Occurrence of Legionella pneumophila in US Drinking Water Distribution Systems

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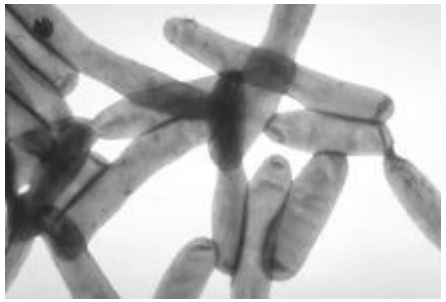
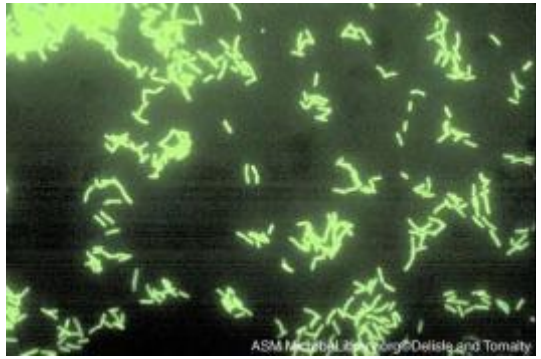
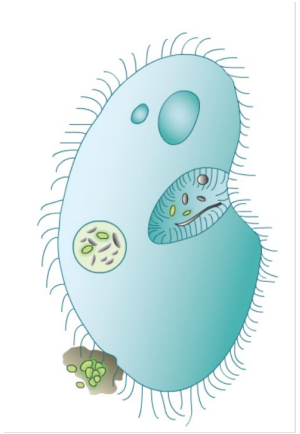
Legionella and Legionnaires' Disease

- Gram-negative bacterium
- Approximately 50 species, only half associated with disease
- *Legionella pneumophila* most important
- Natural to the aquatic environment
- Infects free-living amoeba
- First recognized outbreak in 1976 in Philadelphia
- 44 years and counting….

