SPECIAL PATHOGENS LABORATORY®
THE LEGIONELLA EXPERTS®

MANAGING BACTERIA IN BUILDING WATER SYSTEMS

Frank Sidari III, PE, BCEE
Technical Director, SPL Consulting Services

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Today's Topic

1. Drinking Water Microorganisms
    a. Regulatory Perspective
    b. Drinking Water Microbiology

2. Risk Management
    a. Risk Assessment
    b. Mitigation Approaches
    c. Water Safety Plan

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REGULATORY PERSPECTIVE

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Drinking Water Regulations

- Safe Drinking Water Act (SDWA)
  - 1974, 1986, 1996
  - Ensure safety and protect drinking water
  - Applies to all public water systems
  - EPA
    - Authority to set standards
    - Oversees local implementation

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SDWA Primary Regulations

- MCLG
  - Maximum contaminant Level Goal
  - Below which no know or expected risk to health
  - Non-enforceable
- MCL
  - Maximum Contaminant Level
  - Highest level allowed using best available treatment technology
- TT
  - Treatment technology
  - Process intended to reduce the level of contaminant

Organism	MCLG	MCL
Cryptosporidium	0	TT
Giardia lamblia	0	TT
Heterotopic Plate Count	n/a	TT
Legionella	0	TT
Total Coliforms	0	5.0%
Turbidity	n/a	TT
Viruses (enteric)	0	TT

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PA Drinking Water Regulations

- Microbiological MCLs
  - Total Coliforms …OR…Fecal Coliforms …OR…*E. coli*
  - Turbidity 1 NTU
- Treatment Technology
  - Surface Water
    - Continuous disinfection (>0.2 mg/L) and filtration
    - >99.9% *Giardia lambila*
    - >99.99% Enteric virus
    - >99% Cryptosporidium
  - Ground Water
    - Continuous disinfection

April 2006

PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF DRINKING WATER MANAGEMENT
MAXIMUM CONTAMINANT LEVELS (MCLs)
MAXIMUM RESIDUAL DISINFECTANT LEVELS (MRDLs)

PRIMARY CONTAMINANTS

Volatile Organic Chemicals (VOCs):

BENZENE	0.005	mg/L	MONOCHLOROBENZENE	0.1	mg/L
CARBON TETRACHLORIDE	0.005	mg/L	STYRENE	0.1	mg/L
o-DICHLOROBENZENE	0.6	mg/L	TETRACHLOROETHYLENE	0.005	mg/L
para-DICHLOROBENZENE	0.075	mg/L	TOLUENE	1	mg/L
1,2-DICHLOROETHANE	0.005	mg/L	1,2,4-TRICHLOROBENZENE	0.07	mg/L
1,1-DICHLOROETHYLENE	0.007	mg/L	1,1,1-TRICHLOROETHANE	0.2	mg/L
cis-1,2-DICHLOROETHYLENE	0.07	mg/L	1,1,2-TRICHLOROETHANE	0.005	mg/L
trans-1,2-DICHLOROETHYLENE	0.1	mg/L	TRICHLOROETHYLENE	0.005	mg/L
DICHLOROMETHANE	0.005	mg/L	VINYL CHLORIDE	0.002	mg/L
1,2-DICHLOROPROPANE	0.005	mg/L	XYLENES (Total)	10	mg/L
ETHYLBENZENE	0.7	mg/L			

Synthetic Organic Chemicals (SOCs):

ALACHLOR	0.002	mg/L	GLYPHOSATE	0.7	mg/L
ATRAZINE	0.003	mg/L	HEPTACHLOR	0.0004	mg/L
BENZO(a)PYRENE	0.0002	mg/L	HEPTACHLOR EPOXIDE	0.0002	mg/L
CARBOFURAN	0.04	mg/L	HEXACHLOROBENZENE	0.001	mg/L
CHLORDANE	0.002	mg/L	HEXACHLOROCYCLOPENTADIENE	0.05	mg/L
2,4-D	0.07	mg/L	LINDANE	0.0002	mg/L
DALAPON	0.2	mg/L	METHOXYCHLOR	0.04	mg/L
DIBROMOCHLOROPROPANE (DBCP)	0.0002	mg/L	OXAMYL (Vydate)	0.2	mg/L
DI(2-ETHYLHEXYL) ADIPATE	0.4	mg/L	PCBs	0.0005	mg/L
DI(2-ETHYLHEXYL) PHTHALATE	0.006	mg/L	PENTACHLOROPHENOL	0.001	mg/L
DINOSEB	0.007	mg/L	PICLORAM	0.5	mg/L
DIQUAT	0.02	mg/L	SIMAZINE	0.004	mg/L
ENDOTHALL	0.1	mg/L	2,3,7,8-TCDD (Dioxin)	3×10^{-8}	mg/L
ENDRIN	0.002	mg/L	TOXAPHENE	0.003	mg/L
ETHYLENE DIBROMIDE (EDB)	0.00005	mg/L	2,4,5-TP (Silvex)	0.05	mg/L

