SAFEGUARDING PATIENT HEALTH : CONTROL & MITIGATE WATERBORNE PATHOGENS IN HEALTHCARE FACILITIES

Pascal Bru
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INTRODUCTION

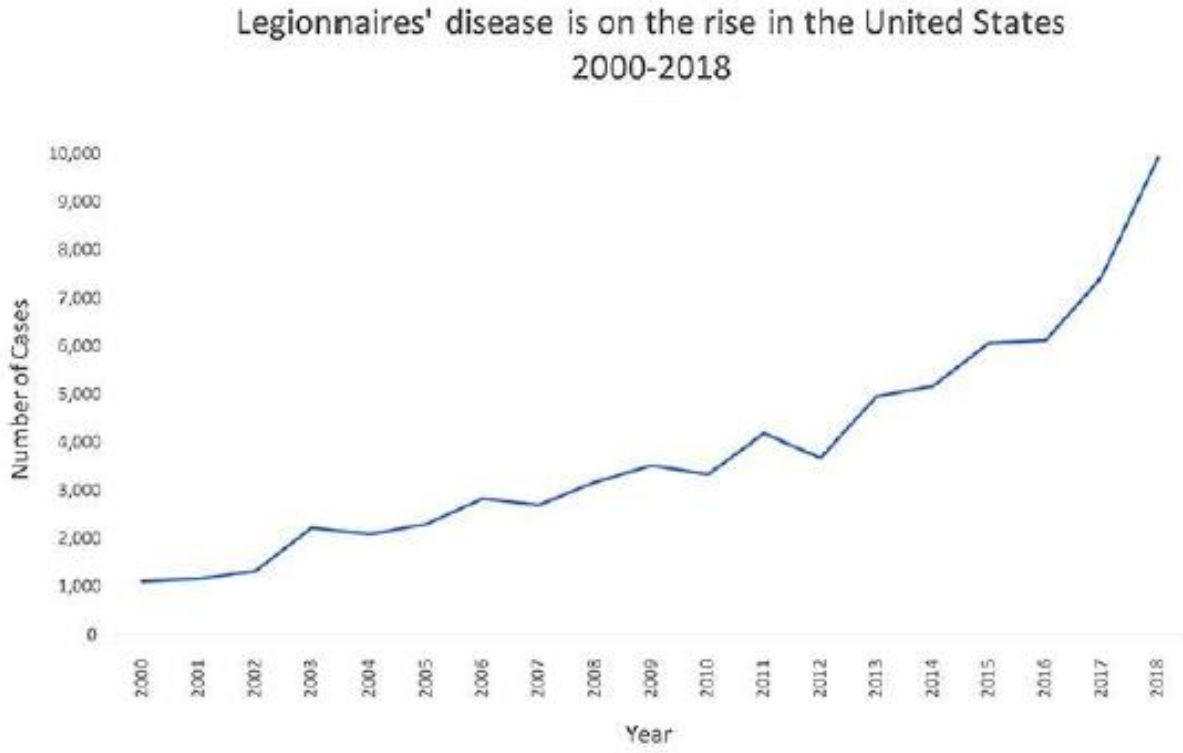
PASCAL BRU

VP OPERATIONS AQUATOOLS INC.

- +20 years as Business Developer & Executive in Analytical Chemistry
- Member of various ASTM & ISO commitees

INTRODUCTION

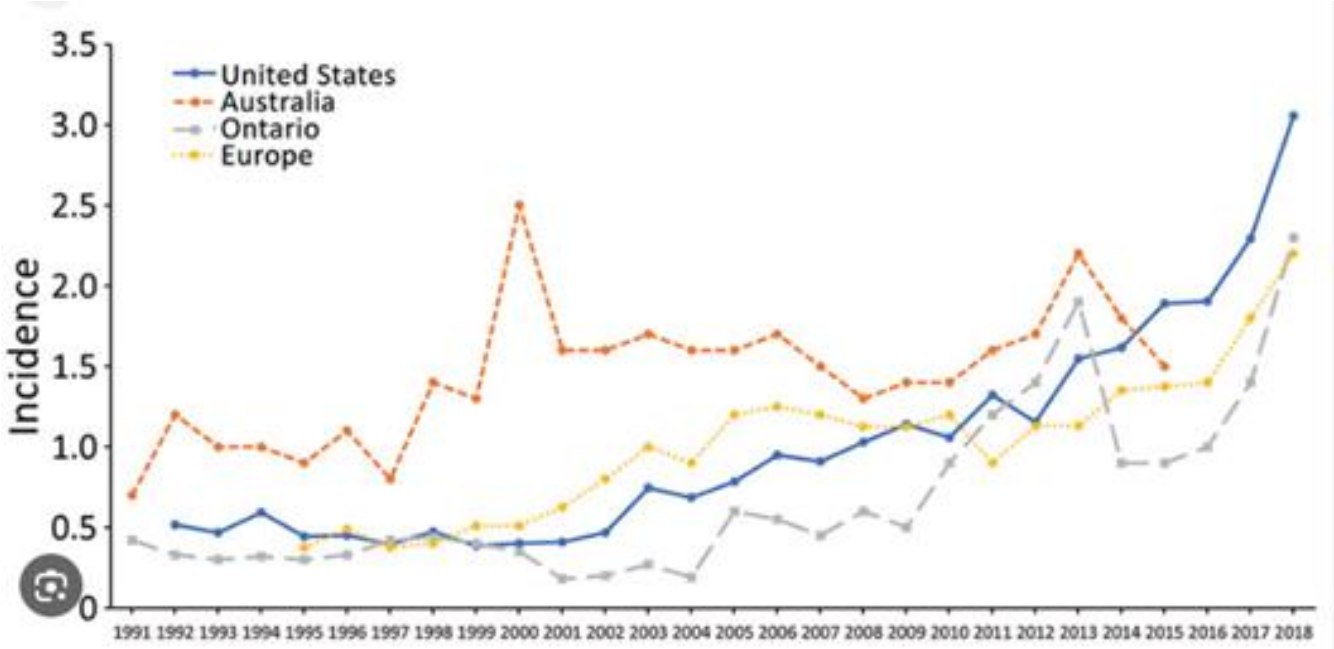
- **+7,200,000** Americans get sick every year from diseases spread through water.