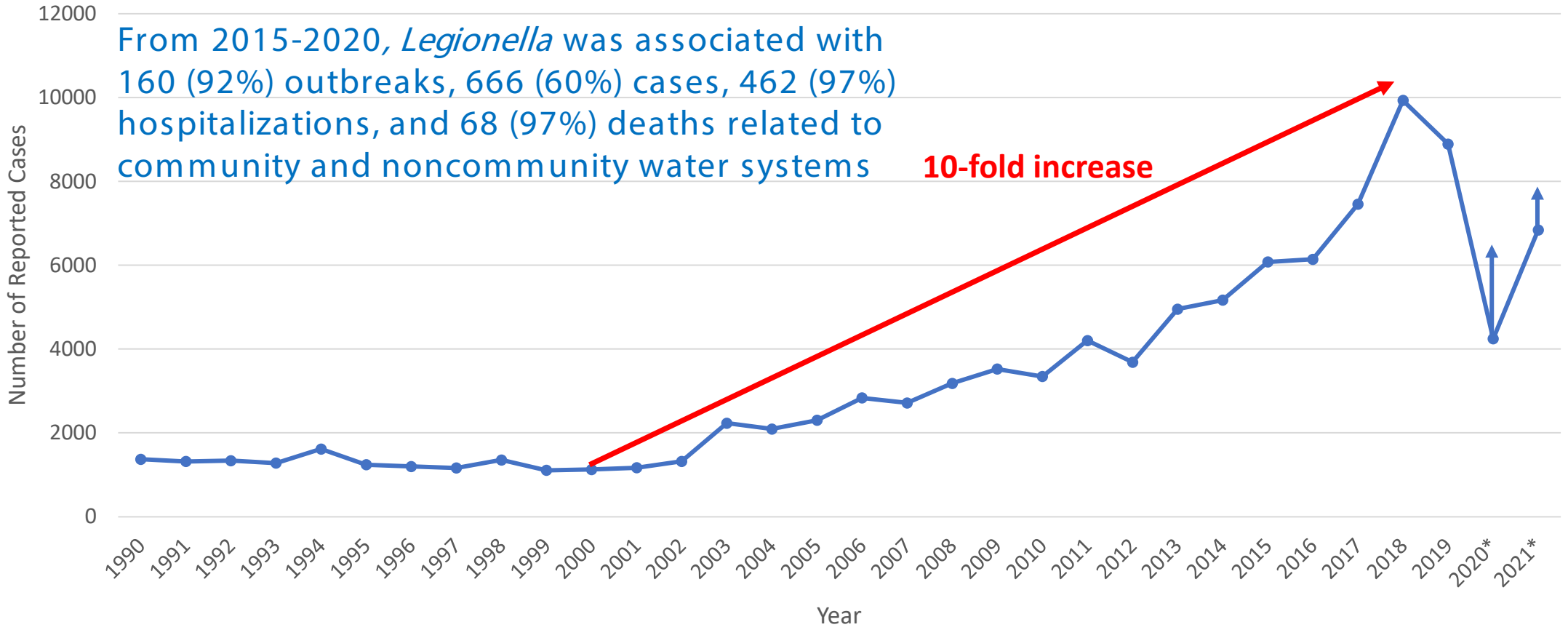




182 cases, 29 fatalities



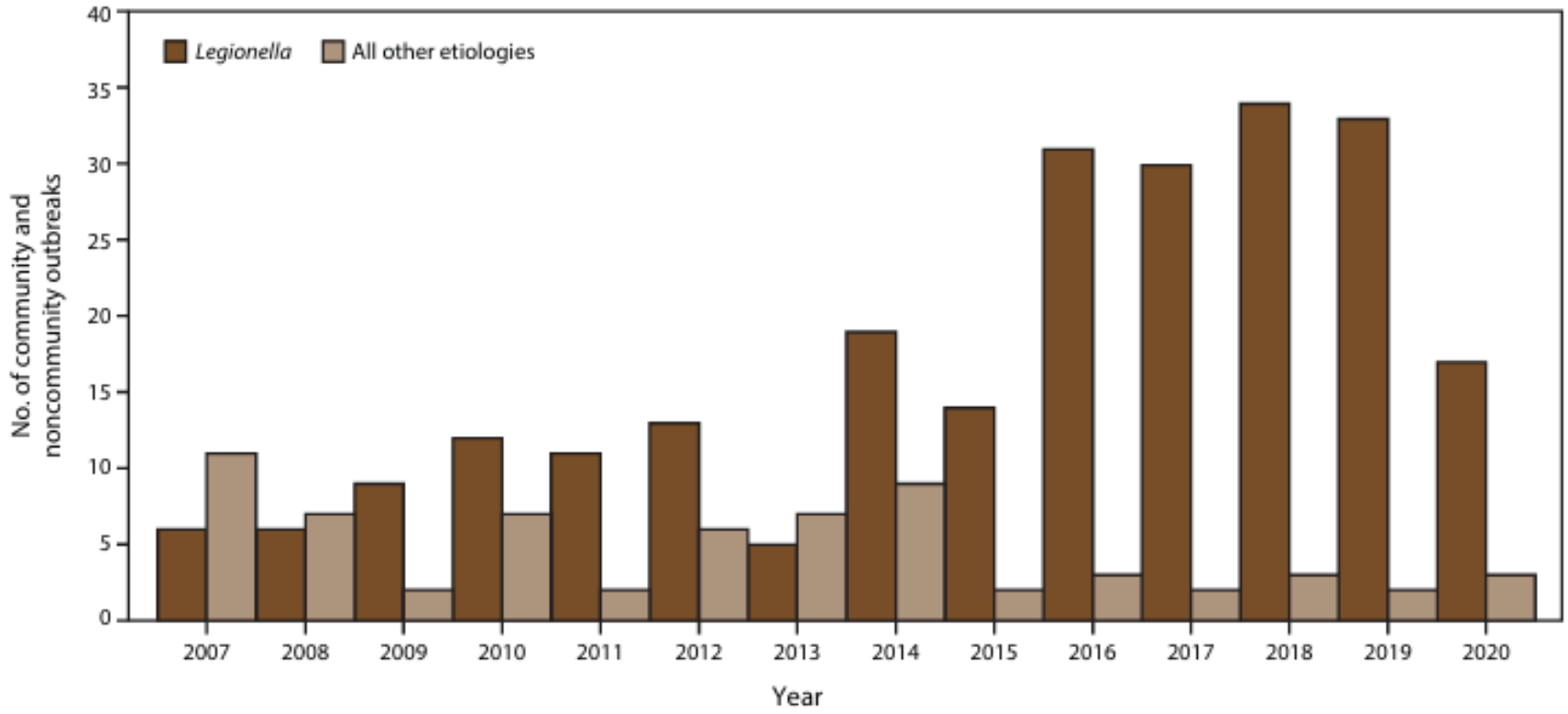
Legionnaires' Disease Cases 1990-2021



Source: National Notifiable Diseases Surveillance System

Kunz JM, Lawinger H, Miko S, et al. Surveillance of Waterborne Disease Outbreaks Associated with Drinking Water — United States, 2015–2020. MMWR Surveill Summ 2024;73(No. SS-1):1–23. DOI: http://dx.doi.org/10.15585/mmwr.ss7301a1

Number of reported drinking water-associated outbreaks in community and noncommunity water settings



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US EPA Regulation of *Legionella*

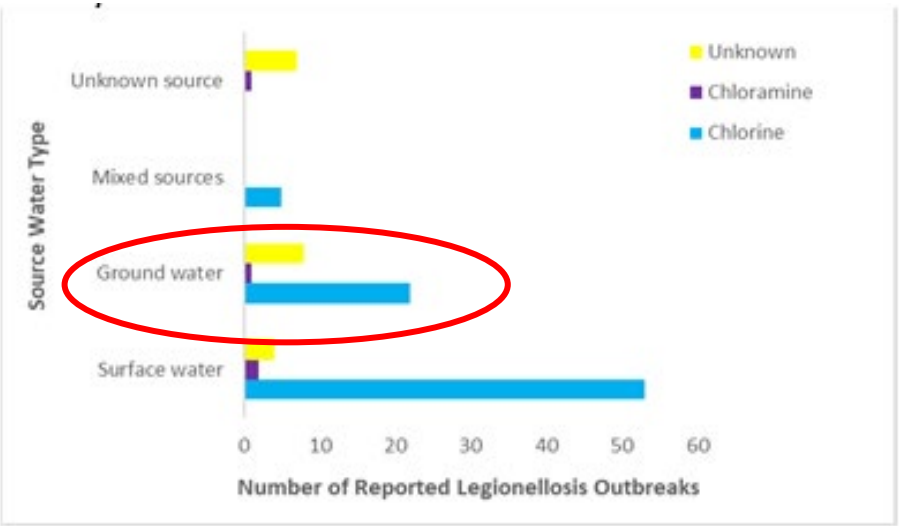
1989 SWTR – Treatment Technique

1989 SWTR sets an MCLG of zero for *Legionella* in surface water supplies

- Filter and disinfect water supplies
- Achieving effluent turbidity of 0.3 NTU
- Maintain a 0.2 mg/L disinfectant residual **entering the distribution system**
- Maintain a **"detectable" residual** within the pipe network in at least 95% of the measurements for two consecutive months

Problems with *Legionella* Regulation

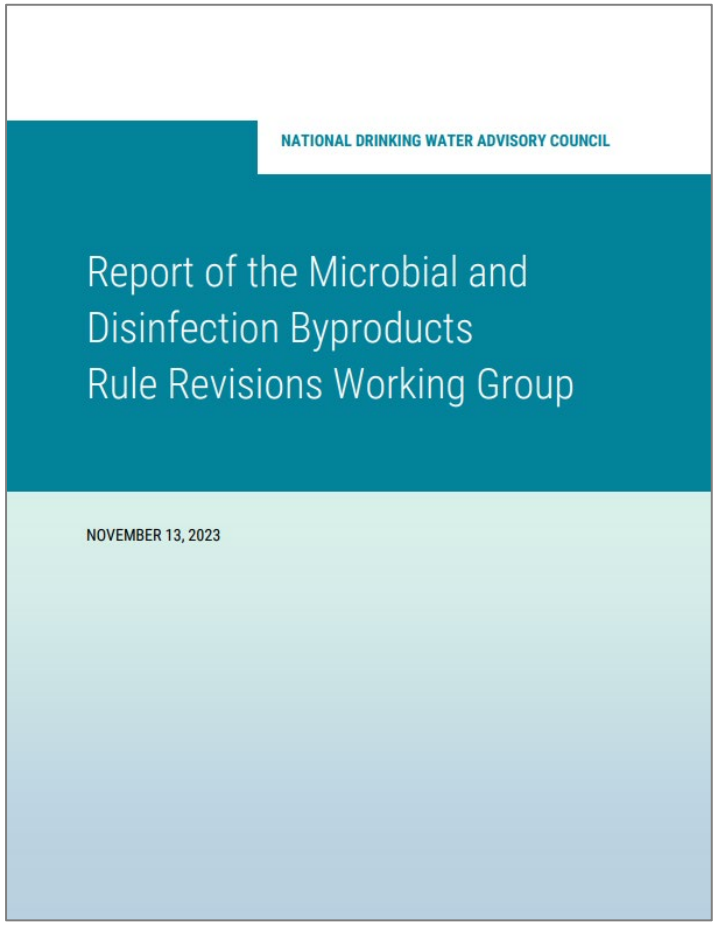
- Most outbreaks are in large buildings – not in public water distribution systems
- SWTR doesn't apply to groundwater systems
- A "detectable residual" is not defined
- 5% of the locations can have no disinfectant residuals
- SWTR is not able to regulate *Legionella* in DWDSs



