Free Monthly Webinar Series
Challenges and Treatment Solutions for Small Drinking Water Systems
Hosted by EPA's Office of Research and Development (ORD) and Office of Water (OW)
Schedule & Recordings: epa.gov/water-research/small-systems-monthly-webinar-series

January 28, 2020

TODAY'S TOPIC:

Legionella Management and Treatment

A certificate for one contact hour will be provided for attending this webinar

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Requirements:

1. You must be registered or be in a room with someone who is.
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Note

Acceptance of certificates is contingent on state/organization requirements—EPA cannot guarantee acceptance. Certificates cannot be provided for viewing webinar recordings.

Upcoming EPA Webinars

- **Small Systems Monthly Webinar Series**

  epa.gov/water-research/small-systems-monthly-webinar-series

  February 25: Drinking Water Regulations 101 and Technical Assistance

- **Water Research Webinar Series**

  https://www.epa.gov/water-research/water-research-webinars-series

  February 26: Science to Support and Implement Microbial Water Quality Criteria

17th Annual EPA Drinking Water Workshop: Small Systems Challenges and Solutions

September 1-3 in Covington, KY (Cincinnati Area)

Earn Continuing Education Contact Hours

Free Workshop Sponsored by

EPA United States Environmental Protection Agency

ASDWA Association of State Drinking Water Administrators

- Monitoring, distribution, source, and treatment topics
- Discussion groups and ask the experts
- Technical talks and demos
- Hands-on training options

Call for Abstracts! **(Closes March 26)**

Submit a proposal for a technical session talk or poster presentation.

epa.gov/water-research/17th-annual-epa-drinking-water-workshop

EPA

Presentation 1

Ken Rotert

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Ken is a physical scientist in EPA's Office of Water, Office of Ground Water and Drinking Water, where he has been involved with regulatory review and development and examination of emerging drinking water issues since 1998. His focus has been on distribution systems, cross connections, and microbiological issues, such as *Legionella*, indicator bacteria, fecal contaminants, cyanobacteria, and Ebola.

Public Water System Characteristics that May Affect *Legionella* Occurrence in Building Water Systems

This presentation will highlight EPA's efforts to reduce *Legionella* risks through regulatory revisions, treatment technologies, and research on premise plumbing. An overview of public health impacts, challenges to addressing *Legionella* in drinking water, and potential risk factors in municipal supplies will be included.

Presentation Overview

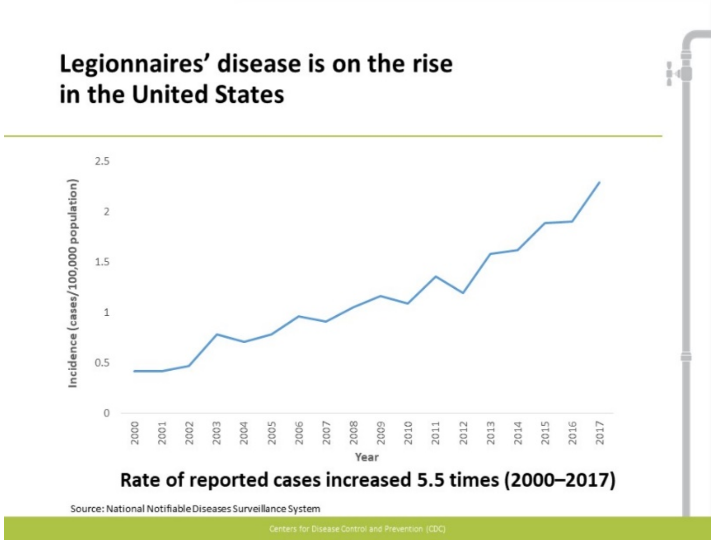
- Public Health Impacts
- Challenges to Addressing *Legionella* in Drinking Water
- Potential Risk Factors in Municipal Supplies
- EPA Efforts to Reduce *Legionella* Risks
- Other Relevant Drinking Water Regulations
- Some EPA Research on Premise Plumbing and *Legionella*
- Summary

PUBLIC HEALTH IMPACTS

Public Health Impacts

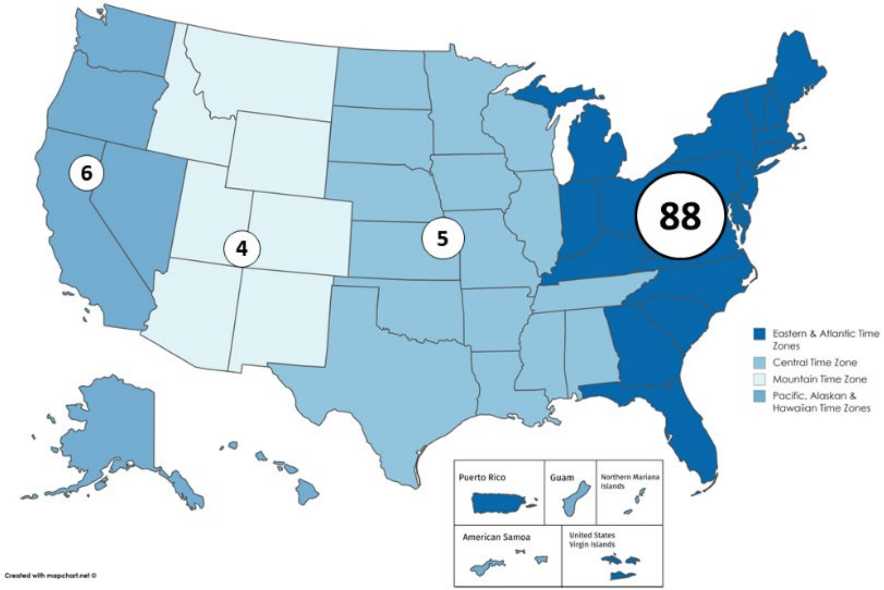
OFFICE OF GROUND WATER AND DRINKING WATER

- EPA recognizes legionellosis as a significant and growing public health concern
  - Health departments reported nearly 7,500 cases of Legionnaires' Disease to CDC in 2017 (CDC, 2018)
  - According to a recent National Academies of Science (NAS, 2019) study there are an estimated 52,000-70,000 cases of Legionnaires' Disease annually
  - Adam, et al. (2017) estimated 3,359 Emergency Department visits annually for Legionnaires' Disease, with 91% resulting in hospitalizations
  - According to the NAS 2019 study, an estimated 3-33% of *Legionella* infections lead to death
  - The rate of cases of Legionnaires' Disease reported to CDC increased 5.5 times from 2000-2017



Public Health Impacts

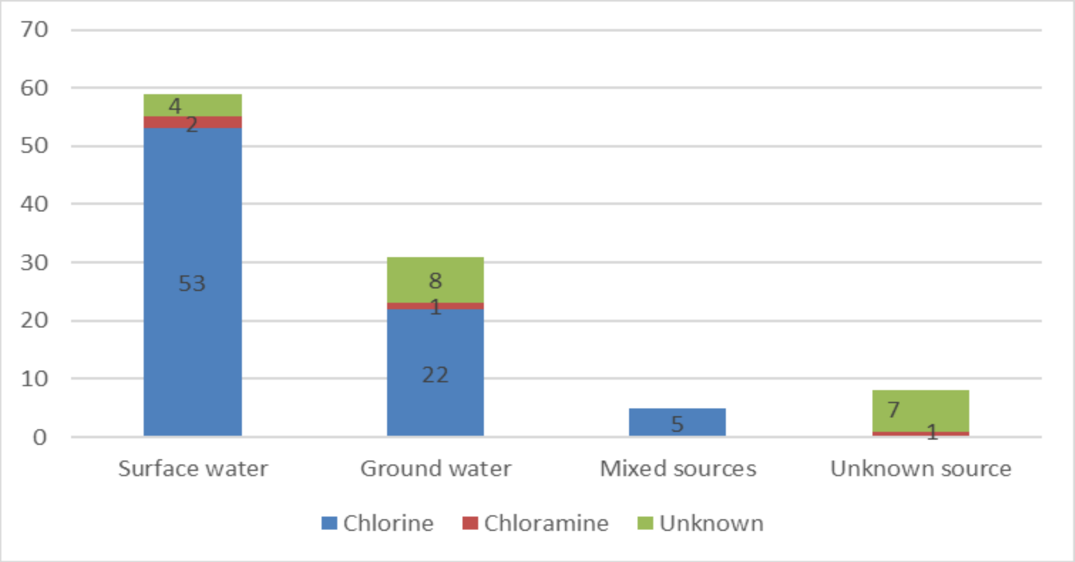
Number of Reported Legionellosis Outbreaks from 2001-2014 using WBDOSS Data, Grouped by Time Zones* (N=103)



Source: Tucker, et al., 2018

Public Health Impacts

Number of Reported Legionellosis Outbreaks by Source Water and Disinfectant Type from 2001-2014 using the WBDOSS, DBP ICR, UCMR 2, UCMR 3 and CCR Data (N=84)

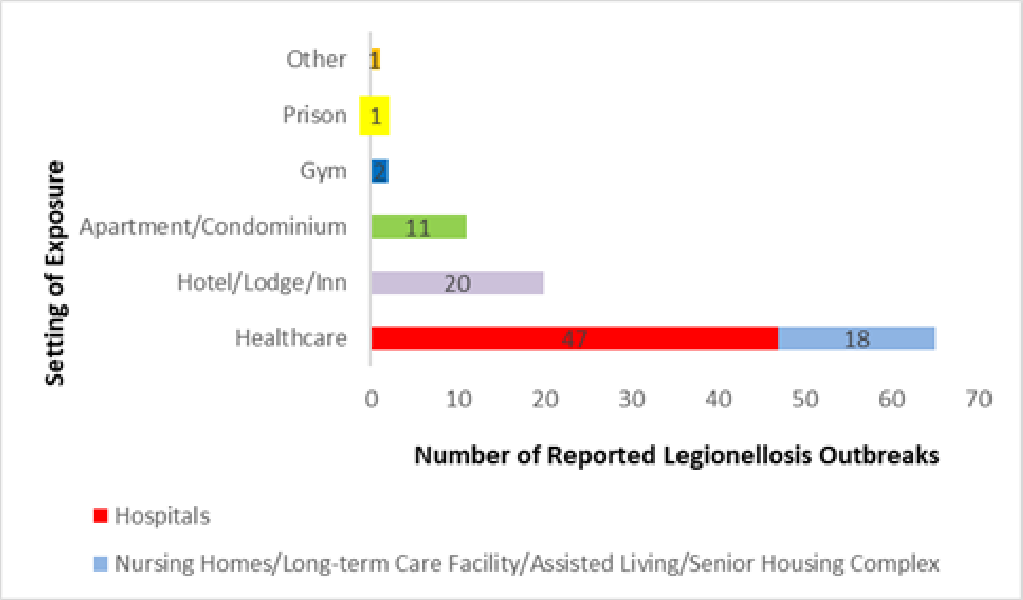


Source: Tucker, et al., 2018

WBDOSS – Waterborne Disease Outbreak Surveillance System. DBP ICR – Disinfection Byproducts Information Collection Rule. UCMR – Unregulated Contaminant Monitoring Rule. CCR – Consumer Confidence Report.