Disinfection Byproducts:

TOTAL TRIHALOMETHANES (TTHMs) (Chloroform, Chlorodibromomethane, Bromoform & Bromodichloromethane)	0.080	mg/L
HALOACETIC ACIDS (HAA5) Monochloroacetic Acid, Dichloroacetic Acid, Trichloroacetic Acid, Monobromoacetic Acid, & Dibromoacetic Acid)	0.060	mg/L
BROMATE	0.010	mg/L
CHLORITE	1.0	mg/L

Disinfectants (MRDLs): *Note 2*

CHLORINE (as Cl_2)	4.0	mg/L
CHLORAMINES (as Cl_2)	4.0	mg/L
CHLORINE DIOXIDE (as ClO_2)	0.8	mg/L

MRDL = Maximum Residual Disinfectant Level

Radionuclides:

GROSS ALPHA	15	pCi/L
COMBINED RADIUM (226 + 228)	5	pCi/L
BETA PARTICLE & PHOTON ACTIVITY	4	mrem/yr

Gross Alpha MCL excludes Radon and Uranium particle activity.
Beta Particle & Photon Activity MCL is for man-made radionuclides.

URANIUM	30	µg/L

Inorganic Chemicals (IOCs):

ANTIMONY	0.006	mg/L	FLUORIDE	2	mg/L
ARSENIC	0.010	mg/L	LEAD **	0.005	mg/L
ASBESTOS (Fibers longer than 10µm)	7	million fibers/L	MERCURY	0.002	mg/L
BARIUM	2	mg/L	NITRATE (as Nitrogen)	10	mg/L
BERYLLIUM	0.004	mg/L	NITRITE (as Nitrogen)	1	mg/L
CADMIUM	0.005	mg/L	NITRATE + NITRITE (as Nitrogen)	10	mg/L
CHROMIUM	0.1	mg/L	SELENIUM	0.05	mg/L
COPPER **	1.0	mg/L	THALLIUM	0.002	mg/L
CYANIDE (free CN)	0.2	mg/L			

** The lead and copper primary MCLs are applicable only to bottled, vended, retail and bulk water hauling systems

Microbiological Contaminants: PRESENCE OR ABSENCE OF TOTAL COLIFORMS BASED ON NUMBER OR PERCENTAGE OF TOTAL COLIFORM POSITIVE SAMPLES/MONTH **OR** FECAL COLIFORM OR E.COLI POSITIVE ROUTINE OR CHECK SAMPLES

Turbidity ..... 1 NTU (applicable only to unfiltered surface water sources)

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EPA
Contaminant Candidate List (CCL4)

- Currently not subject to any proposed or promulgated regulations
- Known or anticipated to occur in public water systems

Microbial Contaminants – CCL 4

Final CCL 4 Microbial Contaminants

Microbial Contaminant Name	Type	Diseases and Infections
Adenovirus	Virus	Respiratory illness and occasionally gastrointestinal illness.
Caliciviruses	Virus (includes Norovirus)	Mild self-limiting gastrointestinal illness.
Campylobacter jejuni	Bacteria	Mild self-limiting gastrointestinal illness.
Enterovirus	Viruses including polioviruses, coxsackieviruses and echoviruses	Mild respiratory illness.
Escherichia coli (0157)	Bacteria	Gastrointestinal illness and kidney failure.
Helicobacter pylori	Bacteria	Found in the environment capable of colonizing human gut that can cause ulcers and cancer.
Hepatitis A virus	Virus	Liver disease and jaundice.
Legionella pneumophila	Bacteria	Found in the environment including hot water systems causing lung diseases when inhaled.

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Commissioning New Building Water Systems

- PA Building Code
  - IPC 2015
  - Section 610
    - AHJ
    - AWWA C651/2
    - IPC Method
  - “bacteriological examination that contamination remains”
- Contamination
  - An impairment of the quality of the potable water that creates an actual hazard to the public health through poisoning or the spread of disease by sewage, industrial fluids or waste.