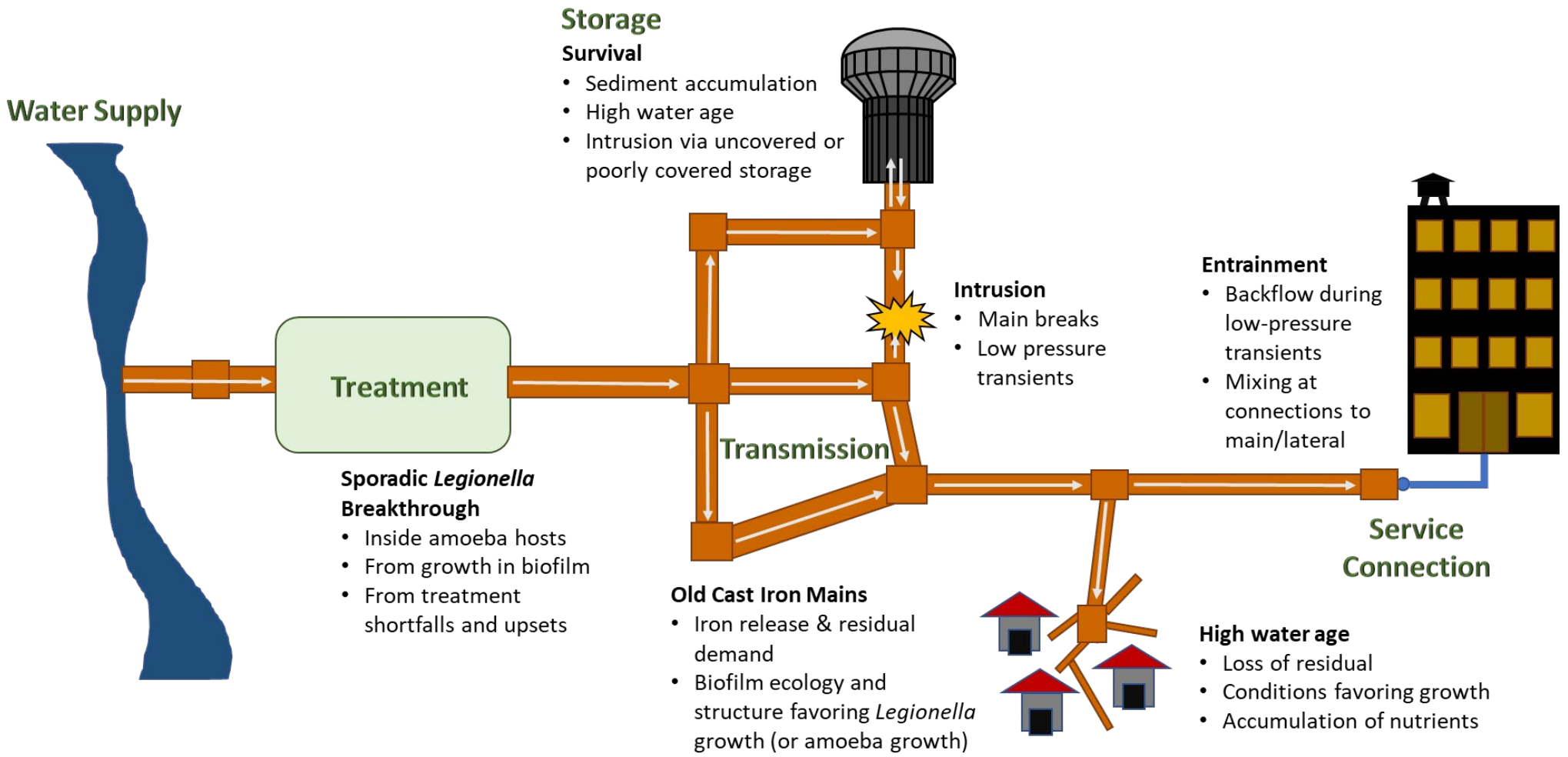
Tucker et al., 2018. American Public Health Association Annual Meeting & Expo. San Diego, CA, November 10-14.

Why Now?

- The USEPA has recognized the importance of *Legionella* and is reviewing microbial and disinfection byproduct (MDBP) rules to assess whether revised rules are needed
- The EPA's MDBP rule working group made *Legionella*-related recommendations, including:
  - A **numeric minimum disinfectant residual requirement**
  - A national building water quality improvement initiative
  - Addressing finished water storage tank vulnerabilities
  - Improving chloramination practices
  - Improving water quality and regulatory compliance rates for consecutive systems
- **EPA's challenge: near-absence of *Legionella* data to inform revised regulations and better protect public health**



Sources, Fate and Transport in a PWS



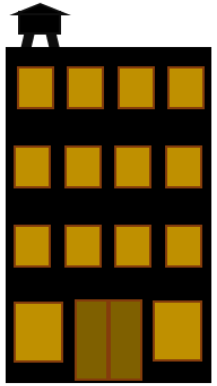
Sources, Fate and Transport in a Building Water System

Building Water Supply

Random entry of clumps of *Legionella*

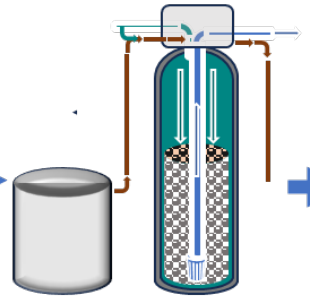
Along with:
- Disinfectant
- Nutrients
- Other microorganisms

Building Water System

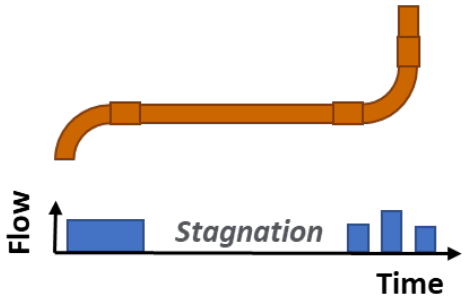


Building Water System Components

Treatment

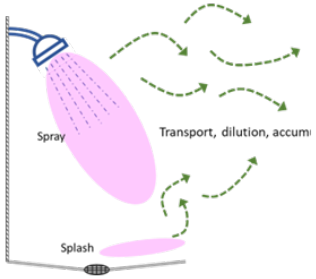


Distribution

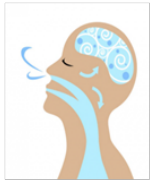


Points of Use

Fixtures



Exposure



Picture from Microsoft Online Pictures 2023

Establishment (or not)	Growth (or die-off)	Release & Transport
Every use of water is a chance for *Legionella* to enter and become established	Growth rate & extent mainly depend on • Nutrients • Stagnation duration • Temperature • Disinfectant • Protection in biofilm	Sloughing, erosion, advection, dispersion, inactivation

WRF 5156 The Team

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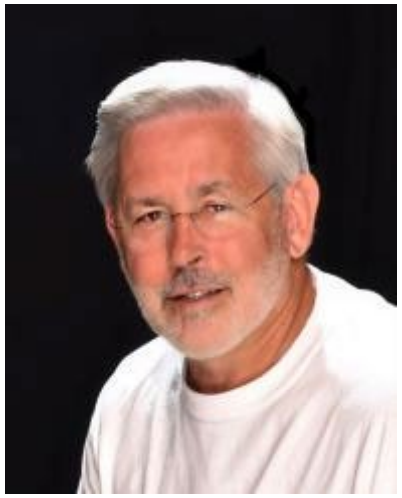

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Other Contributors and Acknowledgments

- First and foremost, we offer our deep gratitude to the staff and management of the 57 utilities that invested their time and resources to produce the data that are the backbone of this study
- Project Partners
  - IDEXX
  - Q Laboratories
  - US EPA (Helen Buse and Jeffrey Szabo)
  - Georgia Tech (Ameet Pinto)
- Co-Sponsoring Agencies
  - AWWA
  - ASDWA
- Project Scientific Advisors
  - Ken Rotert, USEPA
  - Claressa Lucas, CDC
- Project Advisory Committee
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  - Megan Karklins, Communications & Marketing Manager
  - Julia Dinmore, Content Lead

WaterRF 5156: Occurrence of *Legionella* spp. in Drinking Water Distribution Systems

- **57 utilities** volunteer to collect **3 samples per week for 12 weeks** during **warm water months (>15°C) for 2 summers (total: >9,000 samples)**
- Includes: Surface and groundwater supplies
  Free and chloramine residuals
  Various system sizes, geographical distribution
- Parameters: Legiolert 100 mL – identification by qPCR & MALDI-TOF-MS
  Conventional culture by ISO 11731
  Viability qPCR (BIOTECON Diagnostics)

- Workshop: Development protocols for responding to positive *L. pneumophila* in distribution systems

