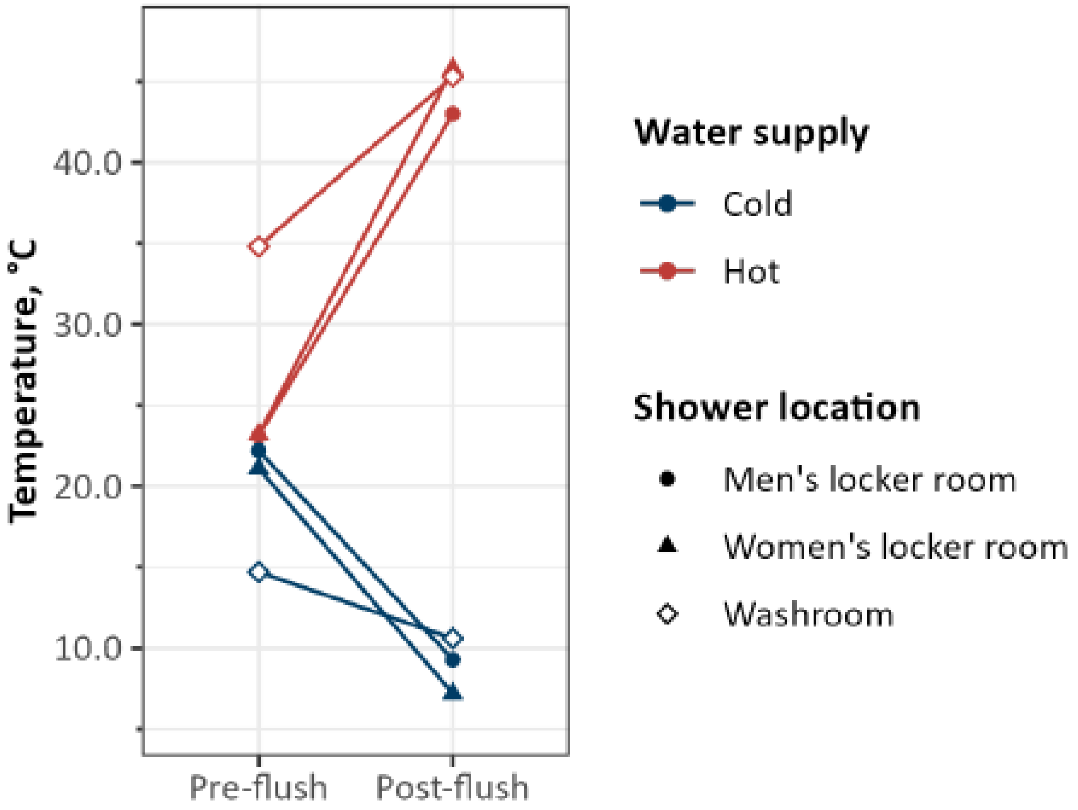
Approach



Offices
Hallway
15 m
5 m
20 m
10°C
50°C
70°C
Water Heater
Men's
Women's
Washroom
Employee Locker Rooms
Hallway
Hallway
Student Locker Room
Student Locker Room