Public Health Impacts

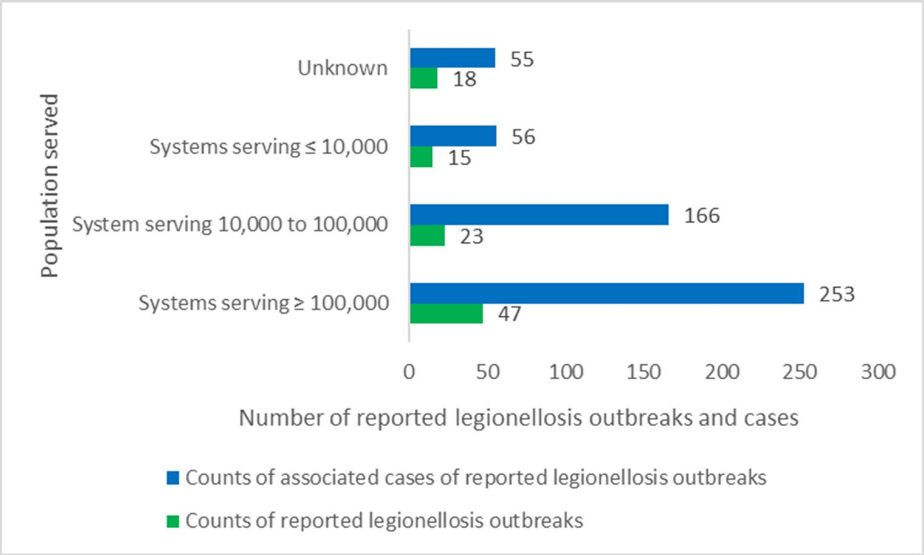
Types of Settings with Reported Legionellosis Outbreaks which Occurred from 2001-2014 using WBDOSSS Data (N=103)



Source: Tucker, et al., 2018

Public Health Impacts

Number of Reported Legionellosis Outbreaks and Outbreak-Associated Cases by Size of the System using WBDOSS and SDWIS Data (N=103)



Source: Tucker, et al., 2018

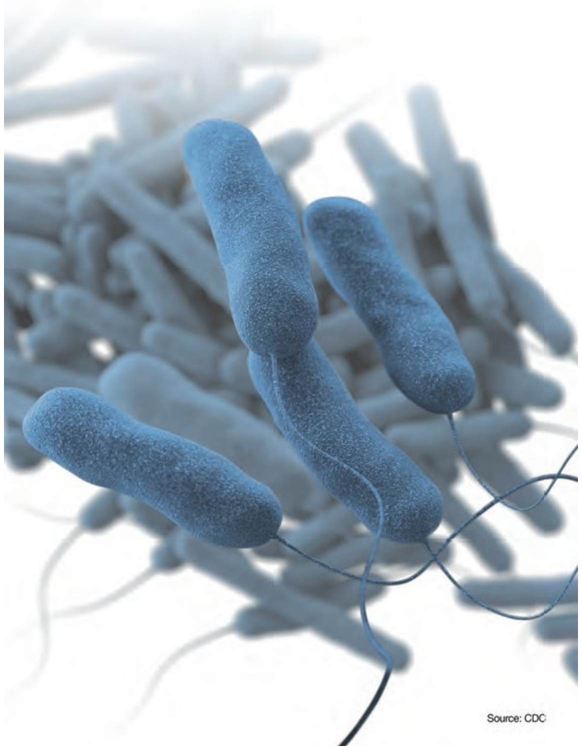
Public Health Impacts

- Most documented drinking water related legionellosis outbreaks and cases are associated with building water systems
- Certain facilities have been implicated in many of the reported outbreaks of Legionnaires' Disease, including health care facilities, hotels, and large institutional buildings
- Public Water Systems can also contribute to *Legionella* outbreaks
    - Cohn et al. (2015) describe two outbreaks in a municipal supply in New Jersey.
- The quality of water entering a building can have an impact on the growth of *Legionella* in building water systems

Challenges to Addressing *Legionella* in Drinking Water

OFFICE OF GROUND WATER AND DRINKING WATER

- Public officials, public water system operators and facility managers need better tools to:
  - Assess *Legionella* Risks (most important risk factors)
  - Manage *Legionella* Risks (most effective strategies)
  - Communicate about *Legionella* Risks (most appropriate messaging for subpopulations)



POTENTIAL RISK FACTORS IN MUNICIPAL SUPPLIES

Potential Risk Factors in Municipal Supplies

- Inadequate Disinfectant Residual in the Distribution System
  - Can enable *Legionella* growth in buildings
  - Can be caused by a variety of factors, including high residence time (e.g., in storage tanks), reactions with distribution system materials (e.g., iron), demand from contaminants entering the distribution system, and excess biofilms
  - According to the NAS (2019) an inadequate disinfectant residual contributed to *Legionella* growth in the Flint, Michigan Legionnaire' Disease outbreak

- Disinfectant longevity can depend on the type of secondary disinfectant used
  - Some building water systems provide additional disinfection which may lead to DBP formation concerns if not properly managed

Potential Risk Factors in Municipal Supplies

- Nutrient Availability to Support *Legionella* Growth
  - Nutrients can enter through a variety of sources, including from the source water, and the distribution system (e.g., pipe and storage breaches)
  - Nutrients that can support growth of *Legionella* include iron and carbon
    - Iron is an essential nutrient for *Legionella* that can enter the water in the distribution system as a result of pipe corrosion
    - Iron corrosion in Flint, Michigan was hypothesized to promote *Legionella* growth, which contributed to the Legionnaires' Disease outbreak according to Rhoads et. al., 2017
    - Corrosion control can limit iron release and subsequent growth of *Legionella pneumophila*
    - Carbon can enter from the municipal supply if not adequately removed, and from some distribution system materials (e.g., rubber gaskets) according to Niedeveld et. al., 1986
    - Stagnant water has also been found to have higher concentration of organics according to Wang et. al., 2012
  - Nutrient control may also help to impact the ability of *Legionella* to grow in free-living amoeba according to NAS, 2019

Potential Risk Factors in Municipal Supplies

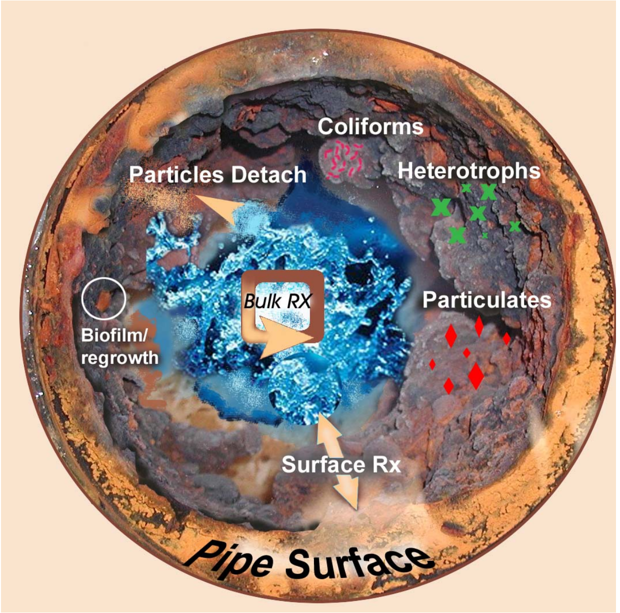
- High Water Age
  - *Legionella* can grow in parts of a distribution system with high water age, such as storage tanks with inadequate water turnover, dead ends, and near closed valves
    - Some finished water storage tanks can have high water age due to tank configuration, infrequent turnover, and water stratification
    - Systems dead legs and parts of the system with oversized pipes can cause high water age
    - While not documented to cause increased *Legionella* concentrations or suspected cases of Legionnaires disease, closed valves were partially responsible for high water age that led to TCR MCL violations in Houston, Texas in 2015 (Smith, 2016)
  - Stagnant water can also lead to the growth of protozoa in which *Legionella* reside
  - Managing distribution system hydraulics can reduce areas of stagnant water, and help maintain disinfectant residual levels according to NAS, 2019
  - Water age can be reduced through several activities, tank management, proper valve operation, elimination of dead legs, and routine flushing

Potential Risk Factors in Municipal Supplies

- Corrosion and Infrastructure Condition
  - Iron corrosion may deplete disinfectant residuals, increase iron bioavailability, increase *Legionella* virulence, enhance biofilm growth, and create a habitat where *Legionella* is protected from disinfection according to NAS, 2019
  - Inadequate corrosion control contributed to the Legionnaires' Disease outbreak in Flint, Michigan according to NAS, 2019
  - Distribution systems (e.g., main breaks) may seed premise plumbing with *Legionella* and lead to Legionnaires' Disease outbreaks or sporadic cases according to NAS, 2019
  - Once *Legionella* enters the system it may grow under favorable conditions
  - The American Society of Civil Engineers (ASCE, 2017) gave U.S. water infrastructure a 'D' rating
    - Many pipes are beyond their expected lifespan, which may increase main breaks, intrusion, and corrosion impacts according to NAS, 2019
  - Distribution system maintenance can reduce many factors that contribute to *Legionella* growth