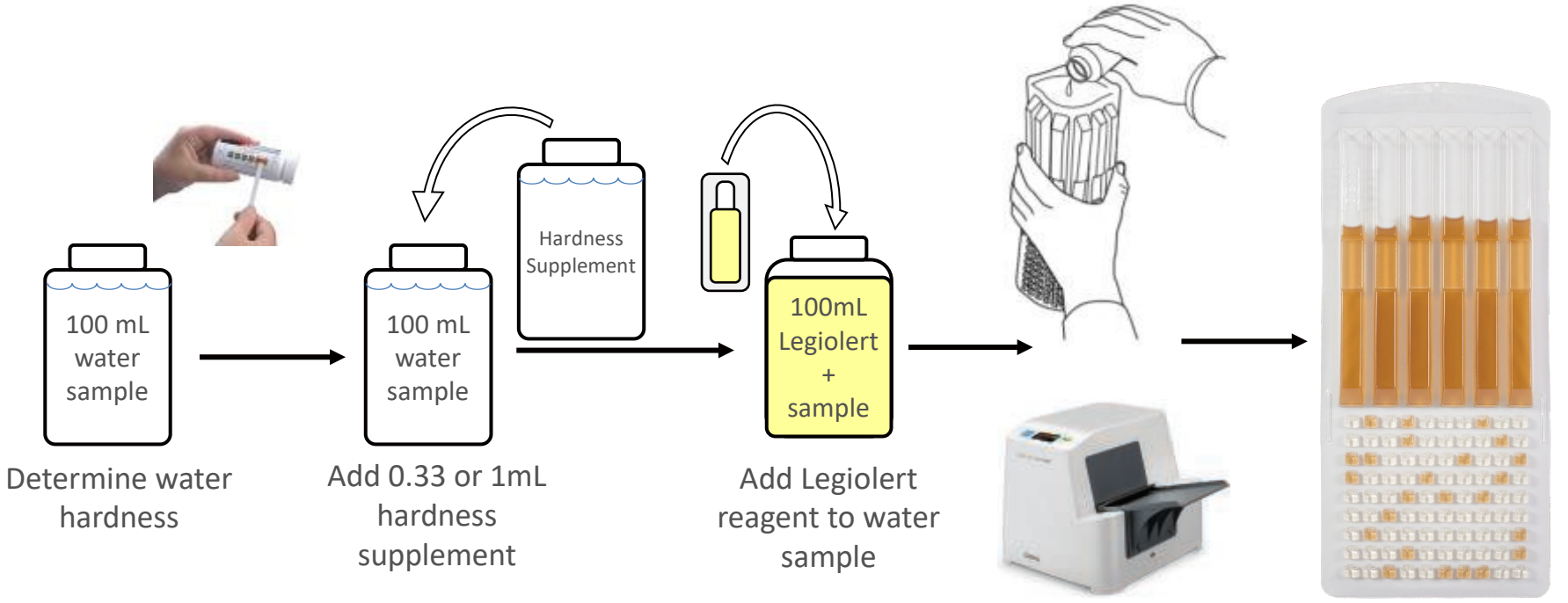
Legiolert platform

- Unique 100 mL “Quanti-Tray” device
  - 6 large wells (overflow)
  - 90 small wells (resolution)
  - Counts *L. pneumophila;* from 1-2272 MPN/ Quanti-Tray
- Blister pack reagent

Reaction with *L. pneumophila*

Negative Sample

Legiolert protocol: potable water



Determine water hardness

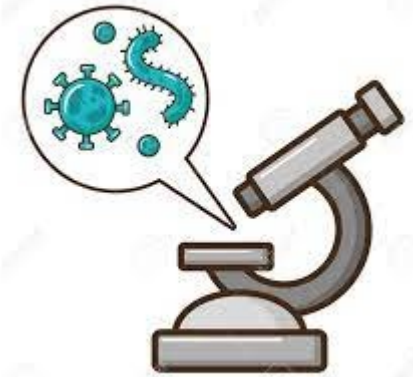
Add 0.33 or 1mL hardness supplement

Add Legiolert reagent to water sample

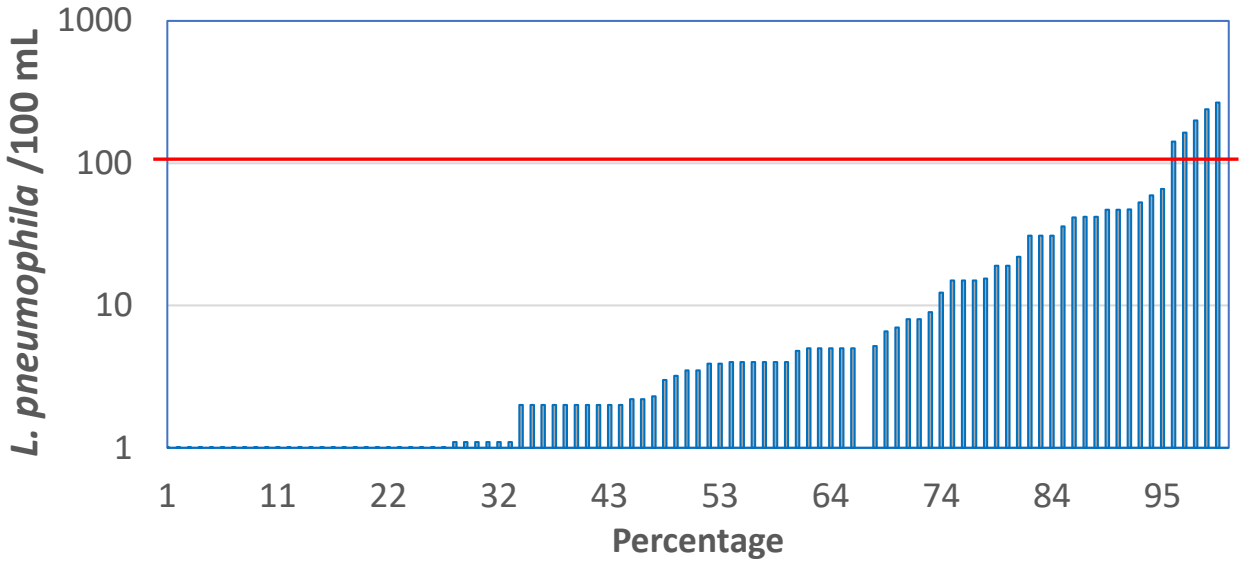
Pour into Quanti-Tray, seal, and incubate **39°C**

Count @ 7 days
=
Confirmed result

WRF 5156 Results: Legiolert



- 57 utilities participating: testing or sending data
- To date: 9,181 samples analyzed
- 109 positives (1.19%), from 18 utilities (32%)
- *L. pneumophila* DS counts ranged from 1 to 267 MPN/100 mL
- 95% were <100 MPN/100 mL
- Most repeat samples negative
- **68% of systems had no positive detections of *L. pneumophila***