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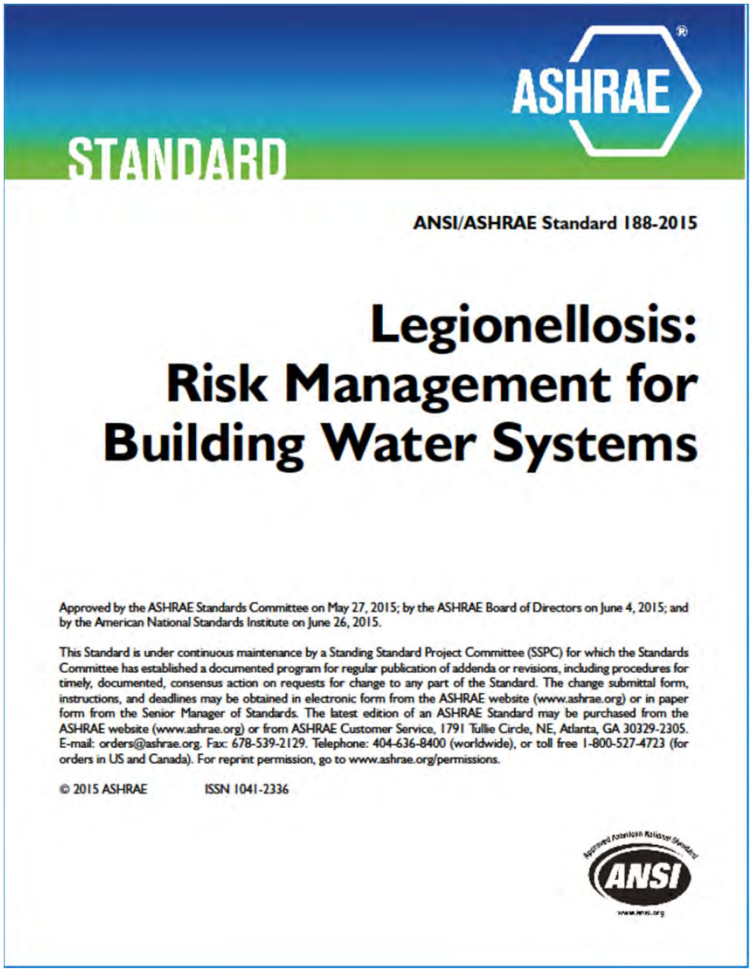
Commissioning New Building Water Systems

- ASHRAE Standard 188
  - Commissioning
    - AWWA C651/2
    - Comply with AHJ



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Building Water Systems

- AWWA C651-14

Building Water System vs. Disinfecting Water Mains

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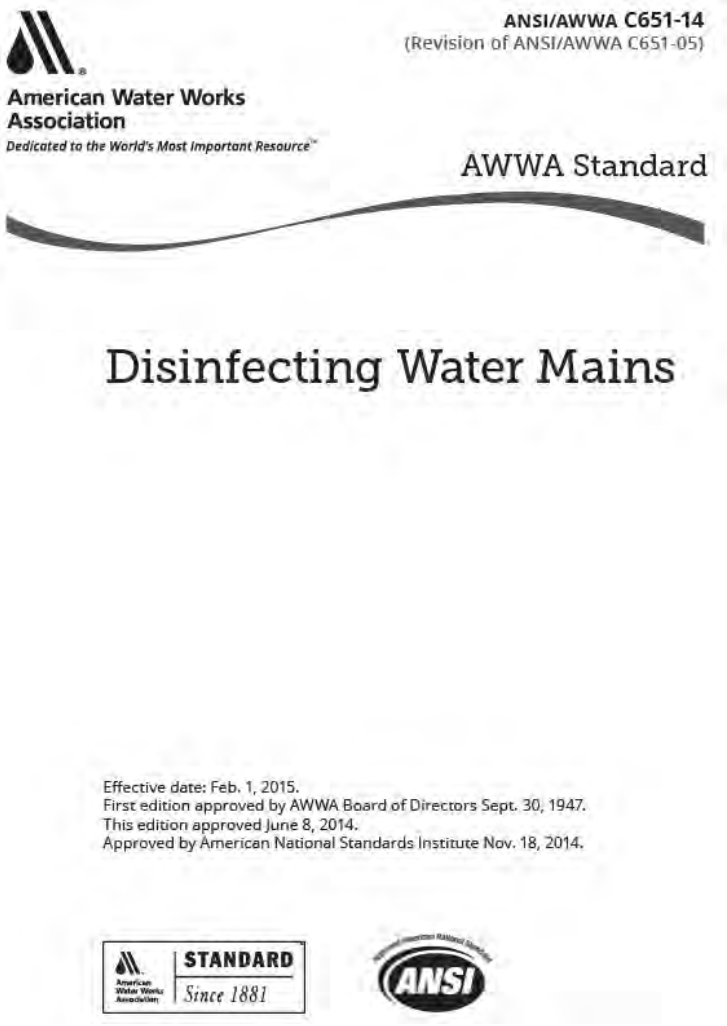
Building Water Systems

- AWWA C651-14
  - "bacteriological quality…shall show the absence of coliform bacteria"
  - "standard HPC may be required"
  - "no coliforms and HPC <500 CFU/mL"



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Centers for Medicare & Medicaid Services
July 2018

DEPARTMENT OF HEALTH & HUMAN SERVICES
Centers for Medicare & Medicaid Services
7500 Security Boulevard, Mail Stop C2-21-16
Baltimore, Maryland 21244-1850

Center for Clinical Standards and Quality/Quality, Safety and Oversight Group

Ref: *QSO*-17-30- Hospitals/CAHs/NHs
REVISED 07.06.2018

DATE: **June 02, 2017**

TO: State Survey Agency Directors

FROM: Director
Quality, Safety and Oversight Group (*formerly Survey & Certification Group*)