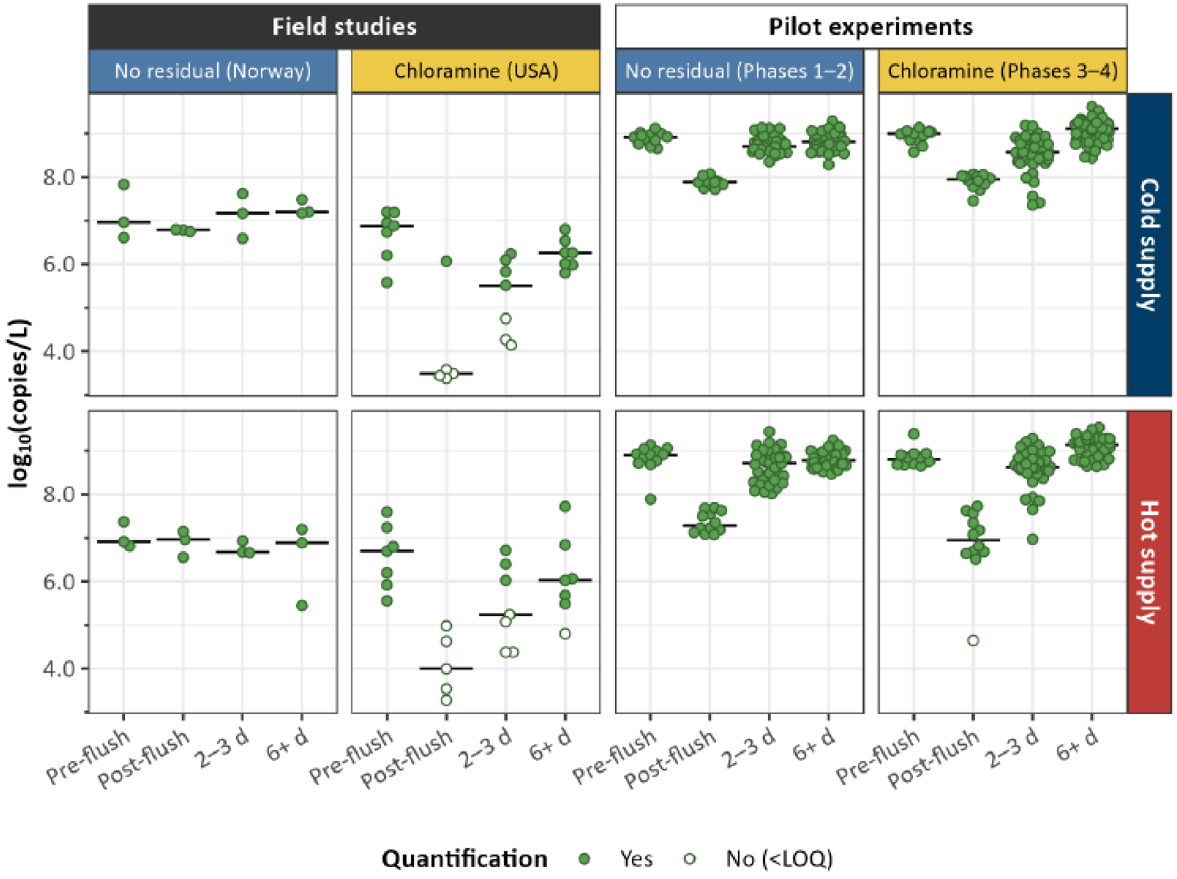


Water Quality Parameters

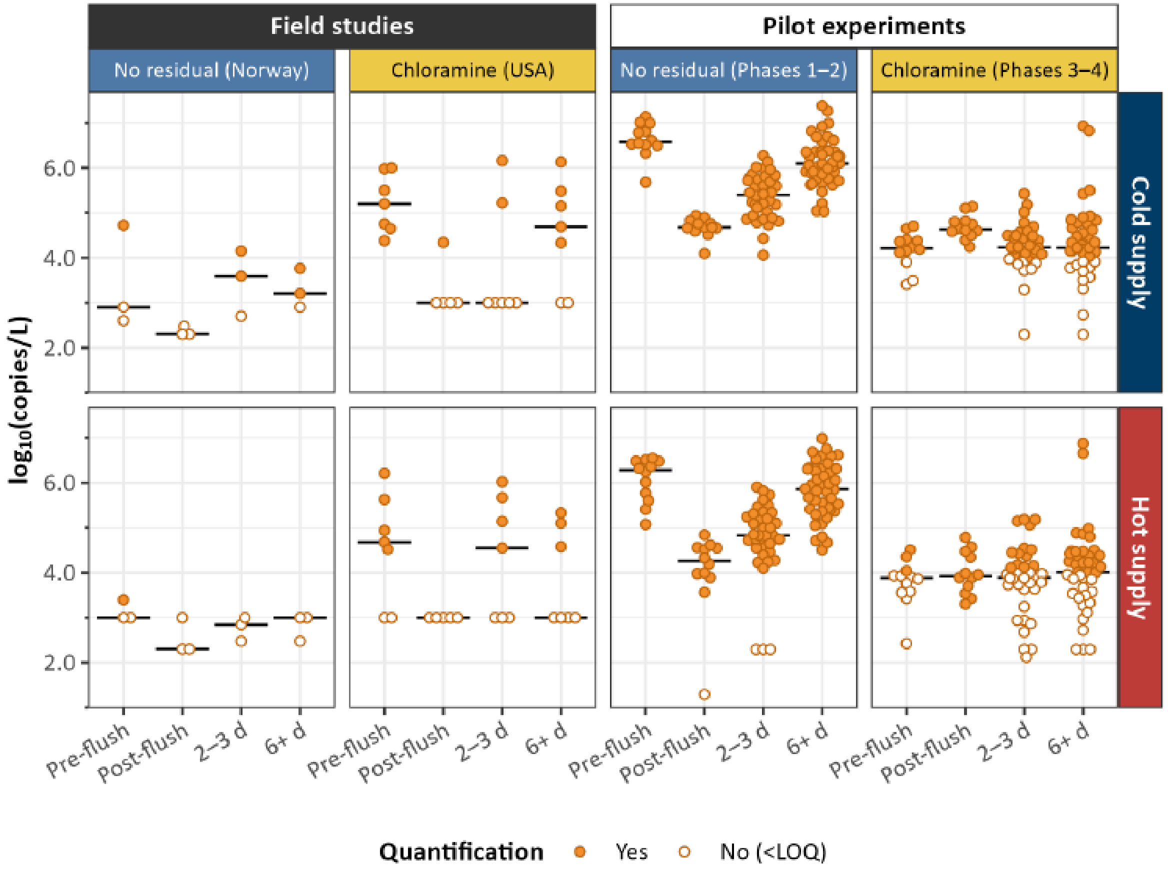


- Pre-flush pH 7.45 to 8.17