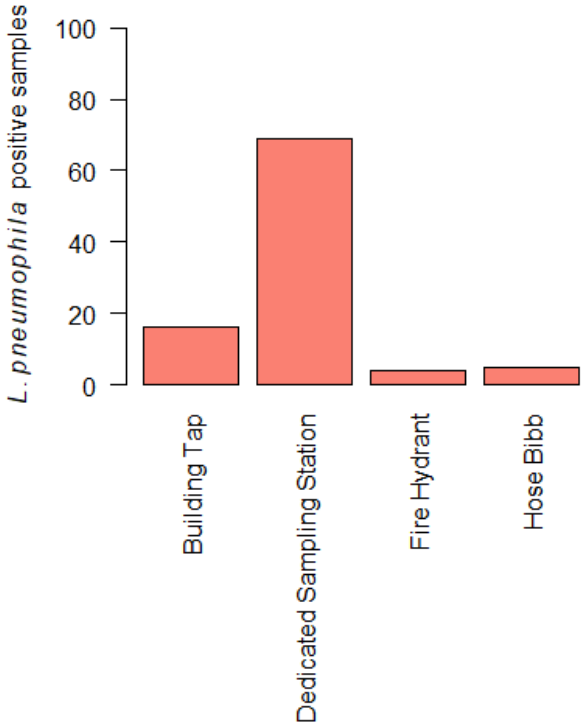
Final Data Set Summary Statistics

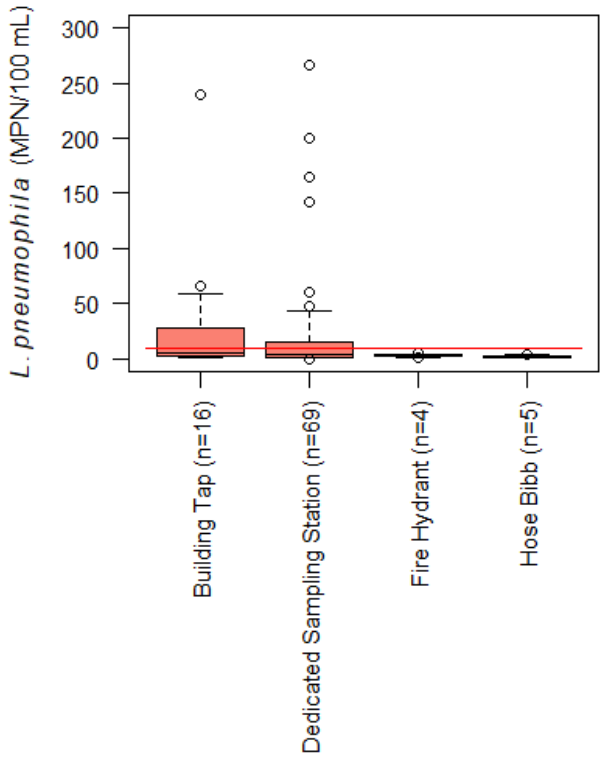
Pooled data†	All systems	Free chlorine systems	Chloramine systems
Included samples‡	9181	6680	2501
***L. pneumophila* positive samples**	109	87	22
% positive *L. pneumophila* samples	1.19	1.30	0.88
Average disinfectant concentration (mg/L)	-	0.99	2.02
Average water temperature (°C)	20.3	20.3	20.3
Number of utilities	57	25	32
Utilities with at least one *L. pneumophila*+ sample	18	11	7

† Data from a prior study (LeChevallier, 2018) that employed similar methods were pooled with data from the current study

‡ 292 out of 8323 samples collected in the current study were excluded from analysis because the sample bottle broke (2), *L. pneumophila* results were not reported (51), the analysis did not pass QA/QC checks (38), or the sample was for a location other than distribution system (201)

Positivity by Sample Collection Location Type

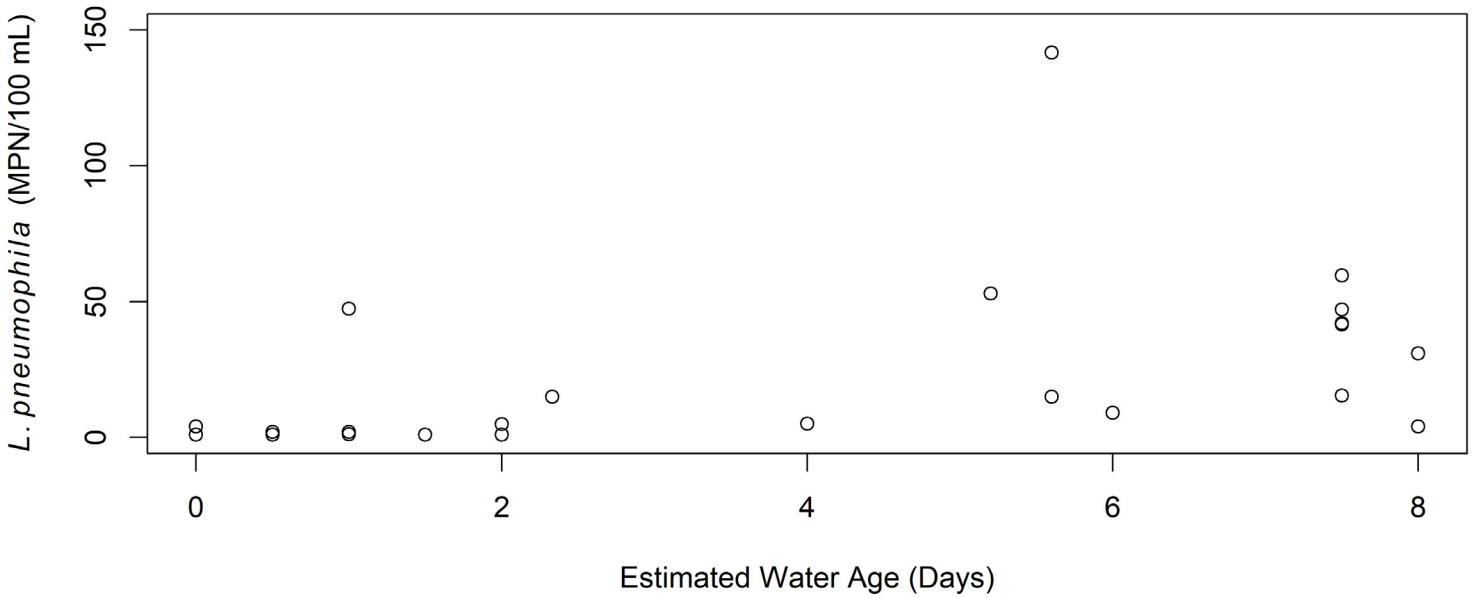




Sample Tap Type	Number of Samples	No. *Lp* positive samples	% positive samples
Building tap	1657	16	0.97 %
Dedicated sampling station	6061	69	1.14 %
Fire Hydrant	103	4	3.88 %
Hose bibb	237	4	1.69 %

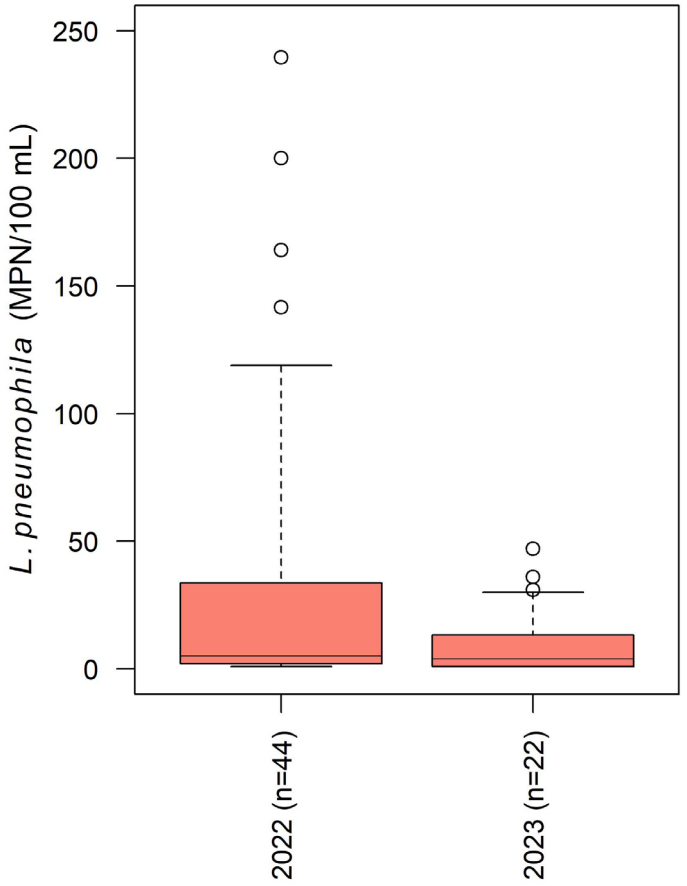
Water Age and *L. pneumophila* Concentration, Positive Samples Only