SUBJECT: Requirement to Reduce *Legionella* Risk in Healthcare Facility Water Systems to Prevent Cases and Outbreaks of Legionnaires' Disease (LD)

****Revised to Clarify Expectations for Providers, Accrediting Organizations, and Surveyors****

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CMS
Opportunistic Waterborne Pathogens

Conducts a facility risk assessment to identify where *Legionella* and other opportunistic waterborne pathogens (e.g. *Pseudomonas*, *Acinetobacter*, *Burkholderia*, *Stenotrophomonas*, nontuberculous mycobacteria, and fungi) could grow and spread in the facility water system.

- *Legionella*
- *Pseudomonas aeruginosa*
- *Acinetobacter*
- *Burkholderia*
- *Stenotrophomonas*
- Nontuberculous mycobacteria (NTM)
- Fungi

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Disclaimer #1
Microbiology

Engineer

Legionellologist

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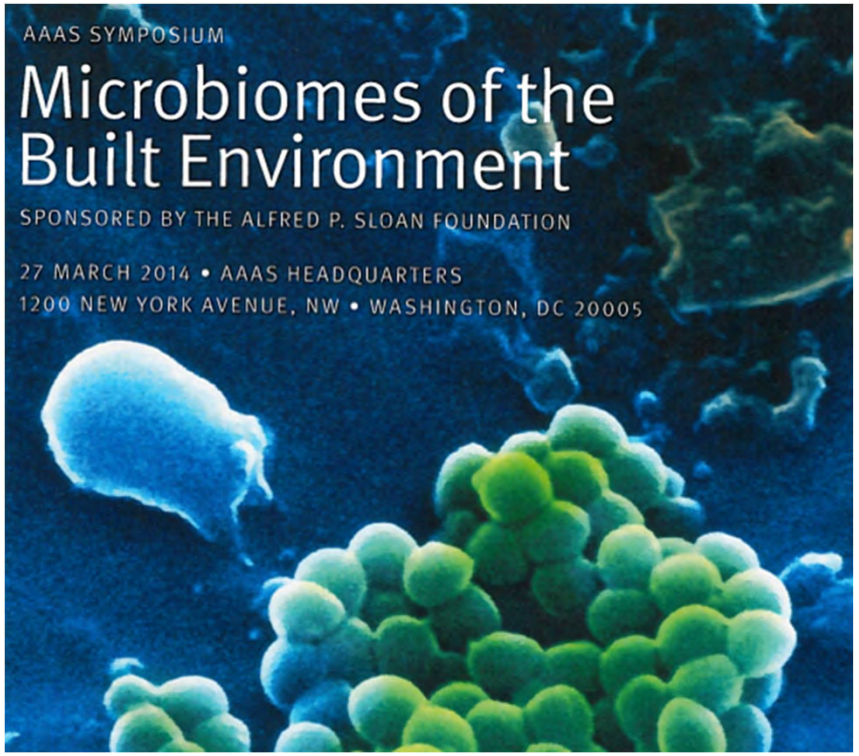
Legionella Is Not Alone

- *Legionella* bacteria are part of a community of microorganisms
  - a consortium
- They live synergistically
  - one benefiting the other for mutual survival