- Chlorine residual <0.1 to 0.1 mg/L
- Conductivity 128 to 133 µS/cm

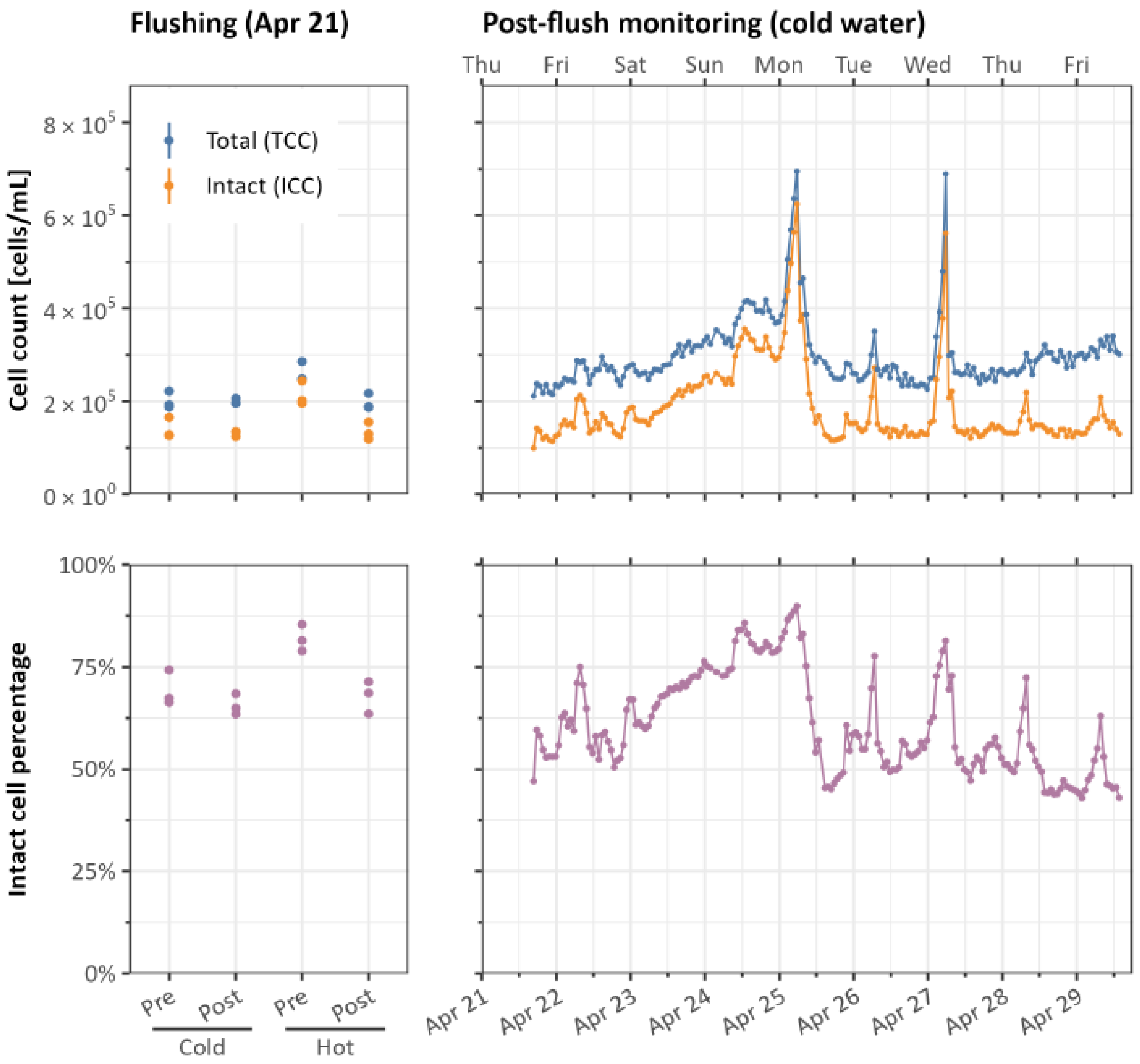
Total Bacteria (16S rRNA genes)