- Water age at sample collection sites was estimated for a relatively small proportion of samples
  - 22 out of 107 positive samples
  - Too few data to make statistically significant conclusions or account for factors such disinfectant type
- Apparent trend in *L. pneumophila* concentration with increasing water age
  - additional data collection and analysis recommended
  - Emphasize high water age locations in monitoring plans



Occurrence and Abundance in Study Years 1 (2022) and 2 (2023)

	2022			2023		
	All	Free chlorine	Chloramine	All	Free chlorine	Chloramine
Number of samples, total	2094	1951	953	2815	1812	1003
Number of positive samples	44	30	14	22	15	12
Percentage positive samples	1.5%	1.5%	1.4%	0.78%	0.83%	1.2%
Mean, + samples (MPN/100mL)	34.5	19.7	66.2	9.7	12.5	3.6
Geo mean, + samples (MPN/100mL)	7.5	3.8	32.4	4.1	5.8	2.0

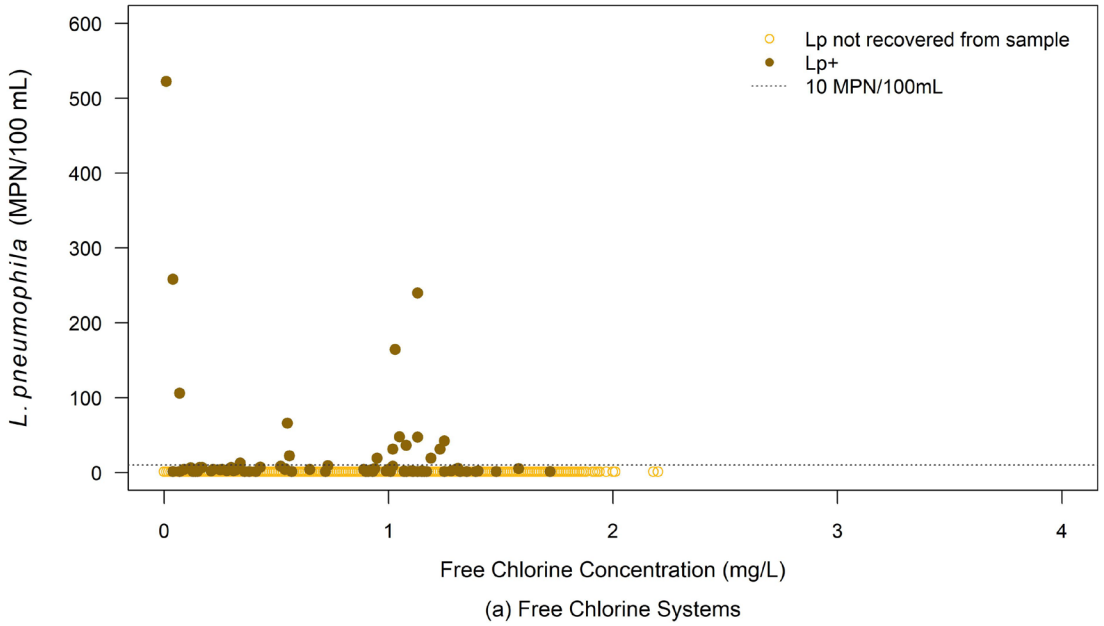


Why the Decrease in Both Occurrence and Abundance in Year 2?

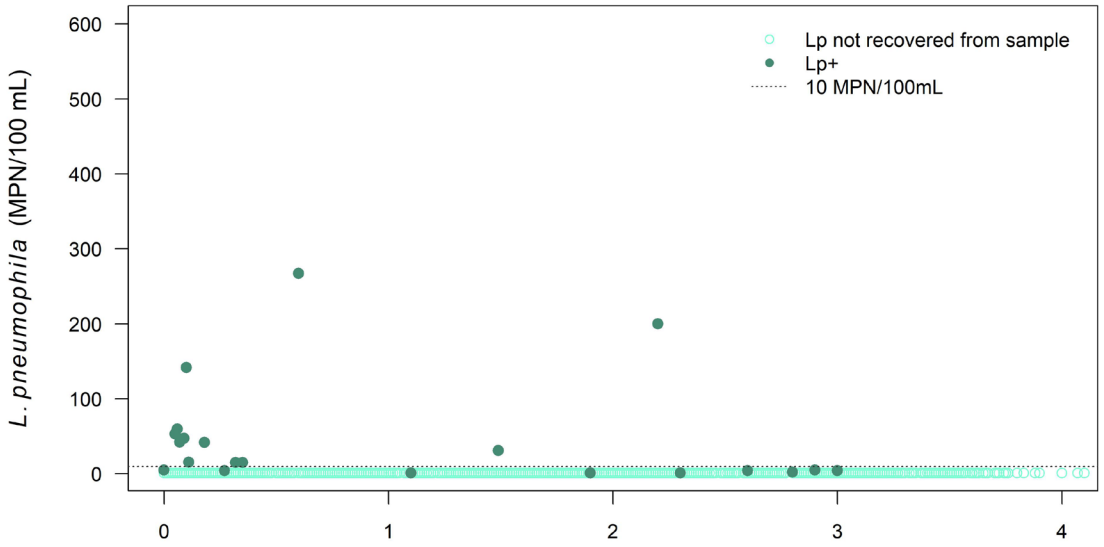
- **No statistical difference in year 1 and year 2 for**
  - the distribution of disinfectant concentrations
  - the distribution of water temperatures
- **Most utilities used the same sample locations in year 1 and year 2**
- **The most plausible explanation is that utilities reduced occurrence and abundance via their responses to positive detections** (monitoring and management of *L. pneumophila*)
  - Even in year 1, levels were never high enough to pose an unacceptable acute health risk
  - Utilities with positive detections conducted follow-up monitoring and instituted mitigative and protective practices such as flushing, cleaning, and improving disinfectant concentrations near the sample collection location with the positive sample
  - Other studies have shown similar improvement in *L. pneumophila* control when utilities have responded to positive detections with deliberate management strategies

L. pneumophila Concentration *v.* Disinfectant Residual Concentration

- No single sample had *L. pneumophila* concentration above a level posing significant public health concern (more on this later)
- Most high *L. pneumophila* concentrations were observed at lower disinfectant concentrations (both free chlorine and chloramines), but …
- Sporadic high *L. pneumophila* concentrations occurred above 1 mg/L (both disinfectants)
  - Disinfectant is not a silver bullet
  - Multiple barriers remain the right approach, even for a latent risk like *L. pneumophila*