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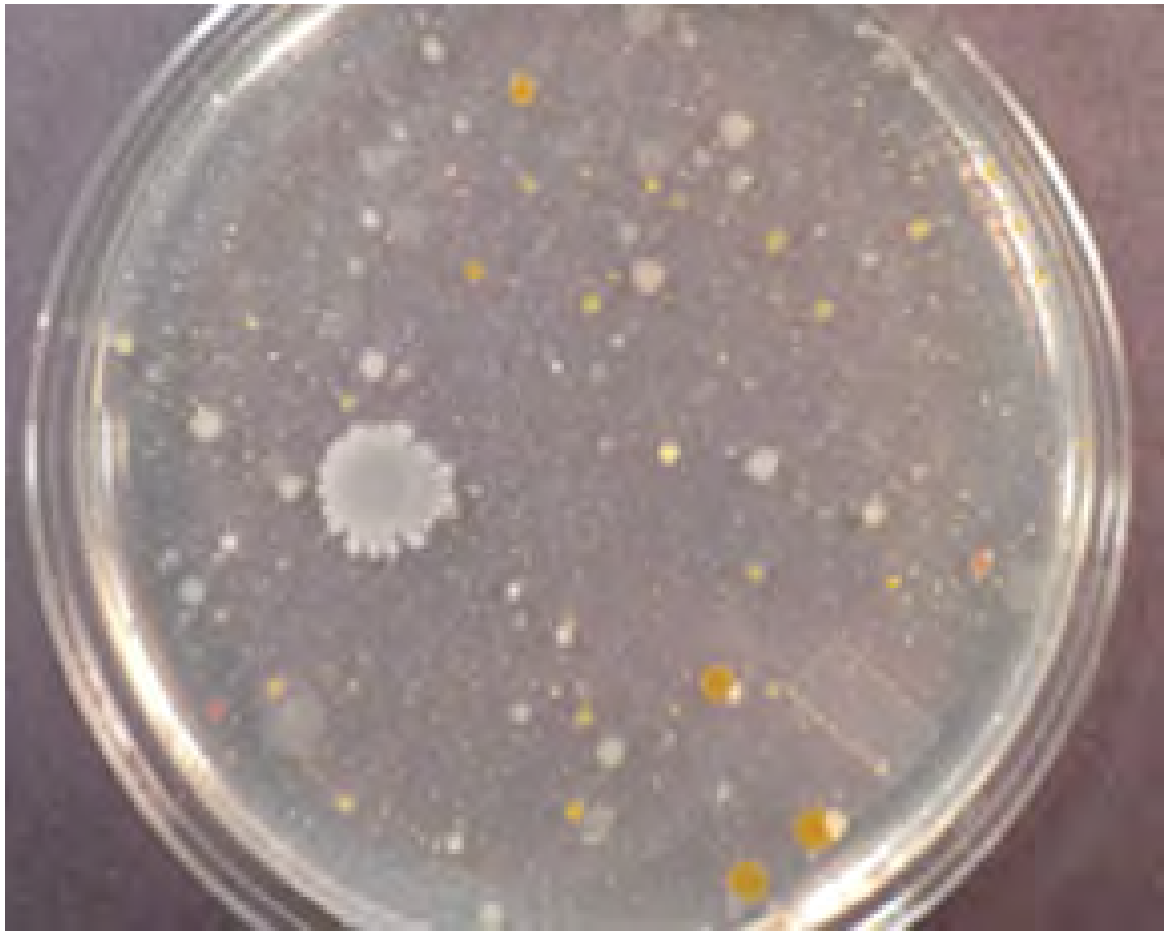

DRINKING WATER MICROBIOLOGY

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Heterotrophic Plate Count (HPC)

- “standard plate count”, “total viable count”, “total count”, “total aerobic bacteria”

- HPC found in drinking water
  - include a range of genera
  - utilize organic carbon for growth
  - can be detected by culture

- Naturally occurring and truly ubiquitous
  - Water, food, surfaces, your body, soil, etc.

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HPC Common in Drinking Water

Water Source	HPC (CFU/mL)	Reference
NJ Drinking Water System	320 – 1,000,000,000	LeChevallier et.al., 1987
Dental Water Lines	>3,000	Rice et.al., 2006
Hospital Hot Water	60,000	Sheffer et.al., 2005
Michigan Lakes	3,000 – >100,000	Jones et.al., 1991
Tucson, AZ Tap Water	>3,000	Pepper et.al., 2004, Chaidez and Gerba, 2004
Administration Building Hot Water	24,700 – 144,000	Sheffer et.al., 2005
Hospital Hot Water	8,000 – 27,000	Zhang et.al., 2009
Hospital Hot Water	2,900 (average)	Duda et.al., 2014
Research Building	16,000 (average)	Siebel et.al., 2008
Apartment Building	300 – 300,000	Bagh et.al., 2004
New Office Building	1 – 100,000 CFU/cm^2 (biofilm)	Inkinen et.al., 2014
New University Building	>10,000	Nguyen et.al., 2008, Nguyen et.al., 2012

Heterotrophic Plate Count Bacteria Testing

- Estimate of bacterial content
- Different measurement methods

Dip Slide
24 hr.

Dip Slide
72 hr.

Culture Plate
120 hr.

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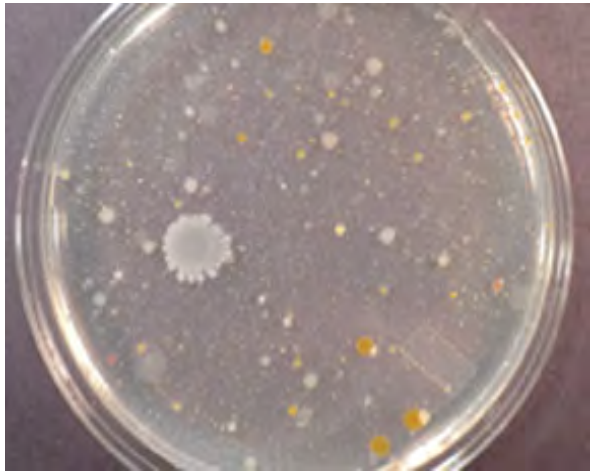
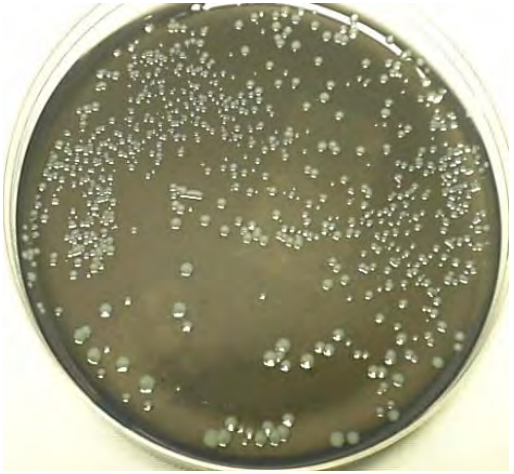
HPC and Coliform Methods Do Not Detect Legionella