Sources: Number of sick American through water: https://www.cdc.gov/healthywater/surveillance/burden/index.html
Number of reported cases of Legionnaires' : CDC

INTRODUCTION

- Various approaches to control and mitigate *Legionella* yield the same results.



Sources: Rising Incidence of Legionnaires' Disease and Associated Epidemiologic Patterns : Barskley, Albert E. (CDC/DDID/NCIRD/DBD)

INTRODUCTION

- Opportunistic Premise Plumbing Pathogens OPPPs « It is not just *Legionella* » !

Healthcare-Acquired Infections:
High Mortality from Waterborne Pathogens

Organism	Mortality rate
Legionella	25-30%
Pseudomonas	22-34%
Acinetobacter	26%
Stenotrophomonas	49%
Burkholderia cepacia	42%
NTM (after 5 years)	31%

Source: Janet Stout – SHEA Spring Conf. Houston April 16 - April 19, 2024

INTRODUCTION

- **Complex organizations** help to promote growth of waterborne pathogens.

- **Healthcare facilities have a complex water organization**.
  - Incoming water
  - Water supply within facilities
  - Different patient populations

- **Water Management Program**
  - Identify hazardous conditions
  - Implement corrective actions, including technical solutions to minimize the growth and spread of waterborne pathgens

OBJECTIVES

Identify the key factors and conditions that promote the growth of waterborne pathogens in healthcare environments.

Provide an overview of the different technical solutions and best practices to control and mitigate the development of bacteria in healthcare facility water systems.

Discuss the pros and cons of various waterborne pathogen control measures, including their effectiveness, feasibility, and any potential limitations.

AGENDA

1. Opportunistic Waterborne Pathogens and Healthcare Associated Infections
2. Water Management Program
3. Solutions to Control & Mitigate Bacteria
4. Conclusions

OPPORTUNISTIC WATERBORNE PATHOGENS

OPPORTUNISTIC WATERBORNE PATHOGENS

- Numerous waterborne bacteria, such as *Legionella pneumophila, Pseudomonas aeruginosa, Non-Tuberculous Mycobacteria (NTM)*, and *Acinetobacter spp.*, are opportunistic pathogens.
- Almost all waterborne opportunistic pathogens are associated with biofilm and free-living amoebae.
- Premise plumbing pipe materials may either enhance or limit their growth (*Cullom A.C. et al., 2020*).
- *Pseudomonas* and NTM are particularly resilient and have unique characteristics.

OPPORTUNISTIC WATERBORNE PATHOGENS

LEGIONELLA : KEY FACTS

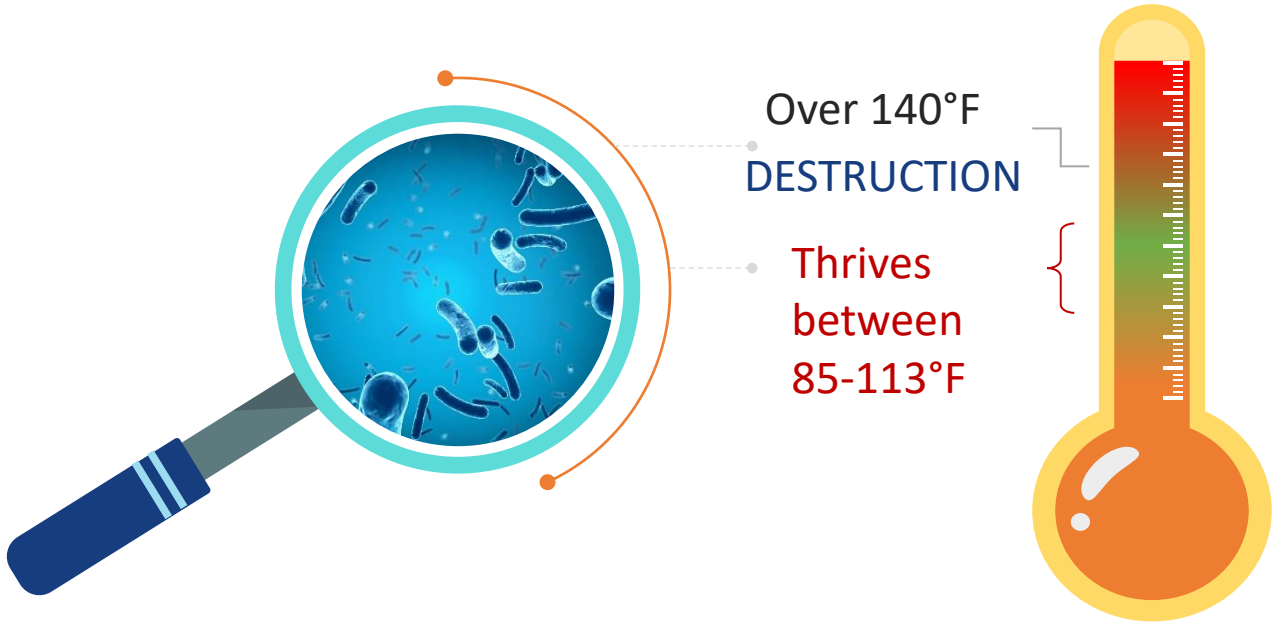
- Gram-negative bacteria: Includes at least 43 species and 64 serological groups.