Potential Risk Factors in Municipal Supplies

- Sediment Accumulation
  - Sediments originate from treatment breakthrough, intrusions, corrosion, and other sources, and can accumulate in low flow areas
  - Sediments and corrosion products can accumulate in pipes and tanks
  - Sediments can provide a niche for the protection of *Legionella* against disinfection and be a source of nutrients that may support *Legionella* growth
  - A study of ten states by Lu et al., (2015) found 12/18 *Legionella* positive samples from storage tanks sediments
  - The NAS recommends that public water systems have a routine distribution system flushing and cleaning program, and storage tanks should also be inspected and cleaned (NAS, 2019)



EPA EFFORTS TO REDUCE *LEGIONELLA* RISKS

EPA Efforts to Reduce *Legionella* Risks

OFFICE OF GROUND WATER AND DRINKING WATER

- Surface Water Treatment Rule (SWTR) published in 1989
  - Applies to public water systems that use surface water and ground water under the direct influence of surface water
  - Established Maximum Contaminant Level Goals (MCLGs) of zero for *Giardia*, viruses, and *Legionella*
  - Established treatment technique requirements to remove these microbial pathogens to the extent feasible
    - System must practice filtration/disinfection to remove/inactivate *Giardia lamblia* and viruses prior to the first customer in the distribution system;
    - Systems must maintain a detectable residual disinfectant level in the distribution system or maintain of HPC < 500/mL in the distribution

EPA Efforts to Reduce *Legionella* Risks

- SDWA requires EPA to review existing NPDWRs every six years and, if appropriate, revise. EPA calls this process Six-Year Review.

- 3rd Six-Year Review, published in January 2017
    - First review to address microbial and disinfection byproduct regulations
    - Determined the following drinking water regulations are candidates for revision
        - Stage 1 and Stage 2 Disinfectants and Disinfection Byproducts Rules, Surface Water Treatment Rule, Interim Enhanced Surface Water Treatment Rule and Long Term 1 Enhanced Surface Water Treatment Rule

EPA Efforts to Reduce *Legionella* Risks

OFFICE OF GROUND WATER AND DRINKING WATER

- The Surface Water Treatment Rule (SWTR) is a candidate for revision
  - Considering a number of pathogens (i.e., *Legionella*, *Mycobacterium avium* Complex, *Pseudomonas*)
- Key elements of SWTR identified for further evaluation:
  - Numerical values for minimum disinfectant residuals in distribution systems
  - Distribution system management to reduce intrusion, leakage, main breaks, cross connections, pathogen growth in storage tanks

EPA Efforts to Reduce *Legionella* Risks

EPA
OFFICE OF GROUND WATER AND DRINKING WATER

- *Technologies for Legionella Control in Premise Plumbing Systems: Scientific Literature Review, 2016*
    - Provides a characterization of the effectiveness of treatment technologies to control for *Legionella* in premise plumbing based on findings from peer reviewed literature.
    - Technical resource for State, local and tribal officials, facility operators and facility owners to use as they evaluate technologies to respond to the risks associated with *Legionella* growth in premise plumbing systems.

EPA 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

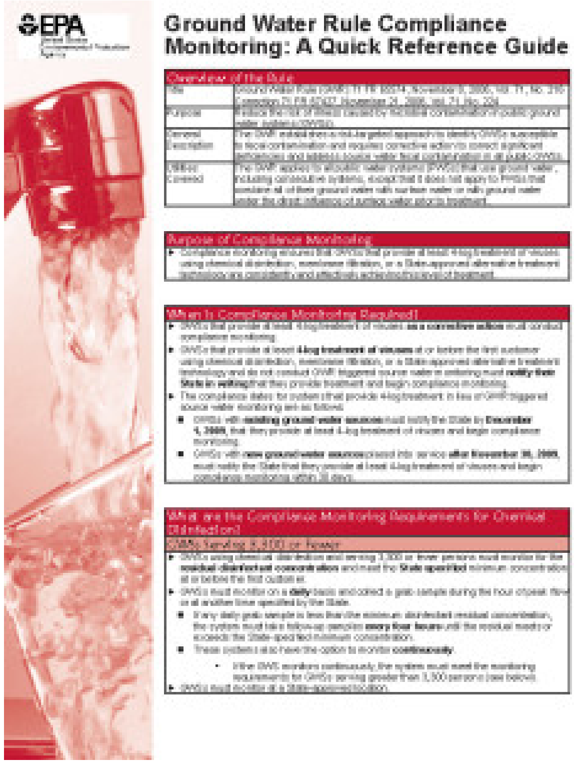
OTHER RELEVANT DRINKING WATER REGULATIONS

Other Relevant Drinking Water Regulations

- Revised Total Coliform Rule
  - Requires monitoring of total coliform and *E. coli* in the distribution system as an indicator of potential treatment upset, or entry of contamination, or biofilm growth within the distribution system
  - Find and fix response actions depending on coliform occurrence
  - A total coliform positive distribution system sample triggers Ground Water Rule mandated source water monitoring

Other Relevant Drinking Water Regulations

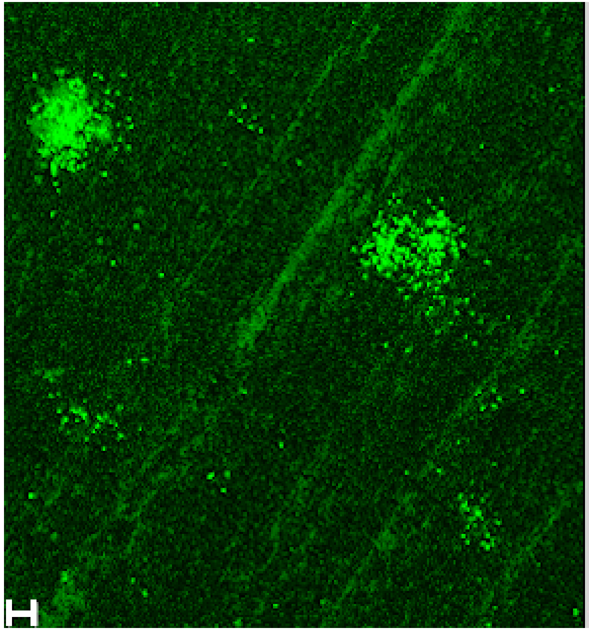
- Ground Water Rule
  - Requires source water monitoring either through triggered monitoring or State-directed assessment monitoring to test for the presence of one of three fecal indicators (*E. coli*, enterococci, or coliphage); if sample tests positive, remedial action such as disinfection is required
  - Requires sanitary surveys (evaluation of source, treatment, distribution system, pumps, finished water storage, etc.) to identify significant deficiencies (also applies to surface water systems in the Interim Enhanced Surface Water Treatment Rule)
  - Remedial action such as disinfection in response to significant deficiencies, as necessary


Ground Water Rule Compliance Monitoring: A Quick Reference Guide

SOME EPA RESEARCH ON PREMISE PLUMBING AND *LEGIONELLA*

Some EPA Research on Premise Plumbing and *Legionella*

- Efficacy of Treatment for the Prevention and Decontamination of *Legionella* in Drinking Water
- Occurrence of *Legionella* and Other Opportunistic Pathogens in Plumbing Systems and Drinking Water Storage Tanks
- Molecular and Culture-Based Methods for the Enumeration of *Legionella*



Some EPA Research on Premise Plumbing and *Legionella*

- Evaluation of *Legionella* Persistence Related to Distribution System Surfaces, Water Quality Parameters, and Other Biotic and Abiotic Factors
- Water Quality Assessment of Model Home Plumbing System
- *Legionella* as an Indicator of Microbial Contamination of Distribution

SUMMARY

Summary

- Legionellosis is a serious and growing health concern
- Challenges to addressing *Legionella* contamination exist regarding assessing, managing and communicating the risks
- According the 2019 NAS report, municipal water supplies can reduce some *Legionella* -related risks by certain management practices and controlling several water quality conditions that can impact *Legionella* occurrence in buildings (NAS, 2019)
- EPA has taken some steps to address *Legionella* and related concerns
- EPA continues to research concerns related to *Legionella*

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Maura Donohue

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Maura is a research chemist in EPA's Office of Research and Development, Center of Environmental Solutions and Emergency Response. For the past ten years, her research has been centered around microbial control and disinfection byproducts. Her current efforts are focused on examining the distribution of *Legionella* and NTM and the water quality characteristics that support their persistence in the built environment. Maura has a Ph.D in chemistry from American University and a B.A. in biological sciences from Elms College.

Impact of Chlorine and Chloramine on the Detection and Quantification of *Legionella pneumophila* and *Mycobacterium* species

Potable water can be a source of transmission for legionellosis and nontuberculous mycobacteria (NTM) infection and diseases. This presentation will investigate the influence of disinfectant type and total chlorine residual (TClR) on the detection and concentration of the five leading pathogens associated with these infections and diseases.

PUBLIC AND ENVIRONMENTAL HEALTH MICROBIOLOGY

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Impact of Chlorine and Chloramine on the Detection and Quantification of *Legionella pneumophila* and *Mycobacterium* Species

Maura J. Donohue,[a] Steve Vesper,[a] Jatin Mistry,[b] Joyce M. Donohue[c]

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ABSTRACT Potable water can be a source of transmission for legionellosis and nontuberculous mycobacterium (NTM) infections and diseases. Legionellosis is caused largely by *Legionella pneumophila*, specifically serogroup 1 (Sg1). *Mycobacterium avium*, *Mycobacterium intracellulare*, and *Mycobacterium abscessus* are three leading species associated with pulmonary NTM disease. The estimated rates of these diseases are increasing in the United States, and the cost of treatment is high. Therefore, a national assessment of water disinfection efficacy for these pathogens was needed. The disinfectant type and total chlorine residual (TClR) were investigated to understand their influence on the detection and concentrations of the five pathogens in potable water. Samples (n = 358) were collected from point-of-use taps (cold or hot) from locations across the United States served by public water utilities that disinfected with chlorine or chloramine. The bacteria were detected and quantified using specific primer and probe quantitative-PCR (qPCR) methods. The total chlorine residual was measured spectrophotometrically. Chlorine was the more potent disinfectant for controlling the three mycobacterial species. Chloramine was effective at controlling *L. pneumophila* and Sg1. Plotting the TClR associated with positive microbial detection showed that an upward TClR adjustment could reduce the bacterial count in chlorinated water but was not as effective for chloramine. Each species of bacteria responded differently to the disinfection type, concentration, and temperature. There was no unifying condition among the water characteristics studied that achieved microbial control for all. This information will help guide disinfectant decisions aimed at reducing occurrences of these pathogens at consumer taps and as related to the disinfectant type and TClR.