IDEXX Colilert



HPC plate count media



Legionella BCYE media

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HPC as an Indicator

- HPC cannot be used as an indicator bacteria for waterborne pathogens
  - No correlation between HPC and
    - Waterborne pathogens
    - Risk for disease

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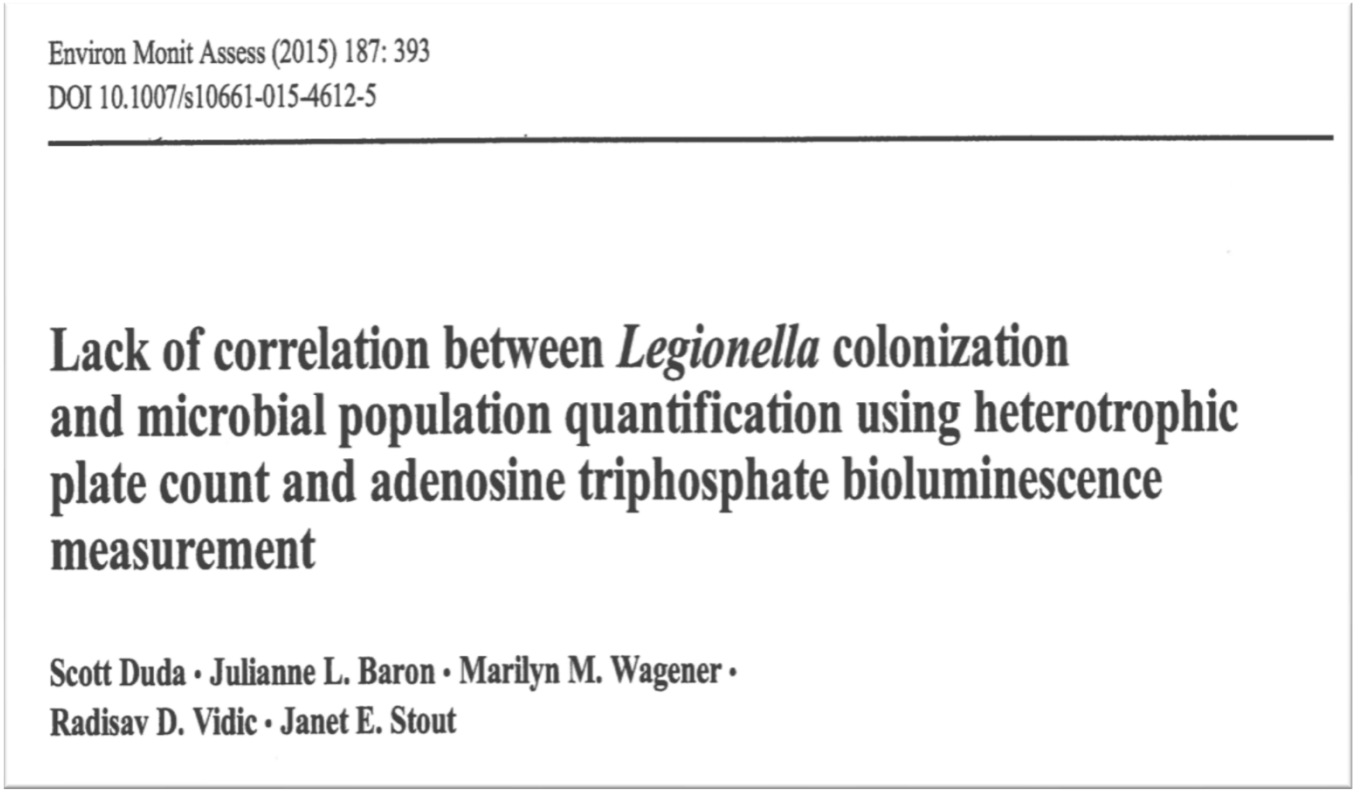
HPC as an Indicator

- HPC cannot be used as an indicator bacteria for waterborne pathogens



Environ Monit Assess (2015) 187: 393
DOI 10.1007/s10661-015-4612-5

Lack of correlation between *Legionella* colonization and microbial population quantification using heterotrophic plate count and adenosine triphosphate bioluminescence measurement

Scott Duda · Julianne L. Baron · Marilyn M. Wagener · Radisav D. Vidic · Janet E. Stout