- ***Legionella Pneumophila***
  - Causes **90% of Legionellosis infections**, with serogroup 1 (LP1) responsible for 80% of cases (Legionnaires' disease & Pontiac fever).
  - Legionnaires' disease fatality rate: 9% overall, rising to **25%-30%** in healthcare settings.

OPPORTUNISTIC WATERBORNE PATHOGENS

LEGIONELLA : KEY FACTS

- Growth conditions :
  - Thermophilic bacteria
  - Requires iron & cysteine, commonly found in biofilms and protected by free-living amoebae.



OPPORTUNISTIC WATERBORNE PATHOGENS

OPPPS Infections

Disease or syndrome	Estimated total cases	% Waterborne Infections	Domestic Waterborne hospitalizations	Direct Healthcare cost, millions
Legionnaires' disease	11,400	97%	10,800	$402
Pseudomonas Pneumonia	31,700	51%	15,500	$453
Nontuberculous Mycobacteria Infection	97,000	72%	51,400	$1,530

Source: Special Pathogens Laboratory

OPPORTUNISTIC WATERBORNE PATHOGENS

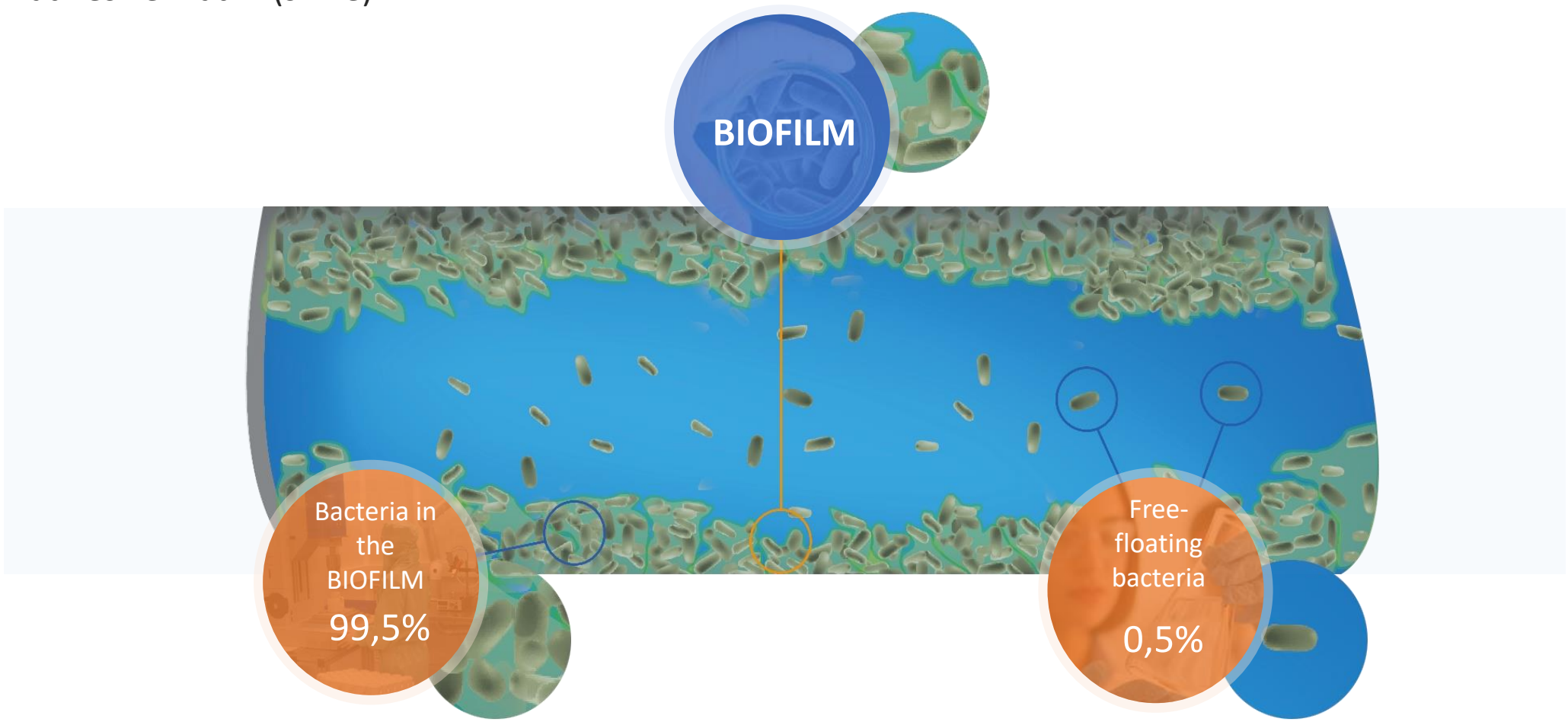
Infection Routes

Pathogen	Inhalation (Aerosols)	Direct Contact (Water, Surfaces)	Ingestion	Medical Device Contamination
Legionella	**YES** (cooling towers, showers, hot tubs, fountains)	RARE	VERY RARE	**YES** (respiratory therapy devices, cooling mist machines)
Pseudomonas Aeruginosa	**YES** (humidifiers, showers)	**YES** (wounds, catheters)	OCCASIONAL	**YES** (ventilators, catheters)
Nontuberculous Mycobacteria (NTM)	**YES** (hot tubs, water heaters)	**YES** (skin exposure)	POSSIBLE	**YES** (endoscopes, surgical tools)
Acinetobacter Baumannii	**RARE**	**YES** (hospital sinks, wounds)	UNCOMMON	**YES** (ventilators, surgical tools)