IMPORTANCE The primary purpose of tap water disinfection is to control the presence of microbes. This study evaluated the role of disinfectant choice on the presence at the tap of *L. pneumophila*, its Sg1 serogroup, and three species of mycobacteria in tap water samples collected at points of human exposure at locations across the United States. The study demonstrates that microbial survival varies based on the microbial species, disinfectant, and TClR.

KEYWORDS chlorine, chloramine, drinking water, *Legionella*, *Mycobacterium*, total chlorine residual

Legionella and *Mycobacterium* are two genera of waterborne environmental bacteria that affect human health by causing the respiratory diseases legionellosis (Legionnaires' disease and Pontiac fever) (1) and nontuberculous mycobacterium (NTM) infections and diseases (2), respectively. Potable water is often suspected or identified as the cause of individual cases or a cluster of cases (an outbreak). Outbreaks for both genera

Citation Donohue MJ, Vesper S, Mistry J, Donohue JM. 2019. Impact of chlorine and chloramine on the detection and quantification of Legionella pneumophila and Mycobacterium species. Appl Environ Microbiol 85:e01942-19. https://doi.org/10.1128/AEM.01942-19.

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Disclaimer: The views expressed in this presentation are those of the author and do not necessarily reflect the views or policies of the U.S. Environmental Protection Agency.

A Tale of Two Bacterium…

Legionellaceae

- Legionella (Genus)
  - Gram negative bacteria (Gammaproteobacteria)
  - Flagella rod (2-20 µm)
  - Slow grower (3 to 10 days)
  - Majority of species will grow in free-living amoebae
  - Aerobic, L-cysteine and iron salts are required for in vitro growth, pH: 6.8 to 7, T: 25 to 43 °C
  - ~65 species
  - Pathogenic or potentially pathogenic for human

Mycobacteriaceae

- Mycobacterium (Genus)
- Nontuberculous Mycobacterium (NTM)
- *M. avium-intracellulare* complex (MAC)
  - Gram positive bacteria
  - Rod shape (1-10 µm)
  - Non-motile, spore-forming, aerobic
  - Rapid to Slow grower (1 week to 8 weeks)
  - ~156 species
  - Some species capable of causing disease

NTM from Environmental Microorganism to Opportunistic Opponent

Genus | **156 Species** | **Disease**

NTM =Nontuberculous Mycobacteria   MAC = *M. avium* Complex

Mycobacterium spp.

Mycobacterium
Mycobacterium abscessus
Mycobacterium africanum
Mycobacterium agri
Mycobacterium aichiense
Mycobacterium algericum
Mycobacterium alsense
Mycobacterium alvei.
Mycobacterium angelicum
Mycobacterium anyangense
Mycobacterium arabiense.
Mycobacterium aromaticivorans
Mycobacterium arosiense
Mycobacterium arupense
Mycobacterium asiaticum
Mycobacterium aurum
Mycobacterium austroafricanum
Mycobacterium avium
Mycobacterium bacteremicum
Mycobacterium boenickei
Mycobacterium botniense
Mycobacterium bouchedurhonense
Mycobacterium bourgelatii
Mycobacterium bovis
Mycobacterium brisbanense
Mycobacterium brumae
Mycobacterium canariasense
Mycobacterium caprae
Mycobacterium celatum
Mycobacterium celeriflavum
Mycobacterium chelonae
Mycobacterium chitae
Mycobacterium chlorophenolicum
Mycobacterium chubuense
Mycobacterium colombiense
Mycobacterium conceptionense
Mycobacterium confluentis
Mycobacterium conspicuum
Mycobacterium cookii
Mycobacterium cosmeticum
Mycobacterium crocinum
Mycobacterium doricum
Mycobacterium duvalii
Mycobacterium elephantis
Mycobacterium europaeum
Mycobacterium fallax
Mycobacterium farcinogenes
Mycobacterium flavescens
Mycobacterium florentinum.
Mycobacterium fluoranthenivorans
Mycobacterium fortuitum
Mycobacterium franklinii
Mycobacterium frederiksbergense
Mycobacterium gadium
Mycobacterium gastri
Mycobacterium genavense
Mycobacterium gilvum
Mycobacterium goodii
Mycobacterium gordonae
Mycobacterium haemophilum
Mycobacterium hassiacum
Mycobacterium heckeshornense.
Mycobacterium heidelbergense
Mycobacterium hiberniae
Mycobacterium hippocampi
Mycobacterium hodleri
Mycobacterium holsaticum
Mycobacterium houstonense
Mycobacterium immunogenum
Mycobacterium insubricum
Mycobacterium interjectum
Mycobacterium intermedium
Mycobacterium intracellulare
Mycobacterium iranicum
Mycobacterium kansasii
Mycobacterium komossense
Mycobacterium koreense.
Mycobacterium kubicae.
Mycobacterium kumamotonense
, Mycobacterium kyorinense
Mycobacterium lacus.
Mycobacterium lentiflavum
Mycobacterium leprae
Mycobacterium lepraemurium
Mycobacterium litorale
Mycobacterium llatzerense.
Mycobacterium madagascariense
Mycobacterium mageritense,
Mycobacterium malmoense
Mycobacterium mantenii
Mycobacterium marinum
Mycobacterium massiliense
Mycobacterium microti
Mycobacterium minnesotense
Mycobacterium monacense
Mycobacterium montefiorense
Mycobacterium moriokaense,
Mycobacterium mucogenicum
Mycobacterium murale
Mycobacterium neoaurum
Mycobacterium nebraskense
Mycobacterium neworleansense
Mycobacterium nonchromogenicum
Mycobacterium noviomagense
Mycobacterium novocastrense
Mycobacterium pallens
Mycobacterium palustre
Mycobacterium paraense
Mycobacterium paraffinicum
Mycobacterium parafortuitum
Mycobacterium paragordonae.
Mycobacterium paraintracellulare
Mycobacterium parakoreense.
Mycobacterium parascrofulaceum
Mycobacterium paraseoulense
Mycobacterium paratuberculosis.
Mycobacterium parmense
Mycobacterium peregrinum
Mycobacterium phlei
Mycobacterium phocaicum
Mycobacterium pinnipedii
Mycobacterium porcinum
Mycobacterium poriferae,
Mycobacterium pseudoshottsii
Mycobacterium psychrotolerans
Mycobacterium pulveris
Mycobacterium pyrenivorans,
Mycobacterium rhodesiae
Mycobacterium riyadhense
Mycobacterium rufum
Mycobacterium rutilum
Mycobacterium salmoniphilum (
Mycobacterium saopaulense
Mycobacterium saskatchewanense
Mycobacterium scrofulaceum
Mycobacterium sediminis
Mycobacterium senegalense
Mycobacterium senuense
Mycobacterium seoulense,
Mycobacterium septicum
Mycobacterium setense
Mycobacterium sherrisii,
Mycobacterium shimoidei
Mycobacterium shinjukuense
Mycobacterium shottsii,
Mycobacterium simiae
Mycobacterium smegmatis
Mycobacterium sphagni
Mycobacterium stomatepiae
Mycobacterium szulgai
Mycobacterium terrae
Mycobacterium thermoresistibile
Mycobacterium timonense
Mycobacterium tokaiense
Mycobacterium triplex
Mycobacterium triviale
Mycobacterium tuberculosis
Mycobacterium tusciae
Mycobacterium ulcerans
Mycobacterium vaccae
Mycobacterium vanbaalenii.
Mycobacterium vulneris.
Mycobacterium wolinskyi
Mycobacterium xenopi
Mycobacterium yongonense

Clinically Relevant Species

M. avium, *M. intracellulare*, *M. fortuitum*, *M. chelonae*, *M. kansasii*, *M. abscessus*, etc.

- Pulmonary NTM lung disease
- Chronic bronchopulmonary disease
- Cervical or other lymphadenitis
- Skin and soft tissue diseases
- Disseminated infections
- Catheter-related infections

Legionellosis: Respiratory Disease

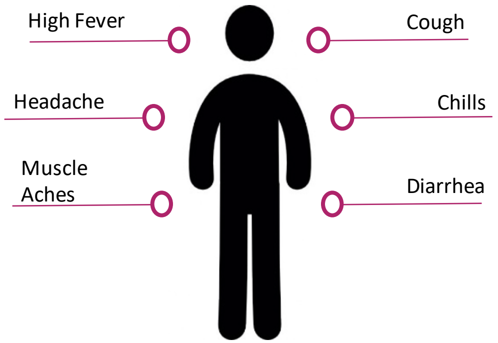
Disease

Legionellosis = pneumonia

- Legionaries' Disease (severe)
- Pontiac Fever (mild)

Signs/Symptoms

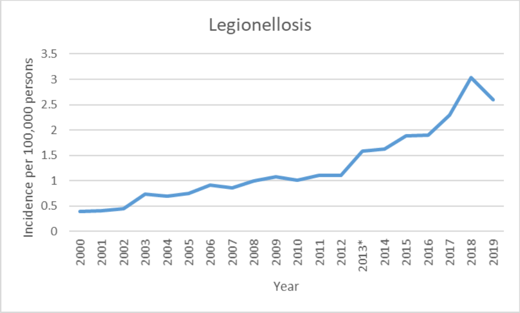
Pneumonia
(Signs/Symptoms)



National Notifiable Disease Surveillance System (NNDSS)

2019 National Reportable Disease List: contained the names of over 110 Diseases/Microorganisms

Number of Cases Reported in 2019:
7,802 cases



LEGIONELLOSIS.
Incidence,* by year — United States, 2000–2019, Source NNDSS

Annual Cost of Treatment in the U.S.