Legionella spp. (*ssrA*)



Pre- and Post-Flush Cell Counts by Flow Cytometry



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FINAL PART

FLUSHING RECOMMENDATIONS

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Dept. of Infrastructure, SINTEF Community

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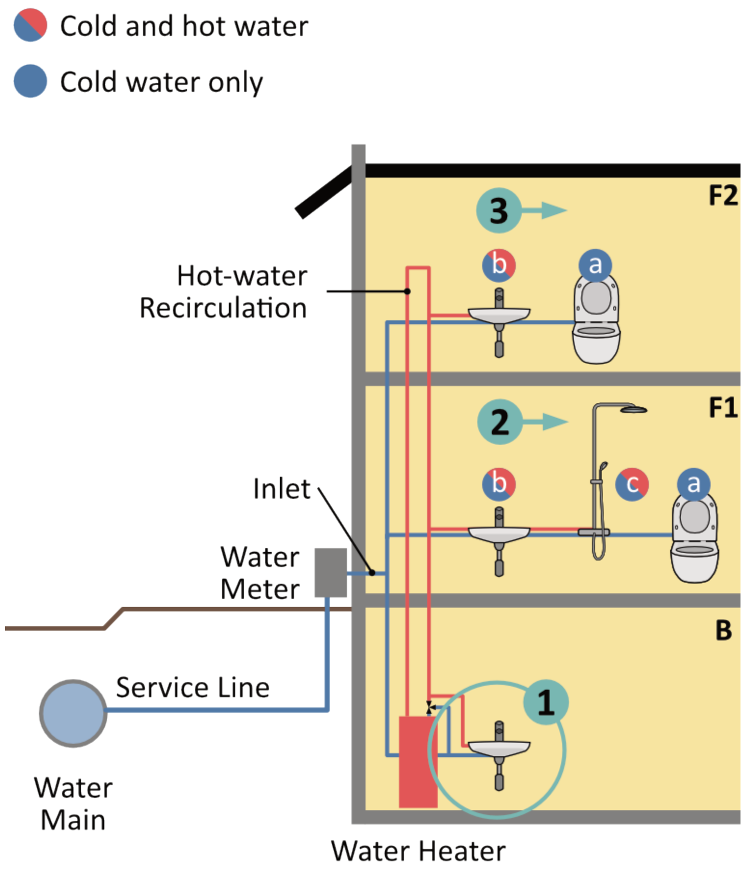
Flushing Considerations, Summarized

- Flushing resets the **water age**
- Know the design and operation of the building water system
- Understand the baseline **water temperature** and **residual disinfectant** (**cold** and **hot** water)
- Identify the scope of where water age is a problem (**whole-building** vs. **targeted**)