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HPC as an Indicator

- HPC cannot be used as an indicator bacteria for waterborne pathogens
  - No correlation between HPC and
    - Waterborne pathogens
    - Risk for disease

- Use to monitor changes in water quality or treatment efficacy

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Table 2
HPC genera commonly found in drinking water

Acinetobacter	*Methylomonas*
Actinomycetes[a]	*Micrococcus*
Alcaligenes	*Mycobacterium*[a]
Aeromonas[a]	*Morexella*
Aeromonas hydrophila[a]	*Nitr*
Arthrobacter	
Bacillus	
Beggiatoa	*roteus*
Citrobacter	*Pseudomonas*
C	*P. cepacia*
	P. fluorescens
L vrio	*P. maltophilia*
Enterobacter agglomerans	*Serratia liquefaciens*
Enterobacter cloacae	*Sphaerotilus*
Escherichia coli	*Sphingomonas*
Flavobacterium	*Staphylococcus*
Flavobacterium meningosepticum	*Streptococcus*
Gallionella	*Streptomyces*
Hafnia alvei	*Yersinia enterocolitica*
Klebsiella pneumoniae	

Legionella Not on List of HPC

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Misapplication of 500 CFU/mL

- EPA target for primary water treatment where disinfection is not applied
  - HPC levels less than 500 CFU/ml after treatment
  - Not a health based target

- Why 500 CFU/mL?
  - Potential interference of HPC bacteria at higher levels with culture based analytical methods for coliform testing
  - Analytical methods now suppress background HPC levels and interferences are no longer an issue in coliform testing.

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Heterotrophic Plate Count (HPC) Bacteria Testing

- What do we know?
  - HPC method does not detect Legionella
  - HPC not correlated with Legionella
  - HPC cannot be used to predict risk for waterborne disease
  - HPC used in water safety programs
    - Monitor water treatment programs
    - Not to validate Legionella control

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Fecal Pathogens

- *E. coli*, *Cryptosporidium*, *Giardia*, enteric viruses, etc.
- DW treatment (filtration/disinfection)
  - Removal and inactivation of pathogen
- Do not amplify after treatment
  - Require an animal host to reproduce
- Total Coliform used as an indicator of removal and/or water quality changes post-treatment

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Opportunistic Pathogens

- *Legionella, Pseudomonas, Mycobacteria,* etc.
- DW treatment (filtration/disinfection)
  - May not remove or inactivate 100%
- Can amplify after treatment in distribution
  - Nutrients, lack of disinfectant, other organisms
- Total Coliform or HPC cannot be used as an indicator or presence/absence

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Disclaimer #2
Infection Prevention

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Legionella vs. Opportunistic Pathogens

- Source/Reservoir
  - Legionella: Building Water Systems
  - OOP: Building Water, Surfaces, Air, Dust, Soil, Drains, Cleaning Solutions, etc.
- Infection Site
  - Legionella: Lungs
  - OPP: Lungs, Urinary Tract, IV, Eyes, Soft Tissue, Burns, Wounds, Blood, etc.
- Transmission
  - Legionella: Aspiration, Aerosolization
  - OPP: Aspiration, Aerosolization, Direct Contact, Medical Equipment, Medical Solutions, Environmental Contact
- Other
  - Different Growth Factors
  - Ability to survive outside of water
  - Susceptibility to disinfectants

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Special (non-clinical) Media To Isolate Waterborne Pathogens

- Pseudomonas
  - M-PA-C Modified Pseudomonas agar
- Burkholderia
  - *Burkholderia cepacia* selective agar
- Acinetobacter
  - Leeds Acinetobacter medium
- Stenotrophomonas
  - Trypticase soy agar (TSA) with imipenem
- Non-tuberculous mycobacteria (NTM)
  - Middlebrook 7H10, Mitchison 7H11

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RISK MANAGEMENT

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Basic Components of a Building Risk Assessment

1. Site Characterization
2. Water System Evaluation
3. Water System Testing
4. Recommendations

A WSP cannot be done solely as a desk study. It must involve site visits to confirm the knowledge, information and schematics available to the utility. (WHO WSP)

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What is the Purpose of a Building Risk Assessment?

- New construction ready for occupancy?
- Risk for Legionella or investigating suspected case?
- Risk for other pathogen or investigating suspected case?

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Answer to Purpose for Assessment Determines Approach

- New construction ready for occupancy?
  - Coliforms/HPC – flushed cold water
  - Legionella in healthcare – first draw hot water
- Risk for Legionella or investigating suspected case?
  - Legionella first draw hot water from outlets
  - Legionella from other equipment
  - Swabs from fixtures around case patient
- Risk for other pathogen or investigating suspected case?
  - First draw and/or flushed samples from potable water
  - Hot or cold water from potable water
  - Other water generating equipment
  - Sanitary drains, surfaces, supplies, etc.