Stenotrophomonas Maltophilia	**RARE**	**YES** (hospital water, surfaces)	UNCOMMON	**YES** (catheters, endoscopes, dialysis)
Bulkholderia Cepacia	**YES** (humidifiers, respiratory devices)	**YES** (hospital water, contaminated products)	**POSSIBLE**	**YES** (mouthwash, IV fluids)

Source: Special Pathogens Laboratory

OPPORTUNISTIC WATERBORNE PATHOGENS

- Biofilm is a collection of micro-organisms (bacteria, algae, fungi, etc.) adhering to each other and to surfaces that are generally in contact with water and which is characterized by the secretion of a protective and adhesive matrix (slime).



OPPORTUNISTIC WATERBORNE PATHOGENS

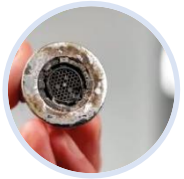
BUILDING FACTORS PROMOTING BIOFILM FORMATION

WATER NETWORK, STAGNATION AND TEMPERATURE
Cold water must stay below 59°F and hot water must remain over 130°F throughout the building

LOW /NO DESINFECTANT RESIDUAL
Water softening and carbon filtration can reduce disinfectant levels

WATER AGE/ FLOW RATE
Even in well-designed networks, flushing is mandatory according to bed occupancy

PLUMBING
Material choice, cross-connections, dead legs and faucet types impact risk

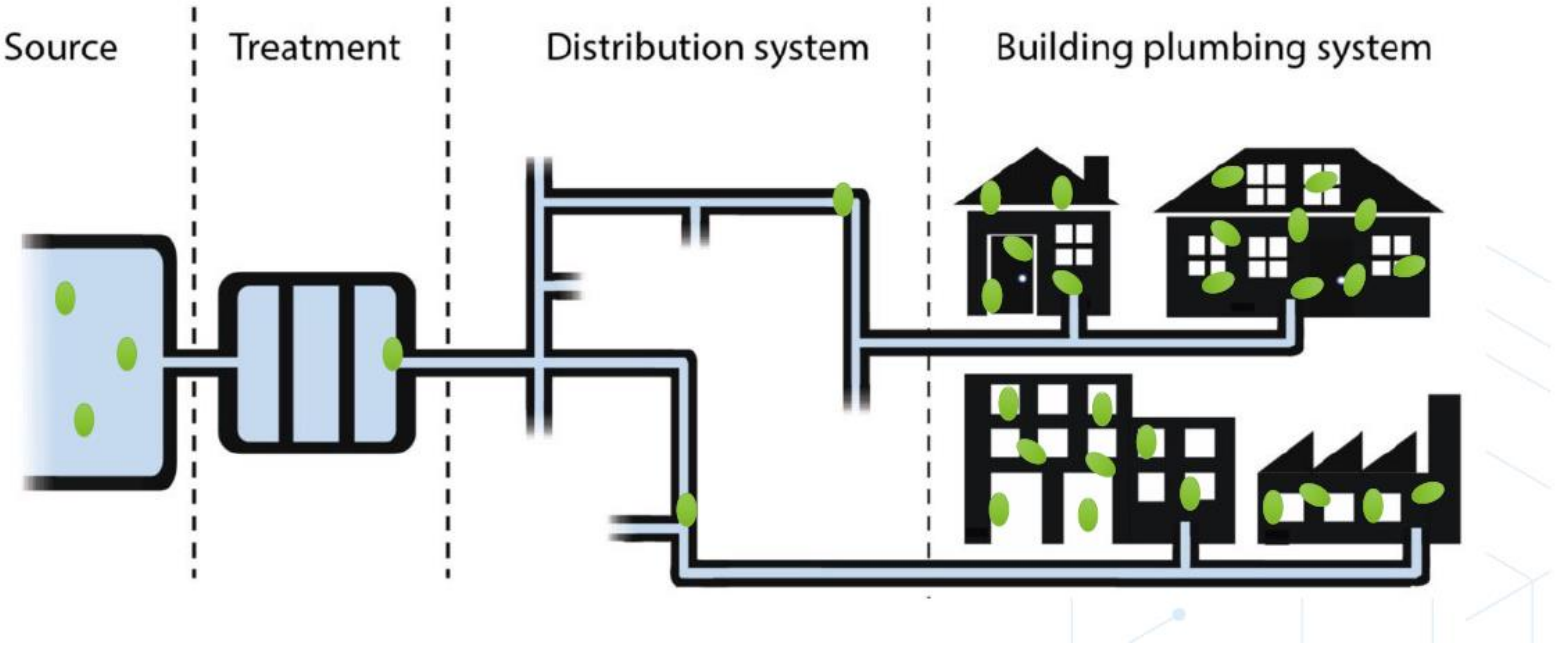


SEDIMENT ACCUMULATION
Provide a “home” for biofilm development

OPPORTUNISTIC WATERBORNE PATHOGENS

BUILDING FACTORS PROMOTING BACTERIAL GROWTH

WATER SUPPLY



Source: Neu Lisa and Frederik Hammes, 2020. " Feeding the Building Plumbing Microbiome : The Importance of Synthetic Polymeric Materials for Biofilm and Management" Water 12. no.6:1774.