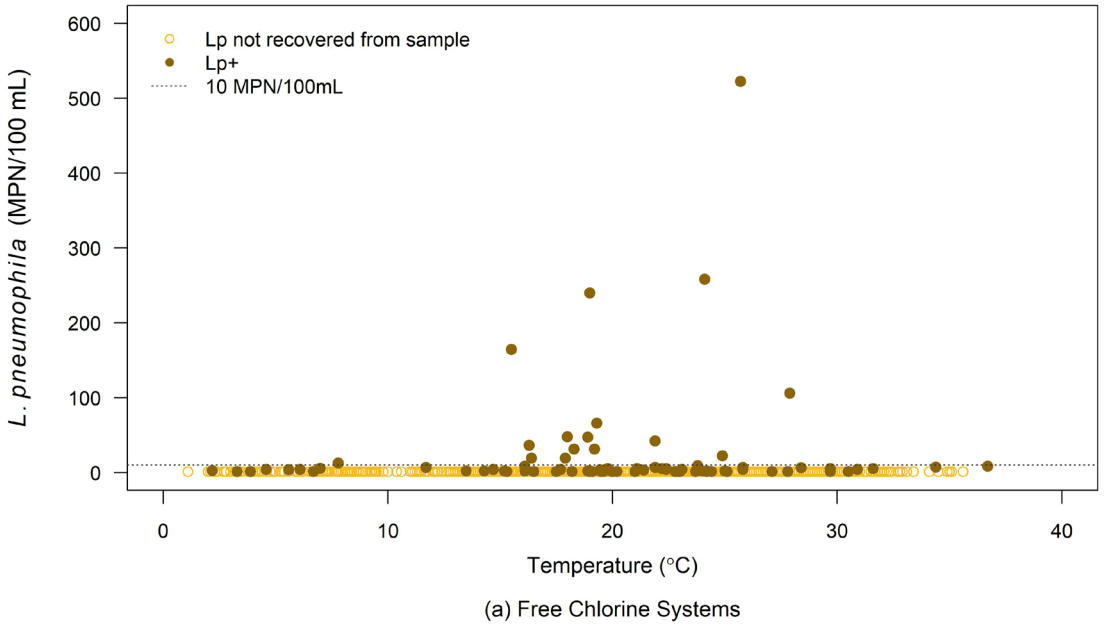
(a) Free Chlorine Systems



(b) Chloramine Systems

L. pneumophila Concentration *v.* Temperature

- For both free chlorine and chloramine systems, most or all detections were at water temperature > 16°C
- The relatively few detections at low water temperature were at very low concentrations
- Very few samples had a temperature > 32°C; more data might demonstrate a trend of increasing occurrence and concentration



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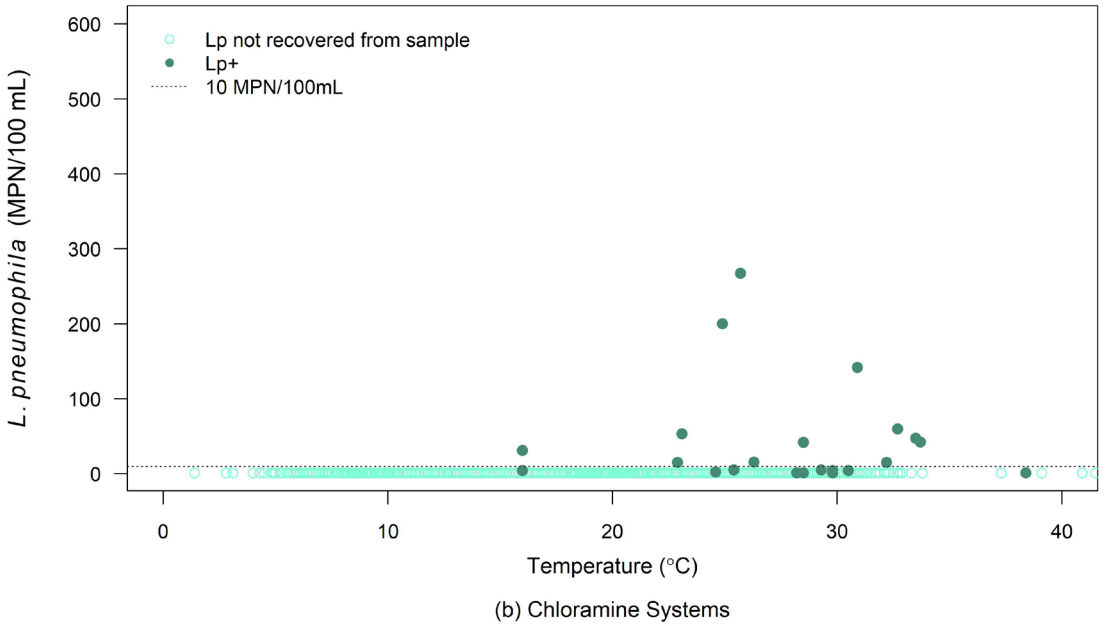
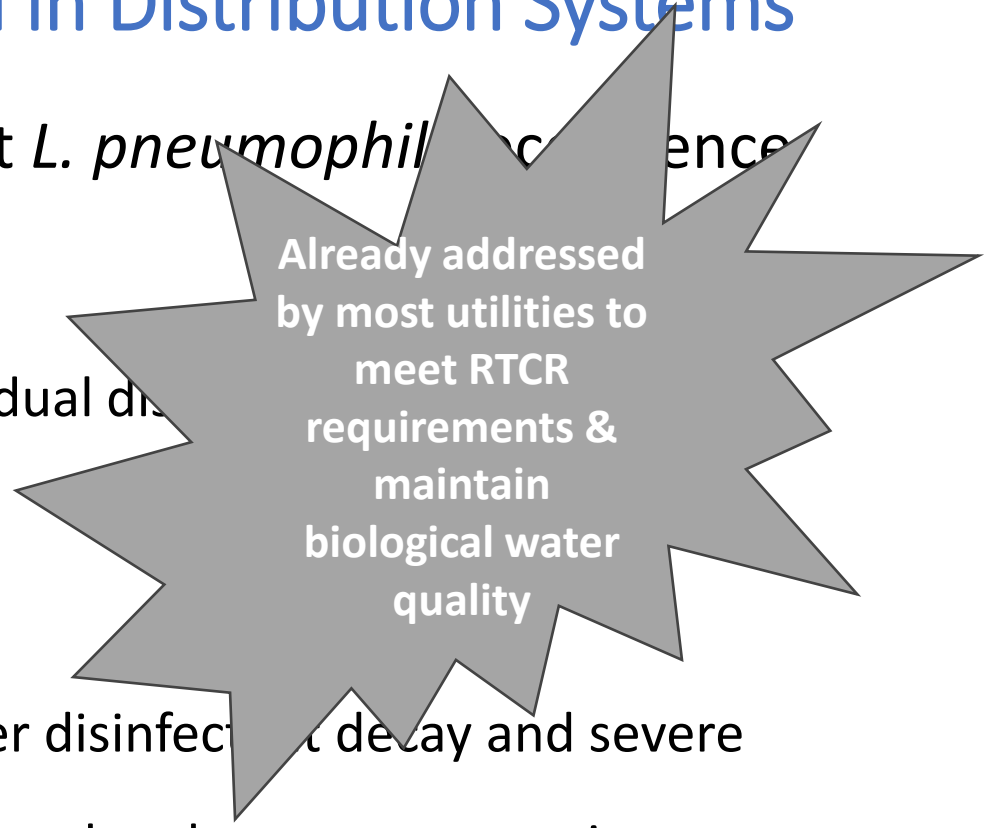