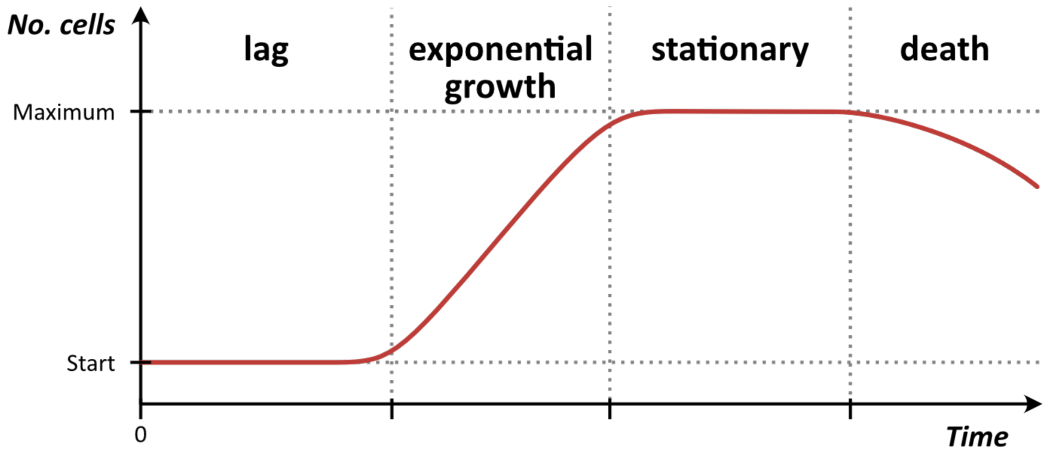
General Flushing Recommendations, Summarized

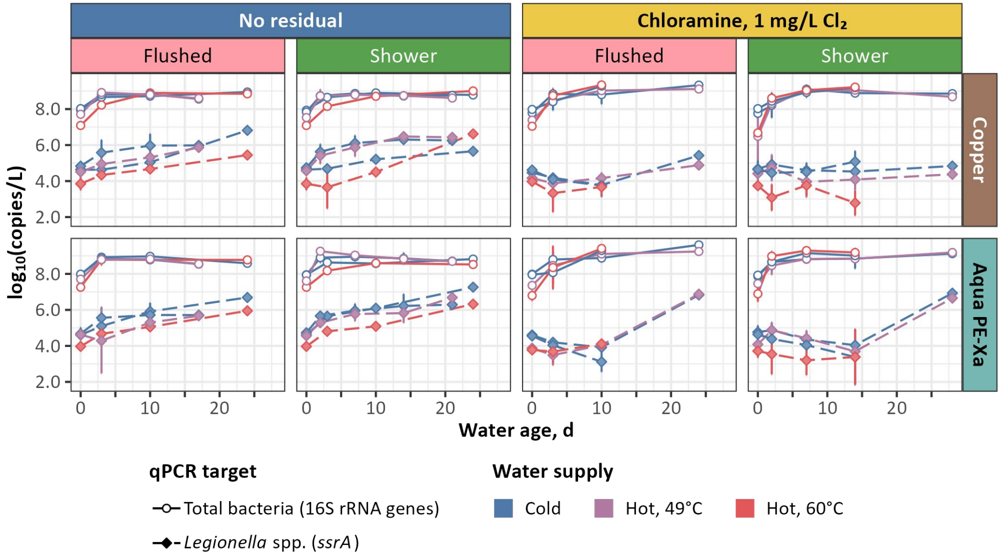
- Prime the **cold**- and **hot**-water systems with **fresh municipal water**
- Flush nearest the inlet and then farther into the building, waiting for baseline water quality
- Prioritize faucets or toilets before showers
- Leave the outlet with water **most hostile** to bacterial growth (temperature, disinfectant residual)



Additonal considerations

- *How often should I flush?*
  - **Residual disinfectant** present?
    Max. water age = 7 days
  - **No** residual disinfectant?
    Max. water age = 3 days
- *When should I flush?*
  - Before water users could be exposed
  - Outside normal or peak hours to minimize hazards for water users





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Q&A

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Acknowledgements

The Water Research Foundation

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THANK YOU!

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