OPPORTUNISTIC WATERBORNE PATHOGENS

BUILDING FACTORS PROMOTING BACTERIAL GROWTH

PLUMBING
Material choice, cross-connections, dead legs and faucet types impact risk

- **Copper pipes & *Legionella* Growth**
  - **Aging copper** pipes develop rougher surfaces, promoting biofilm growth.
  - **Corrosion & Copper Release:** Corroding copper pipes can release copper ions in the water, which gave antimicrobial properties. However, they wan also interact with water chemistry (pH, organic matter) that reduce their effectiveness against Legionella.
  - **Water Chemistry & Stagnation:** High pH, water stagnation and organic matter can limit copper ions' biocidal efficacy.
  - **Chlorine Decay:** Copper may catalyze chlorine degradation, weakening disinfection effectiveness and enabling *Legionella* growth.

OPPORTUNISTIC WATERBORNE PATHOGENS

BUILDING FACTORS PROMOTING BACTERIAL GROWTH

PLUMBING
Material choice, cross-connections, dead legs and faucet types impact risk

- **PVC (Polyvinyl Chloride) & *Legionella* Growth**
  - PVC pipes have **rougher surfaces** compared to copper pipes, which allows biofilm to attach and develop more easily.
  - **No Antimicrobial Properties:** Unlike copper, PVC does not inhibit bacterial growth.
  - **Temperature tolerance:** *Legionella* can survive and grow in biofilm on plastic materials including PVC, even at higher temperatures (up to 50°C)

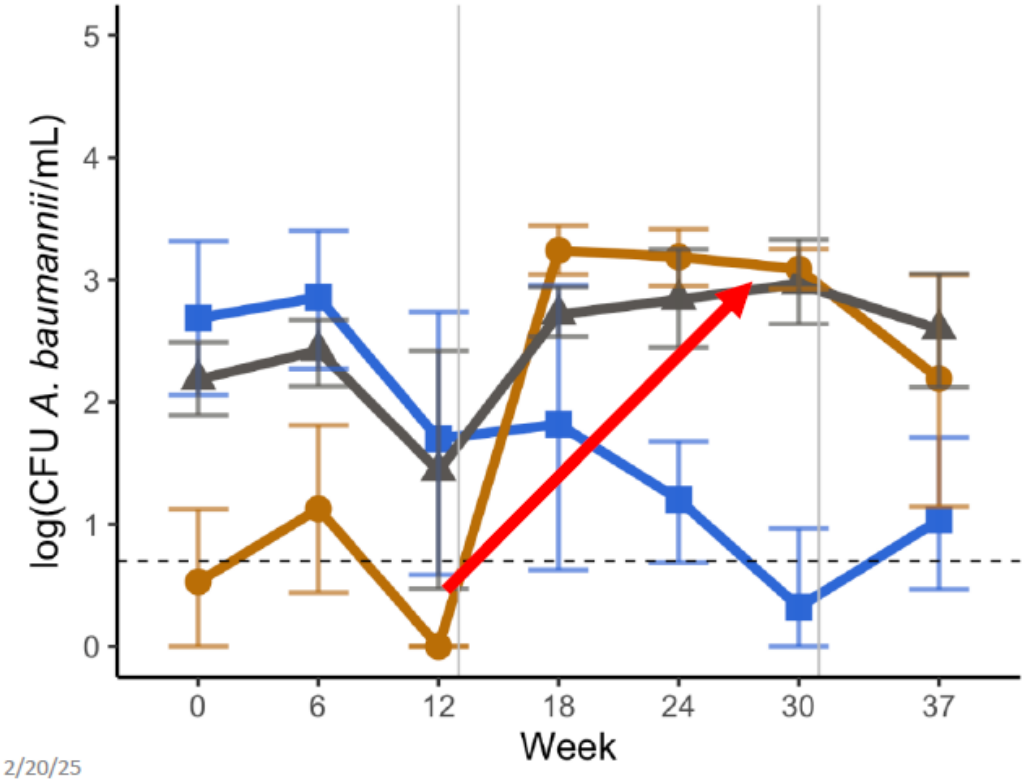
OPPORTUNISTIC WATERBORNE PATHOGENS

Antimicrobial activity is temporary !

Copper

PVC

Mild Steel



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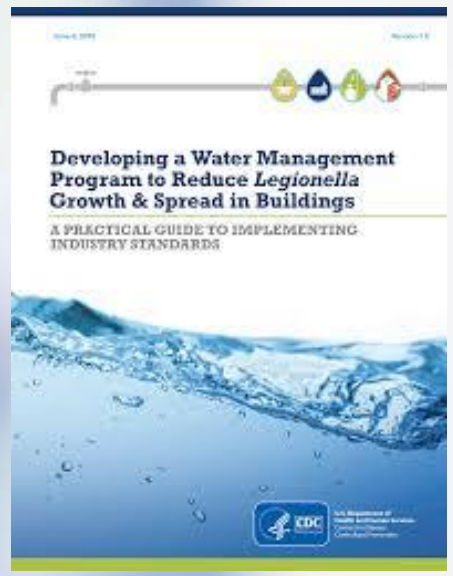
Source: Abraham Cullom, Mattheu Storme Spencer, Myra D. Williams, Joseph O. Falkinham, Amy Pruden, Marc A. Edwards. Influence of pipe materials on In-building disinfection of *P. Aeruginosa and A. Baumanii* in simulated hot water plumbing. Water Research X. Volume 21.2023.