Number of Hospitalization/year
8,000-18,000 cases Marston, (1997)
avg(13,000)

Total Hospitalization Cost:
$433,758,000

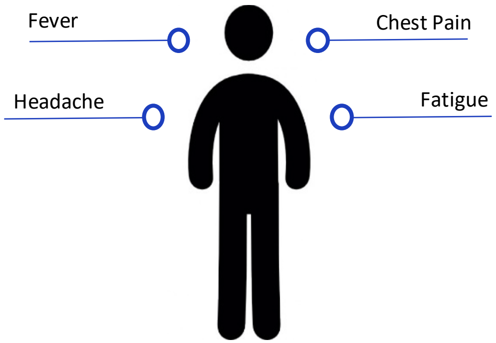
Collier, S.A. et al 2012:
Direct healthcare costs of selected disease primarily or partially transmitted by water. Epidemiology Infection, 140, p2003-2013

Nontuberculous Mycobacteria Infection/Disease: Primarily Respiratory Diseases

Infection/Disease

- Pulmonary NTM lung disease
- Chronic bronchopulmonary disease
- Cervical or other lymphadenitis
- Skin and soft tissue diseases
- Disseminated infections
- Catheter-related infections

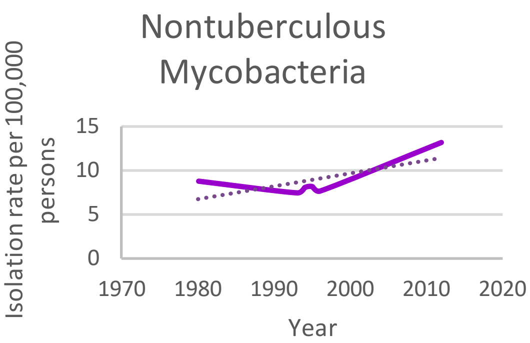
Signs/Symptoms



State Health Departments

Laboratory Reports
*Report is defined as the presence of culturable NTM from a human specimen (Lavage, Sputum, Blood, and/or Tissue)

Number of Cases Reported in 2010:
Est 86,244 cases



NONTUBERCULOUS MYCOBACTERIA.
Isolation Rate,* by year — United States, 1980–2013,
Sources: Good et al. (1980), CDC, NTM 1993-1996 report (1999), Donohue et al. (2016)

Annual Cost of Treatment in the U.S.

Number of Hospitalization/year
16,386 cases: 2007

Total Hospitalization Cost:
$425,788,469

Collier, S.A. et al 2012:
Direct healthcare costs of selected disease primarily or partially transmitted by water. Epidemiology Infection, **140**, p2003-2013

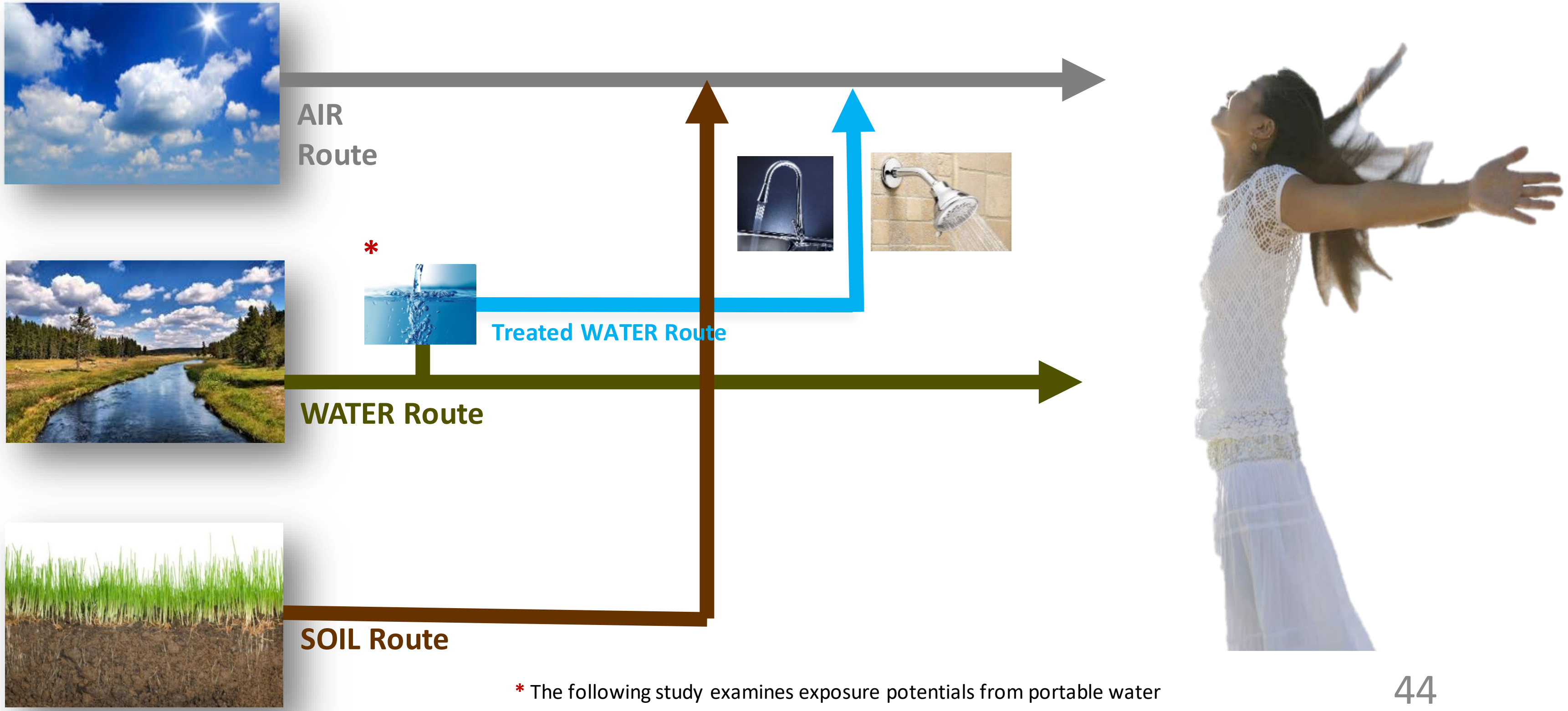
Number of NTM Cases
est 86,244 cases: 2010

Total Hospitalization Cost:
$815,098,690

Strollo S.E. et al 2015: The Burden of Pulmonary N0ntuberculous Mycobacterial Disease in the United States. AnnalsATS, **12**, p1458-1464

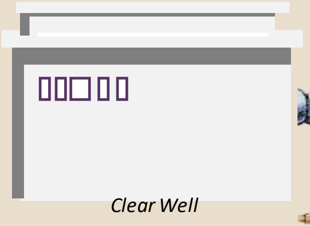
Exposure Routes: Environmental Sources

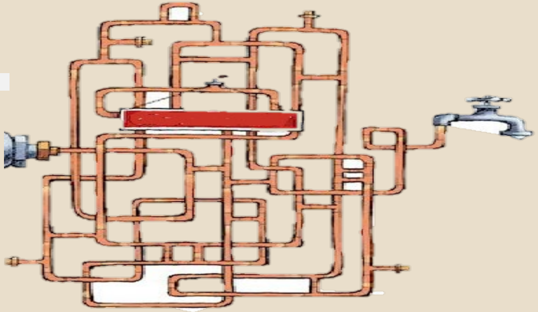
Legionella pneumophila and Mycobacterium avium are microorganisms of the natural environment found in soil and water.



* The following study examines exposure potentials from portable water

What Is the Purpose of this Study?





Houses/Building

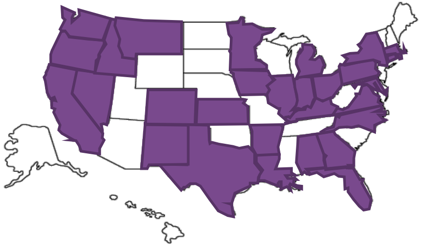
Source Water	Waterworks	Distribution	Point of Use
King et al. 2016: STOEN	King et al. 2016: STOEN	In Progress	Donohue et al 2019: JAM & AEM

- The purpose of this study was to understand what is occurring at point of use, where human exposure could potential occur.

Study Design

46 States and Territories	Structure/ Point of Use 358 Samples	5 qPCR Assays	Water Quality Testing

46 States and Territories



Structure/ Point of Use
358 Samples

Cold/Hot Water

Houses

Buildings

5 qPCR Assays

- *Legionella pneumophila*
  Donohue et al. 2014
- *L. pneumophila* Sg1
  Merault et al. 2011l
- *Mycobacterium avium*
  Chen et al. 2015
- *Mycobacterium intracellulare*
  Chen et al. 2015
- *Mycobacterium abscessus*
  Steindor M. et al. 2015

- Detection Frequency (FD)
- Persistence
- Concentration

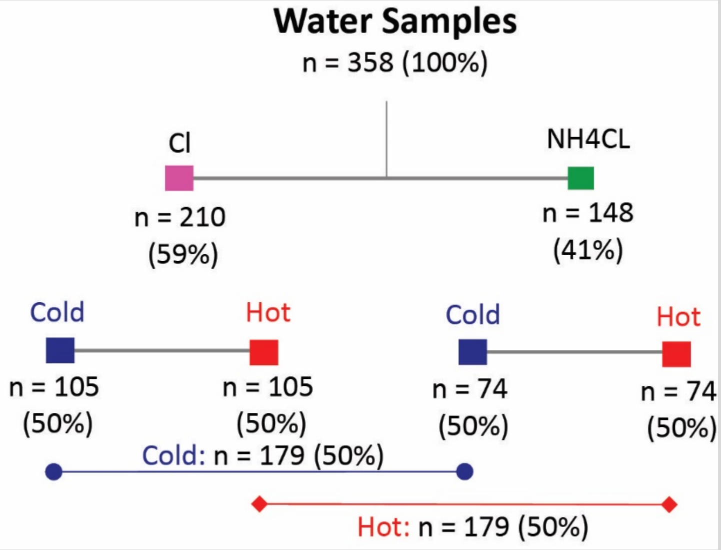
Water Quality Testing

- Total Chlorine
  DPD Total Chlorine Test
- Monochloramine
  Monochlor F Test
- Temperature
  Cold water line
  Hot water line
- Heterotrophic Plate Counts (HPC)
  Standard Method 9215