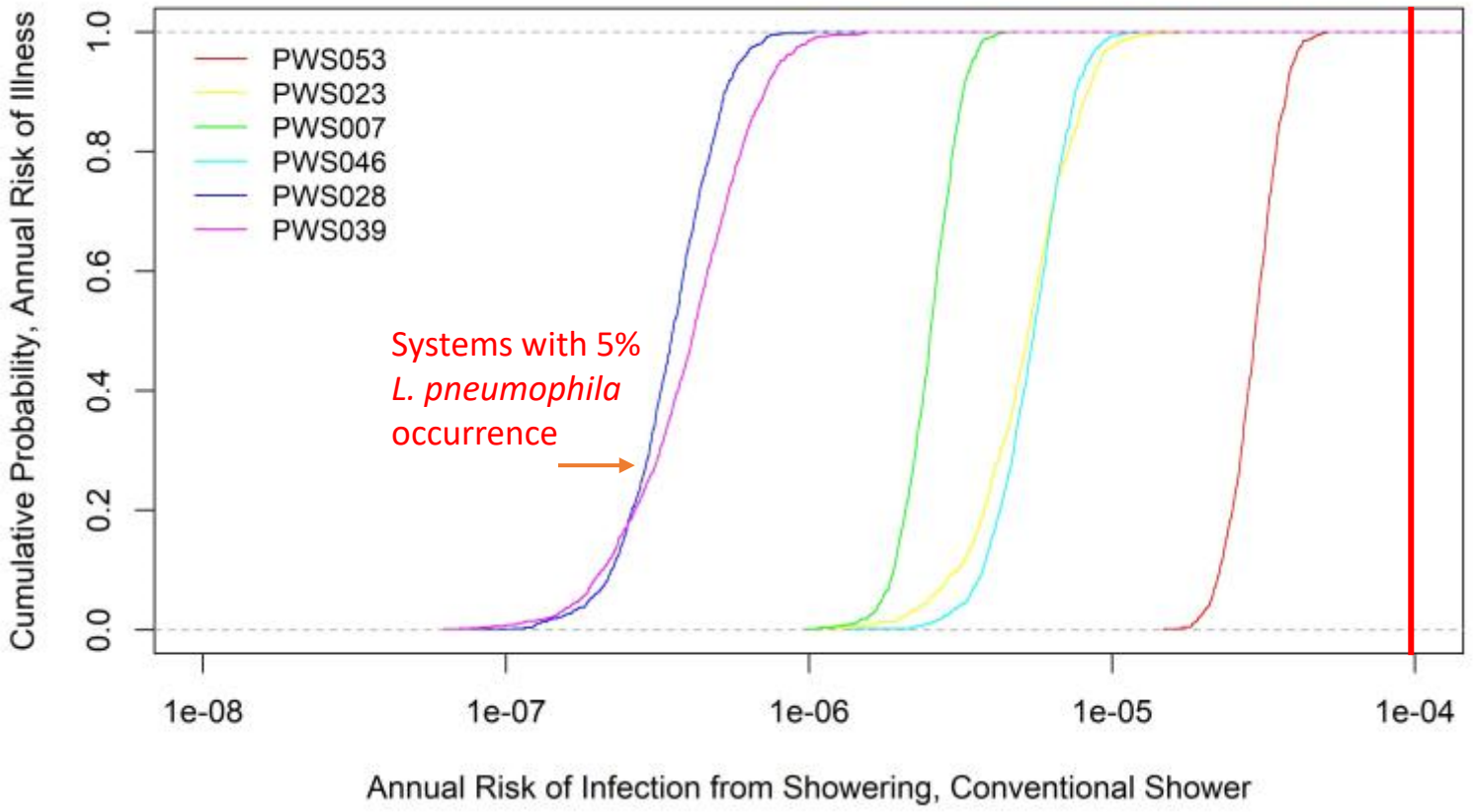
(b) Chloramine Systems

L. pneumophila Occurrence and Control in Distribution Systems

- Primary factors known or suspected to impact *L. pneumophil* c ence in distribution systems:
  - Water temperature
  - Residual disinfectant type and concentration
  - Water age (related to water temperature and residual di
  - Pipe material and condition
  - Sediment accumulation
  - Distribution system integrity
- Factors are coupled
  - Higher water temperatures associated with greater disinfec t decay and severe nitrification
  - Old, unlined cast iron pipes exert disinfectant demand and generate corrosion products
  - …



Risk of *L. pneumophila* Infection is Low



- All risks are below the 10^{-4} infection/yr reference level
- A national estimate of risk would be exceedingly small ($<1x10^{-7}$ annual risk of infection)
- Even the highest concentration (267 MPN/100 mL) was less than a $1x10^{-4}$ risk of infection for a single exposure

These findings open the door to utilities monitoring and managing *L. pneumophila* at levels that are well below risk thresholds!

Big-Picture Conclusion

- Overall, this research project finds that *L. pneumophila* occurrence in the well-run PWS DSs that participated in this study is, on average, very low.
- Positive samples have concentrations far below any current level of public health concern.
- Conscious and consistent understanding and management of *L. pneumophila* by utilities can make *L. pneumophila* occurrence even rarer and reduce concentrations in positive samples even further.
- Among the utilities participating in this study,
  - Most had occurrence rates (the percentage of culturable *L. pneumophila* positive samples) of 5% or less and 68% had no detections of *L. pneumophila.*
  - The utilities with higher occurrence rates in year one conducted system assessments, reevaluated their controls, conducted remedial activities such as flushing, and saw reductions in their occurrence rates in the second year of the study.

Residual Disinfectant is not a Silver Bullet

- Conscious and consistent management does not mean treating secondary disinfectant as a silver bullet.
- For both free and total chlorine systems, the greatest reduction in occurrence of *L. pneumophila* was achieved as disinfectant concentration increased from below 0.2 mg/L to above 0.2 mg/L. Further increases in disinfectant concentration yielded small or negligible reductions in *L. pneumophila* occurrence.
- Occurrences even at high disinfectant residual concentrations imply high disinfectant levels alone are not a guarantee of *L. pneumophila* control and that many factors contribute to *L. pneumophila* survival and amplification; *L. pneumophila* is not effectively managed if the factors beyond disinfectant are not identified and addressed.

Utilities can and should proactively manage *L. pneumophila*

- Even without a specific *L. pneumophila* management program, **many utilities already manage *L. pneumophila*,** albeit indirectly, to achieve low occurrence and abundance in their DSs.
- Utilities would not have to start their *L. pneumophila* management programs from scratch – **Most of the activities that likely promote *L. pneumophila* management are already in place** as within RTCR compliance activities, good water quality management activities, nitrification control programs, and other regulatory and water industry programs.
- Effective control requires more than maintaining a secondary disinfectant residual throughout the DS. It requires **maintaining and managing the multiple barriers** with high reliability.

Regulators should develop consensus on reporting and communication requirements for utilities detecting *L. pneumophila* in distribution system samples

- **Reporting requirements, or lack of them, can be a strong disincentive** against starting new monitoring programs for unregulated contaminants.
- At present, there is no pertinent national guidance, and most primacy agencies and health departments **lack guidance or infrastructure for assisting utilities** in appropriately addressing *L. pneumophila* positive samples.
- Thus, **many utilities are hesitant to monitor**, despite the likely benefits to the utility and for public health.
- This study provides a **starting point for developing reasonable consensus**.

THANK YOU!

Questions and Comments

WRF 5156 report is available for download for free on the Water Research Foundation website

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