OPPORTUNISTIC WATERBORNE PATHOGENS

BUILDING FACTORS PROMOTING BACTERIAL GROWTH

NEW CONSTRUCTION, RENOVATION, REFURBISHMENT, REPLACEMENT OR REPURPOSING A FACILITY

- **Disruption of Water Systems**
  - Vibration and pipework dislodge *Legionella* biofilms
  - Water stagnation from temporary shutdowns
- **Changes in Water Temperature & Flow**
  - Hot water temperatures drop
  - Intermittent water use
- **Introduction of Contaminated Materials**
  - New pipes, fittings, and storage tanks
  - Construction dust and debris
- **Chlorine & Biocide Reduction**
  - Pipe flushing dilutes disinfectants
  - Biofilm, scale, or sediment disruption



WATER MANAGEMENT PROGRAM

WATER MANAGEMENT PROGRAM

KEY GOALS OF A HEALTHCARE WATER MANAGEMENT PROGRAM

- Identifying areas, equipment, and systems at risk where *Legionella* and other pathogens could grow and spread
- Implementing risk-mitigating strategies and control measures to prevent pathogen growth
- Monitoring the effectiveness of the water management program and making adjustments as needed
- Establishing an outbreak response plan to detect, investigate, and respond to any infection events
- Ensuring compliance with relevant regulations, standards and guidelines, such as those set by CMS, the Joint Commission, ASHRAE, CDC, VA…

WATER MANAGEMENT PROGRAM

- CMS, CDC, the Joint Commission and ASHRAE have established a coordinated set of requirements, standards, and tools to ensure that healthcare facilities implement effective water management programs.

ASHRAE Standard 188
Legionellosis : Risk Management for Building Water Systems

ASHRAE Guideline 12
Guidance for complying with Standard 188

CDC Toolkit
Developing a Water Management Program to Reduce Legionella Growth and Spread in Buildings

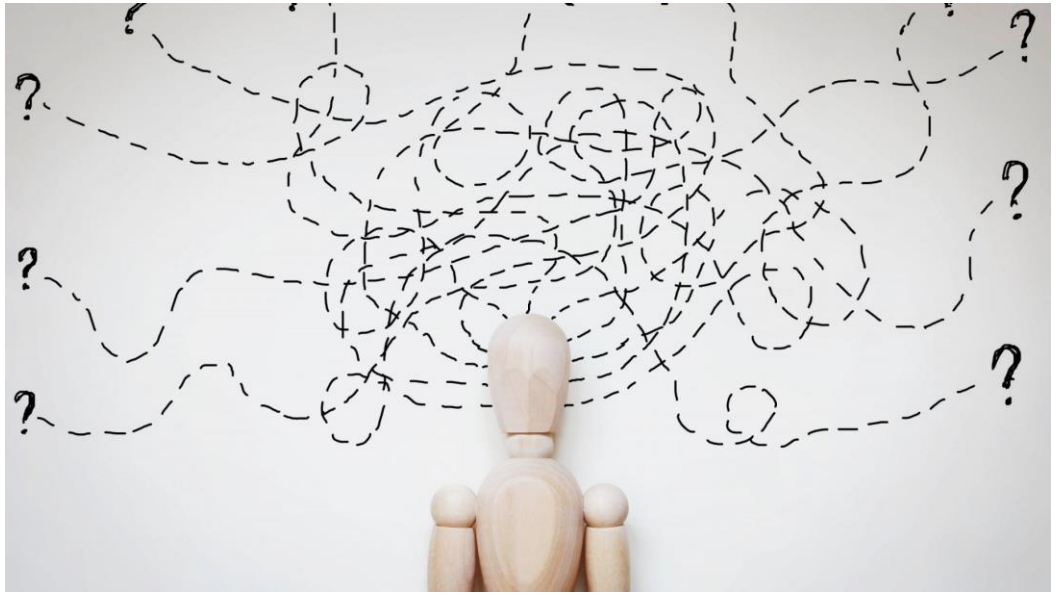
CDC Checklist
Helathcare Facility Water Management Program Checklist

Joint Commission Standard EC.02.05.02

CMS QSO-22-20-Hospitals Memo
Requires Medicare-certified hospitals to have a water management program

WATER MANAGEMENT PROGRAM

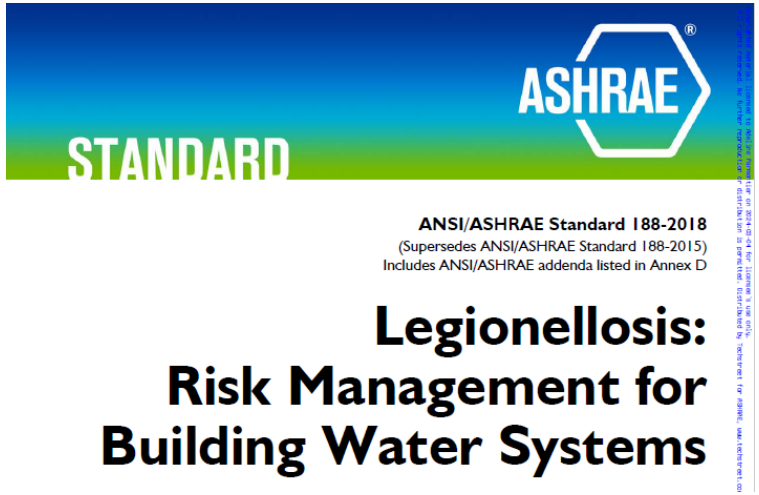
- Guidelines list methods & technical solutions to control ad mitigate waterborne bacteria **BUT**
  - Many solutions are available.
  - Implemention depends on many parameters : facility/buildings, type of patient, budget, etc.