Sampling Time Frame : 2011 – 2017

Variables Evaluated

- Chlorine (Cl) versus Chloramine (CLM)
- At the tap disinfectant residuals (Total Chlorine Test) – Temperature (Cold vs Hot)
- *L. pneumophila* (Lp) – Mycobacterium spp.(Myco) includes MA/MI/Mab



Molecular Testing: qPCR

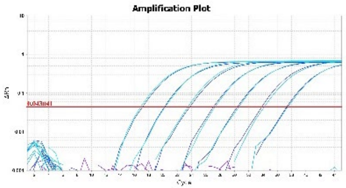
Method

Water

Membrane Filtration
Polycarbonate 0.4 µm

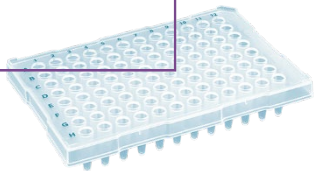
DNA Extraction
Bead Beating
DNA precipitation

qPCR
40 cycles
1hr 45 min



Assays

- *Legionella pneumophila*
- *L. pneumophila* Sg1
- *Mycobacterium avium*
- *Mycobacterium intracellulare*
- *Mycobacterium abscessus*



1 Well = 1 Reaction

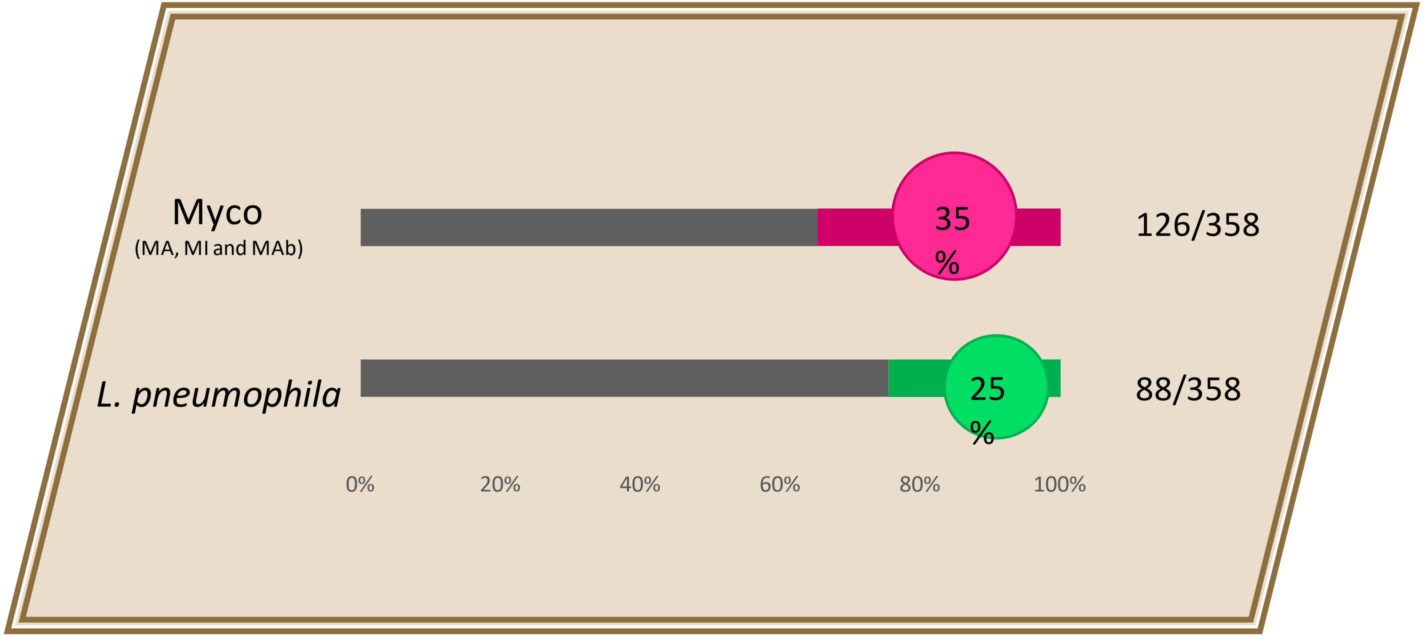
96 plate well: Well Format

- Assay/Mastermix
- Primer/Probes
- Template(DNA/ddH_2O
- Internal Control

Study: Percent Positive

Point of Use

Houses/Building



Is *L. pneumophila/ Mycobacteria spp.* Occurrence Influenced by Disinfectant Choice?

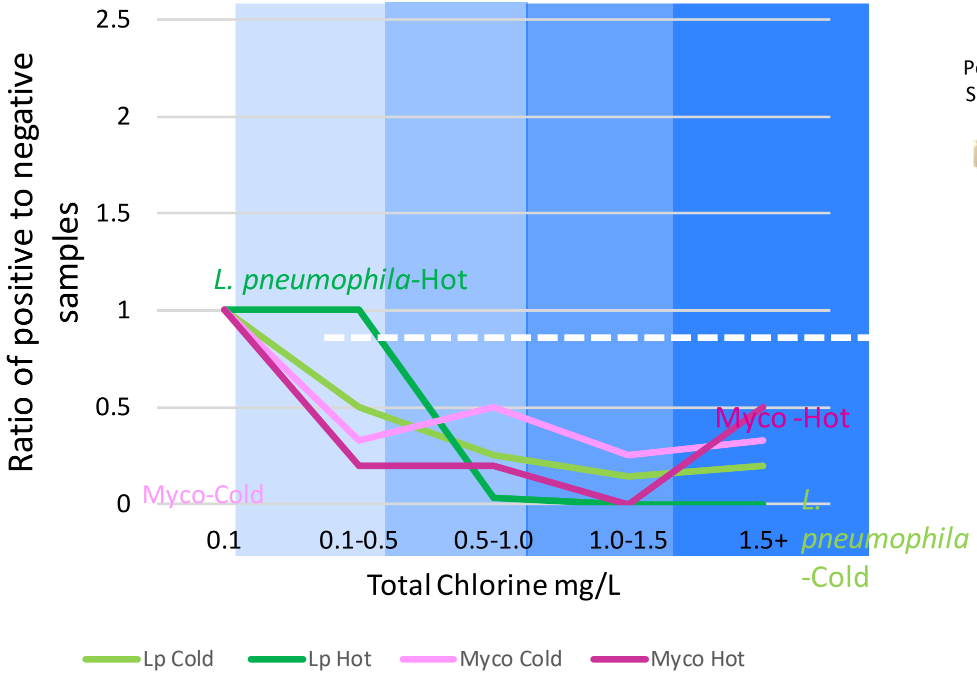
Detection Frequency

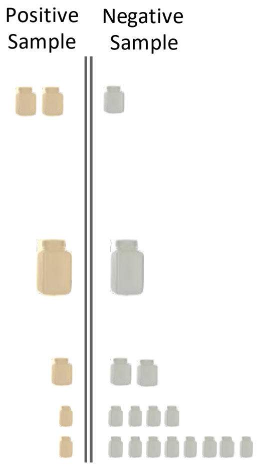
Yes, detection frequency for *M. avium* and *M. abscessus* were significantly detection more often in chloramine treated water.

Species-Serogroup	Chlorine Number of Positive Samples (Percent)	Chloramine Number of Positive Samples (Percent)	Chi-Square p-value
All Samples	**N = 210**	**N = 148**	
L. pneumophila	55 (26)	32 (22)	NS
L. pneumophila Sg1	18 (9)	7 (5)	NS
M. avium	26 (12)	32 (22)	P = 0.02
M. intracellulare	44 (21)	29 (20)	NS
M. abscessus	19 (9)	25 (17)	P = 0.03
Cold Water Line	**N = 105**	**N = 74**	
L. pneumophila	29 (28)	17 (24)	NS
L. pneumophila Sg1	8 (8)	4 (6)	NS
M. avium	15 (14)	16 (22)	NS
M. intracellulare	21 (20)	16 (22)	NS
M. abscessus	11 (10)	13 (18)	NS
Hot Water Line	**N = 105**	**N = 74**	
L. pneumophila	27 (26)	16 (22)	NS
L. pneumophila Sg1	10 (9)	3 (4)	NS
M. avium	11 (10)	16 (22)	NS
M. intracellulare	23 (22)	13 (19)	NS
M. abscessus	8 (8)	12 (17)	NS

Chlorine: Does the Total Chlorine Residual (TCLR) Concentration Influence *L. pneumophila* /*Mycobacterium spp*. Detection Frequency?

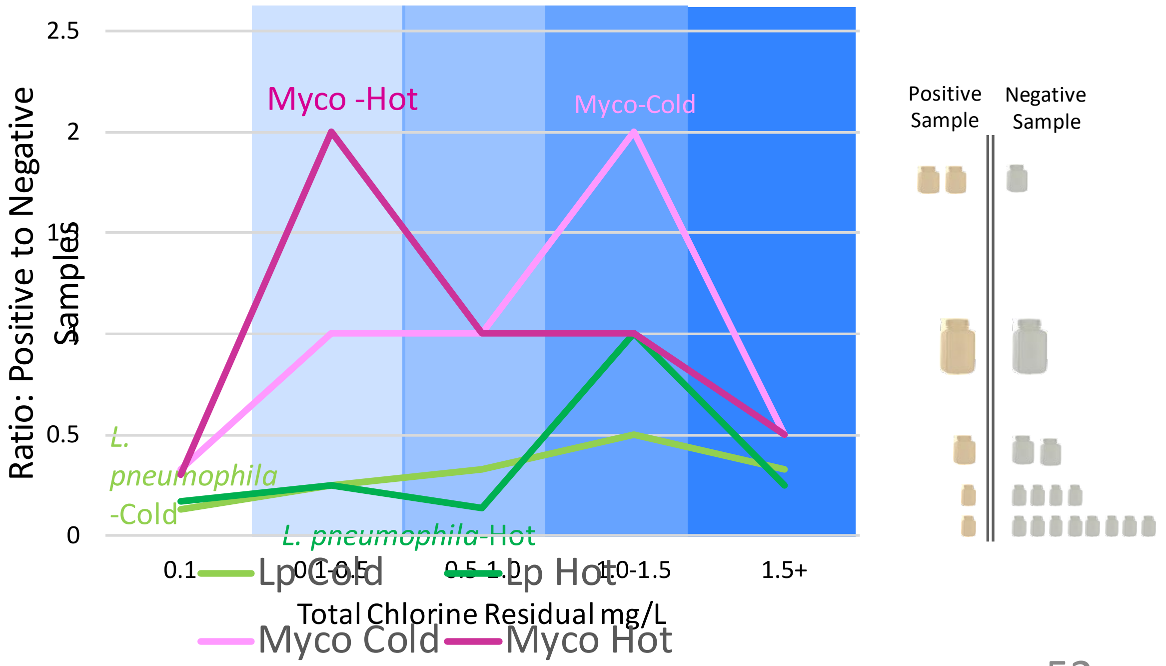
- As the at the tap concentration of the residual increases, the less likely it is to find a positive sample.
- This is true for all five bacteria.