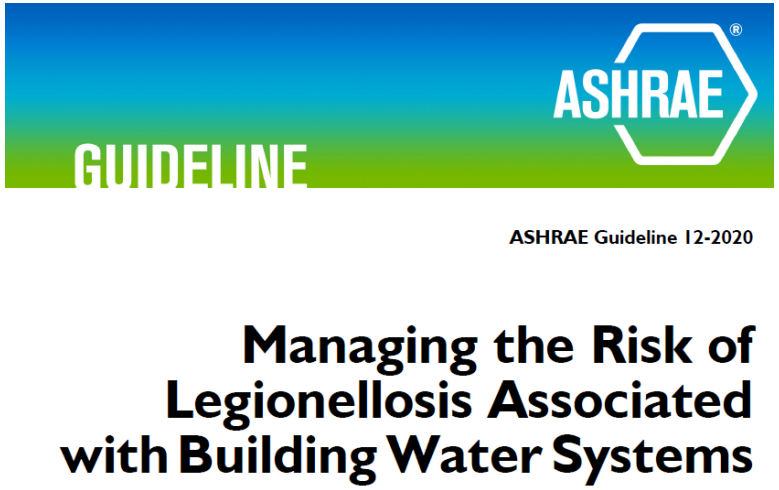


SOLUTIONS TO CONTROL & MITIGATE BACTERIA

SOLUTIONS TO CONTROL & MITIGATE BACTERIA

4.2.2 *Legionella* in Building Water Systems





4.2.2 *Legionella* in Building Water Systems. *Legionella* bacteria are present, often in very low or undetectable concentrations, in most natural water sources. Physical and chemical conditions in water utility distribution systems and building water systems may support *Legionella* growth.

Eliminating uncontrolled growth of *Legionella* in building water systems is the central mechanism for managing the risk of disease. **Complete elimination of *Legionella* bacteria from building water systems is difficult to achieve and typically not sustainable**.

Determining success in control of *Legionella* growth in building water systems should take into account that ***Legionella* bacteria are part of the natural water environment and can be controlled but not completely eliminated.**

SOLUTIONS TO CONTROL & MITIGATE BACTERIA

- ***Routine Flushing***
- ***Temperature Control***
  High> 140°F & Low < 68°F. Must guarantee constant temperature everywhere i.e from the point of entry to the point of use.
- ***Secondary disinfection***
  Chlorine, monochloramine. Must keep concentration constant from the point of entry to the point of use.
- ***Point-of-use filtration***
  Physical barrier to eliminate risk of exposure

SOLUTIONS TO CONTROL & MITIGATE BACTERIA

FLUSHING AND TEMPERATURE CONTROL

- ***Temperature control:***
  - Essential for hot & cold water to prevent cross-contamination in taps.
  - **BUT** some bacteria can survive at 130°F.
  - Maintaining required temperatures in final tubing sections is difficult.

- ***Thermal disinfection & biofilm resilience***:
  - Effectiveness depends on hydrodynamic conditions – **bacteria can regain culturability & viability** (*Silva A.R et al.,2023).*
  - Periodic thermal shocks offer **limited long-term control** to *Legionella spp*. in hot water systems (*Molina J. et al. 2022).*
  - At 136°F, thermal disinfection is :
    - Effective on copper surfaces
    - Ineffective on **shower hoses after 60 min of exposure** *(Yui S. et al., 2021).*

SOLUTIONS TO CONTROL & MITIGATE BACTERIA

SECONDARY DISINFECTION

- ***Efficacy gap:***

- Many disinfectants are highly effective in vitro but their efficiency in situ is influenced by water quality & pipe materials (*Wang H. et al., 2015*).

- Disinfectant efficacy ranking: Chloramine > Chlorine dioxide > Chlorine.

- Efficacy depends on multiple factors beyond disinfectant concentration, including degradation rates & environmental conditions (*Xi H. et al.,2024*).

SOLUTIONS TO CONTROL & MITIGATE BACTERIA

SECONDARY DISINFECTION

- ***Chlorine :***
  - ⊕ Simplest, cheapest chemical available.
  - ⊖ Limited biofilm penetration, Specific pH range effictiveness, degration in hot water, possible issue with pipe integrety.
- ***Chlorine dioxide:***
  - ⊕ More biofilm penetration.
  - ⊖ Highly aggressive on plumbing, rapid degradation in hot water. Alone, it has limitations, as tolerant bacterial strains can emerge.