Chloramine: Does the Residual (TCLR) Concentration Influence *L. pneumophila*/ *Mycobacterium* spp. Detection Frequency?

- Each Bacteria responded differently to the increasing residual.
- Legionella was rarely detected at the lower residual concentrations but despite this positive detections increase at the higher residual levels.
- Myco-Cold and Myco-Hot each responded differently to the residual concentration.

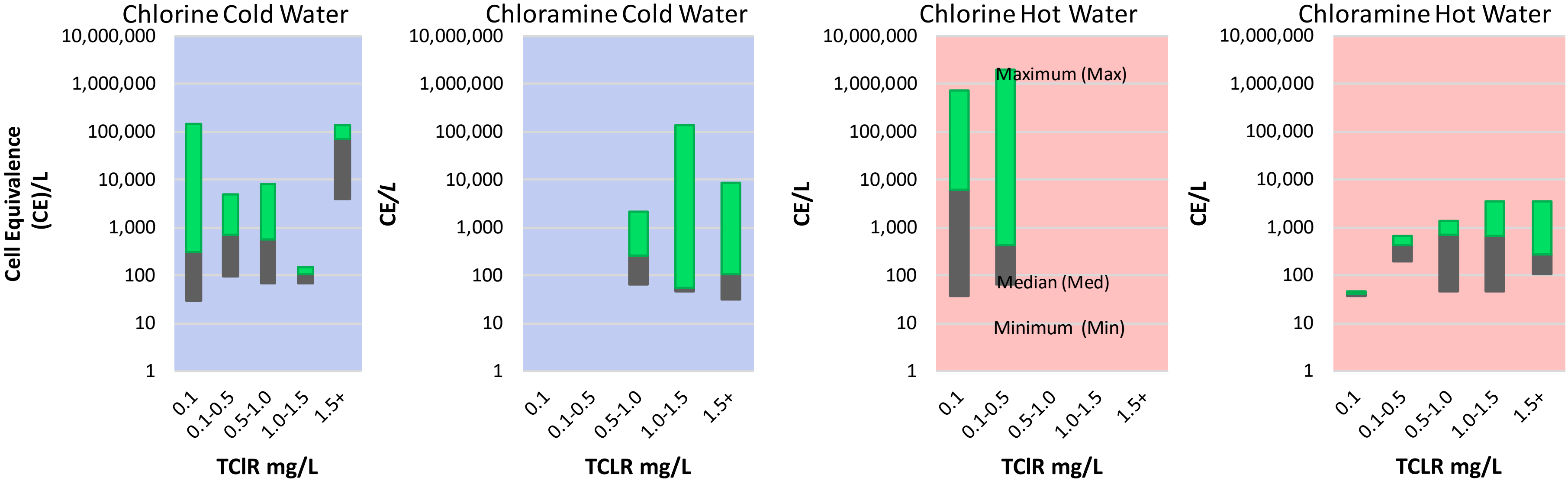


Does *L. pneumophila*/*Mycobacterium* spp. Concentration Differ by Disinfectant Residual Choice?

- Yes, significant differences were observed for *L. pneumophila* in both cold and hot water line samples and for *M. intracellulare* (cold water line samples).
- Significantly higher amounts of *L. pneumophila* are observed in Chlorine treated water, especially hot water illustrating the effectiveness of chloramine in controlling for legionella.
- Significantly higher amounts of *M. intracellulare* are observed in Chloramine treated water suggesting better control with chlorine.

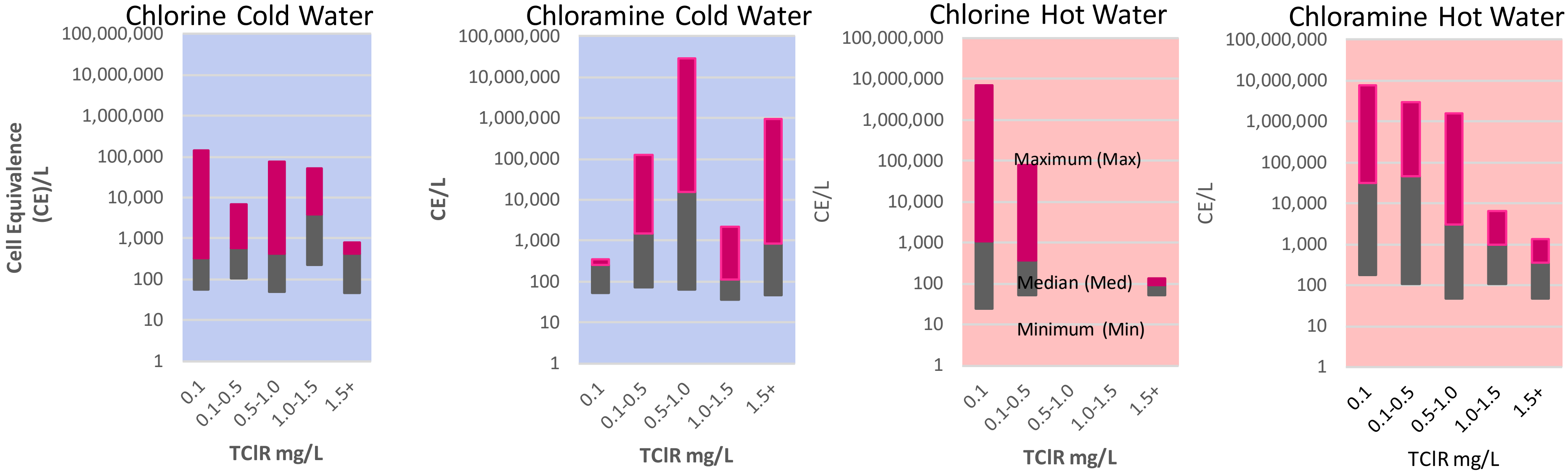
Species-Serogroup	Chlorine	Chloramine	Mann-Whitney U
	Median (CE/L)	Median (CE/L)	p-value
All samples	**N = 210**	**N=148**	NS
L. pneumophila	581	132	P = <0.001
L. pneumophila Sg1	15,721	863	NS
M. avium	603	1,243	NS
M. intracellulare	487	661	NS
M. abscessus	1,339	2,157	NS
Cold Water Line	**N = 105**	**N = 74**	
L. pneumophila	341	82	P = 0.04
L. pneumophila Sg1	938	570	P = 0.05
M. avium	616	1,880	NS
M. intracellulare	359	928	P = 0.02
M. abscessus	1,113	834	NS
Hot Water Line	**N = 105**	**N = 74**	
L. pneumophila	4,201	187	P = 0.01
L. pneumophila Sg1	85,316	942	NS
M. avium	425	761	NS
M. intracellulare	542	602	NS
M. abscessus	9,048	17,304	NS

Does Residual Concentration Influence *L. pneumophila* Concentration?



- The residual type and residual concentration have independent impacts on *L. pneumophila*.
- It depend on the context
- Chlorine's (CL) impact on *L. pneumophila* concentrations is dose dependent based on the residual concentration.
- CLM impact on *L. pneumophila* isn't as dose dependent.

Does Residual Concentration Influence *Mycobacterium* spp. Concentration?



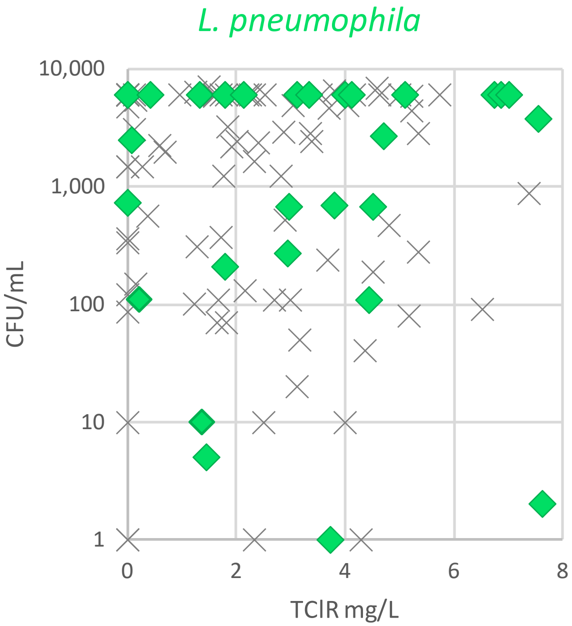
- Chlorine (CL) in cold water "keeps the lid on" the *Mycobacterium spp*.
- However, CL plus hot water does have a dose dependent impact on *Mycobacterium spp.* concentrations.

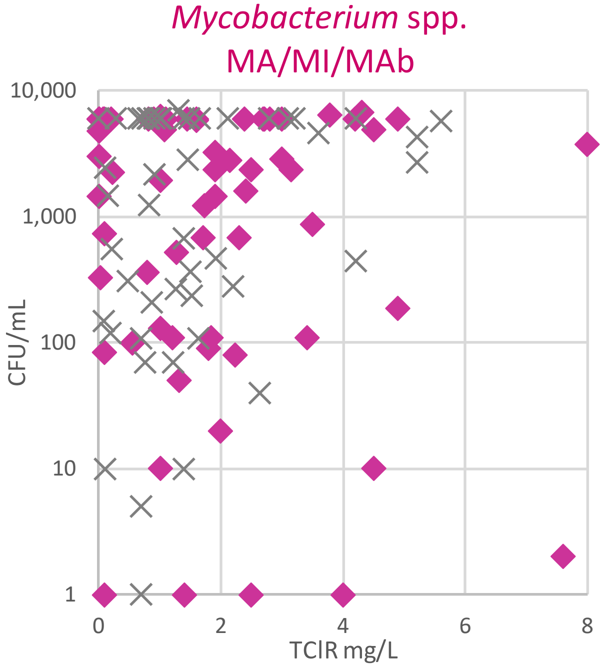
- CLM in cold water doesn't appear to impact on the *Mycobacterium spp.* species concentration.
- CLM plus heat does impact *Mycobacterium spp.* in a dose dependent manor.

Chloramine: Heterotrophic Plate Counts

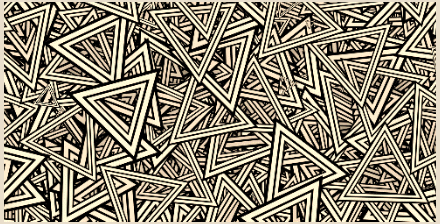
Many of the *L. pneumophila* and *Mycobacterium spp.* detections are in water that has a high viable bacteria load.

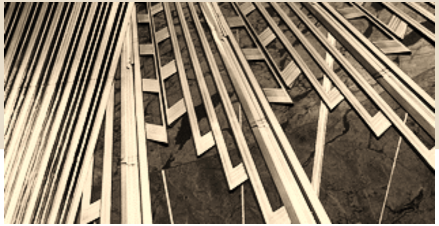
HPC Scale





Lp/Myco positive Samples ◆ Negative samples X





Conclusions

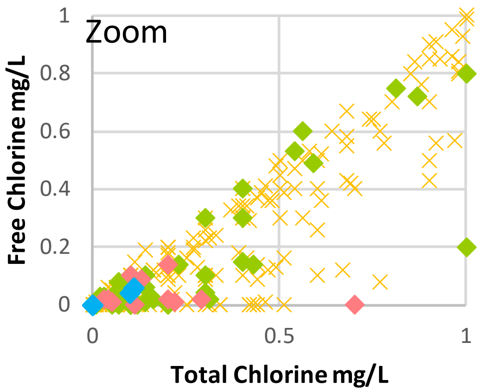
- Residual type (Cl/CLM) does significantly influence occurrence patterns *M. avium* and *M. Abscessus*.
- Residual type (Cl/CLM) does significantly influence concentration *L. pneumophila* and *M. intracellulare*.
- CLM is effective for controlling *L. pneumophila*, but not MA/MI/Mab.
- CL is relatively more effective at controlling MA/MI/Mab, than CLM.
- Temperature is a stimulant for microbial growth, but acts as a deterrent especially if a residual is maintained in the hot water.

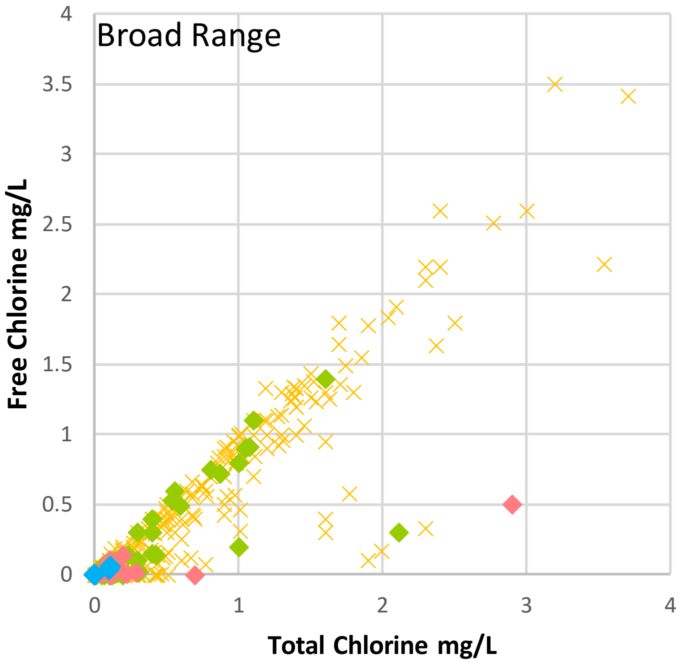
Influence of Total and Free Chlorine on *L. pneumophila* Occurrence

qPCR Framework: Lee et al. 2011

- Action: (Concern) >4,000 GU/100mL/Typically Culture Positive
- Alert: (Concern) >400-4,000 GU/100mL
- Satisfactory: (Not of concern) 1-400 GU/100mL
- Samples **NOT** *L. pneumophila* positive

GU= Genomic Unit/Genomic Target



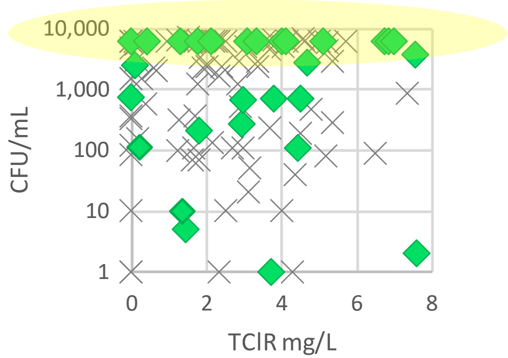


Influence of Monochloramine and Free Ammonia on *L. pneumophila* Occurrence

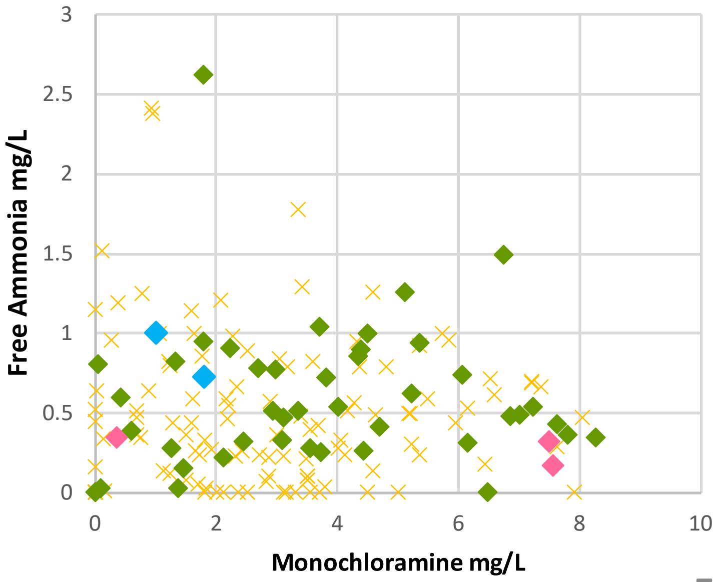
qPCR Framework: Lee et al. 2011

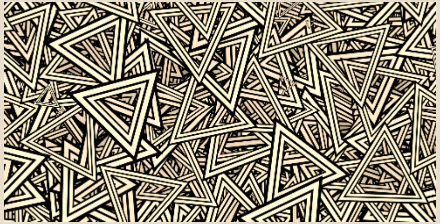
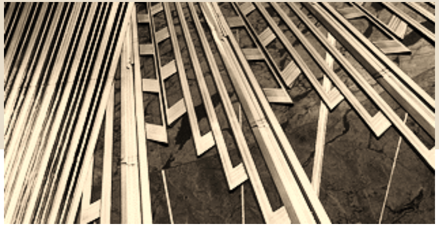
- Action: (Concern) >4,000 GU/100mL/Typically Culture Positive
- Alert: (Concern) >400-4,000 GU/100mL
- Satisfactory: (Not of concern) 1-400 GU/100mL
- Samples **NOT** *L. pneumophila* positive

HPC Results



***L. pneumophila* Occurrence by Monochloramine and Free Ammonia**



In the Larger Context

- JUST because your system uses CLM. Does NOT mean your water has MA/MI/Mab issues.
- JUST because your system uses CL doesn’t mean you have *L. pneumophila* issues.
- If you have *L. pneumophila* issues and you’re on a CL system is most likely due to a lack of an active residual.
- A residual correction is not available for CLM systems.
- REMEMBER these observations are broad brush strokes which may or may not be applicable to your specific water system.
- Also REMEMBER, today I talked about just two water-borne bacteria and these observations do NOT take into account how other water pathogens will responds to our treatment and practices with water.

EPA RESEARCHERS

Collaborators:

- **Jatin Mistry**
- **Dr. Stacy Pfaller**
- **Dawn King**
- **Dr. Steve Vesper**

Chlorine and Monochloramine Disinfection of *Legionella pneumophila* Colonizing Copper and Polyvinyl Chloride Drinking Water Biofilms

Electrophoretic mobility of *Legionella pneumophila* serogroups 1 to 14

Electrically heatable carbon nanotube point-of-use filters for effective separation and in-situ inactivation of *Legionella pneumophila*

Removing arsenic and co-occurring contaminants from drinking water by full-scale ion exchange and point-of-use/point-of-entry reverse osmosis systems

Draft Genome Sequences of Seven *Legionella pneumophila* Isolates from a Hot Water System of a Large Building

Application of diagnostic criteria for non-tuberculous mycobacterial disease to a case series of mycobacterial-positive isolates

Efficacy of inactivation of human enteroviruses by dual-wavelength germicidal ultraviolet (UV-C) light emitting diodes (LEDs)

The sporadic nature of *Legionella pneumophila*, *Legionella pneumophila* Sg1 and *Mycobacterium avium* occurrence within residences and office buildings across 36 states in the United States

Thank You!

Q&A Session

We highly value your feedback.

Please take a few minutes to complete our survey at your convenience:

surveymonkey.com/r/EPASmallSystems