SOLUTIONS TO CONTROL & MITIGATE BACTERIA

SECONDARY DISINFECTION

- ***Monochloramine:***
  - ➕ Stable, More biofilm penetration ,handles hot temperature
  - ➖ Nitrification: Excess ammonia from chloramine disinfection increases the potential for nitrification in the distribution system : Disinfectant depletion, Formation of nitrite and nitrate, corrosion issues.
  - ➖ Effectiveness against certain pathogens limited: While monochloramine is effective against Legionella, its impact on other opportunistic pathogens like *Nontuberculous Mycobacteria* (NTM) is limited.
  - ➖ Persistence in the environment: Monochloramine hydrolyses slowly in aqueous solutions, making it persistent in the environment.
  - ➖ Odor & taste

SOLUTIONS TO CONTROL & MITIGATE BACTERIA

FREE-LIVING AMOEBAE : TROJAN HORSES FOR OPPORTUNISTIC BACTERIA

- ***Amoebae internalize*** many species of waterborne bacteria, shielding them from external stresses.
- ***Bacterial protection***:
  - Inside amoebae, bacteria are highly resistant to disinfectants***.***
  - Cystic forms can withstand up to 70 mg/L of chlorine.
- ***Increased virulence:*** Bacteria may become more aggressive after these interactions***.***
- ***Case study*** *:* Repeated chlorine shocks led to the selection of *Legionella Pneumophila* serogroup 1.

Sources: Shi Y. Appl. Environ. Microbiol. 2021.

SOLUTIONS TO CONTROL & MITIGATE BACTERIA

SECONDARY DISINFECTION

Field studies show *Legionella* can survive disinfectants with *L.Pneumophila* serogroup 1 being especially resistant (*Cervero-Aragó S. et al., 2015*)

DISINFECTION ALONE CANNOT CONTROL ALL OPPORTUNISTIC PATHOGENS – WATER NETWORKS MUST BE DRASTICALLY IMPROVED.

SOLUTIONS TO CONTROL & MITIGATE BACTERIA

POINT-OF-USE FILTRATION

- ***Physical barrier to block and trap any bacteria, ensuring safe water.***
  - *Retain all bacteria*
  - *Ensures no bacterial exposure during water usage, including taps, showers, and ice machines.*
- ***Requirement:***
  - Must be replaced at a specific time and depending on water quality and membrane surface condition.

The unique solution to protect vulnerable patients, regardless of existing water management methods.

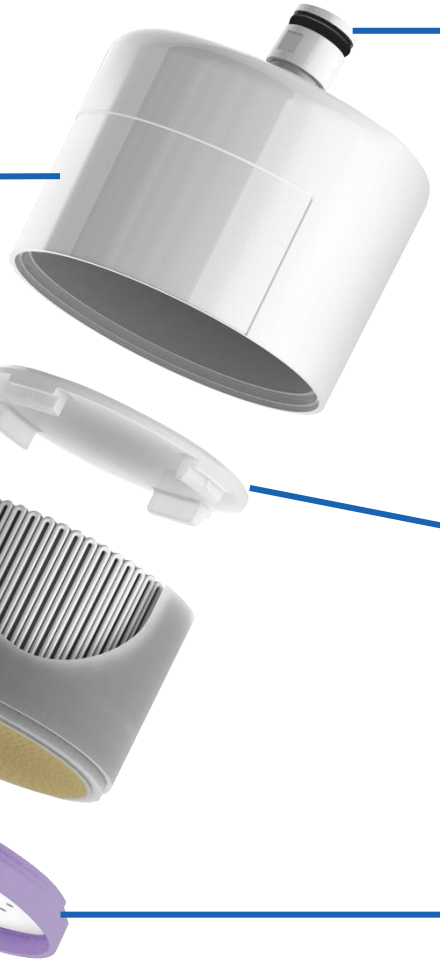
SOLUTIONS TO CONTROL & MITIGATE BACTERIA

POINT-OF-USE FILTRATION

- ***Easy to install, easy to use***

SOLUTIONS TO CONTROL & MITIGATE BACTERIA

POINT-OF-USE FILTRATION



Tilted connector
Optimised filter position

Casing
Space-saving
Smooth surface

Guard
Protect fibres
Increased lifespan

Filter unit
0,1 µm Hollow fibre membrane

Protective skirt

Diffuser
Optimised spray

SOLUTIONS TO CONTROL & MITIGATE BACTERIA

POINT-OF-USE FILTRATION

FAUCET AND SHOWER FILTERS

SOLUTIONS TO CONTROL & MITIGATE BACTERIA

POINT-OF-USE FILTRATION

IN-LINE FILTERS (Ice Machine)

FILTERS TO RINSE MEDICAL DEVICES

SOLUTIONS TO CONTROL & MITIGATE BACTERIA

POINT-OF-USE FILTRATION

- Hospitals are using POU filters for long-term use in the following departments to prevent infections in ***high-risks units***:
  - Transplant Units
  - NICU
  - Oncology
  - Burn
  - ICU
  - Endoscope & MD Rinsing

SOLUTIONS TO CONTROL & MITIGATE BACTERIA

POINT-OF-USE FILTRATION

- POU filters are strongly recommended in the event of **positive test results or an outbreak** because they offer:
  - An immediate solution
  - Quick and easy installation
  - An alternative to thermal or chemical treatments, which can cause pipe degradation, have short-term effects, and are labor-intensive.

CERTIFIED FILTERS

Production meets the most rigorous certification requirements to guarantee the highest standards

FDA Class II Medical Devices

EPA

ASTM F838

Standard Test Method for Determining Bacterial Retention of Membrane Filters utilized for Liquid Filtration with evaluation for complete bacteria retention > $10^7/cm^2$.

CONCLUSIONS

CONCLUSIONS

- Waterborne bacteria remain a persistent challenge in healthcare.
- Multiple factors contribute to bacterial growth.
- There is no single, universal solution to completely eliminate the problem.
- For immunocompromised patients, physical barriers such as point-of-use filters are strongly recommended as a protective measure & curative solution.

THANKS

FOR YOUR ATTENTION

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