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Building Water System Evaluation and Testing

- Process Flow Diagrams
- Water System Operation
- Field Assessment
  - System components
  - Source water quality
  - Temperature, pH, disinfectant residual
  - *Legionella*, other pathogens
  - Water chemistry
- Infection Prevention
  - Patients / Surveillance
  - Root Cause Analysis

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Why Test for Legionella in Building Water Systems?

- Water is the only reservoir for Legionella

- Testing…
  - Establishes risk
  - Validates water safety plan
  - Validates clinical diagnostic method
  - Supports need/efficacy of disinfection

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Why Test for Opportunistic Pathogens in Building Water Systems?

- Water may not be the source of Opportunistic Pathogens

- Testing…
  - Supports infection prevention investigation or program

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Before You Act, Ask

- *Legionella* in the water systems?
  - Pathogenic species? (serogroup 1)
  - Extent of colonization? (>30%)
- Confirmed case of Legionnaires' disease?
- On-going clinical surveillance?
- Susceptible hosts in the facility?
- Engineering controls in place?
- Water system operating efficiently?

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MITIGATION APPROACHES

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Mitigation Options

- Shock (Short-Term) Disinfection
  - Thermal
  - Hyper-Chlorination
  - Short Course Ionization
- Supplemental (Long-Term) Disinfection
  - Supplemental Chlorination
  - Chlorine Dioxide
  - Copper Silver Ionization
  - Monochloramine
- Barriers
  - Point of Use Filters
  - UV

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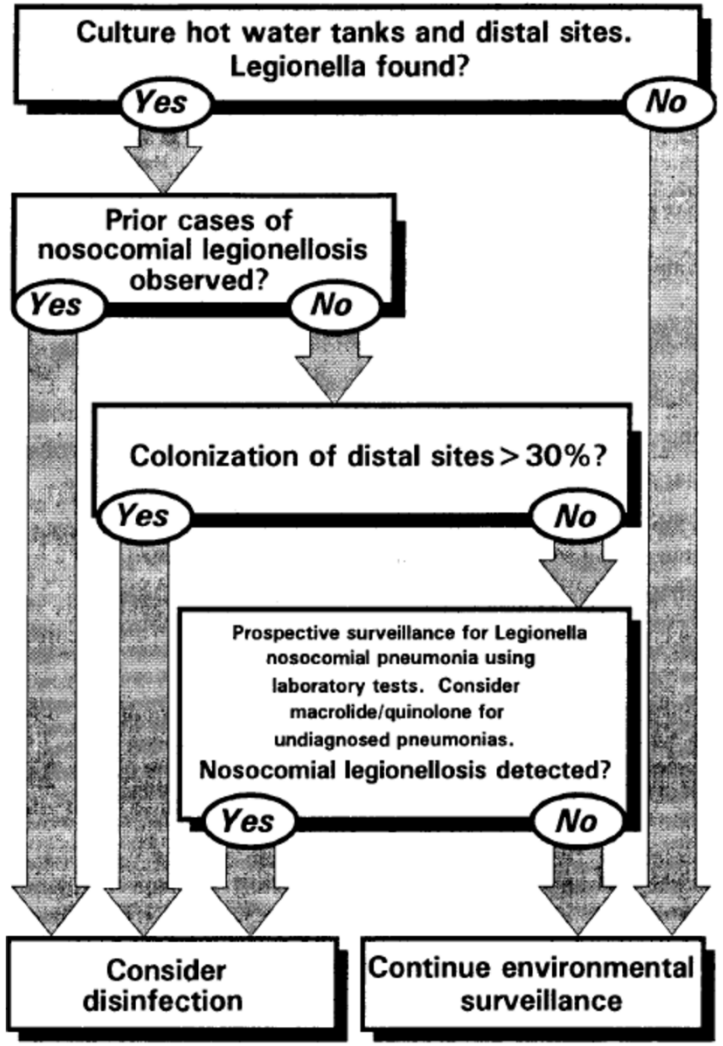
Supplemental Disinfection

- Supplemental disinfection has long term impacts
- Recommendation for disinfection needs to be evidenced-based

Reference: *Approaches to Prevention and Control of Legionella Infection in Allegheny County Health Care Facilities*. 1997.



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Selecting an Application Point

	Hot Water Treatment	Cold Water Treatment
Treats where Legionella growth typically occurs?	**Yes**	
Treats where other pathogens may be present?	**Maybe**	
Ability to maintain residual in hot water?	**Yes**	
Treats the Fixture	**Yes**	
Equipment Size/Cost	**Small/Low**	
Chemical Use	**Low**	
Occupant exposure to disinfectant and by-products	**Low**	

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Selecting an Application Point

	Hot Water Treatment	Cold Water Treatment
Treats where Legionella growth typically occurs?	Yes	No
Treats where other pathogens may be present?	Maybe	Maybe
Ability to maintain residual in hot water?	Yes	Maybe
Treats the Fixture	Yes	Yes
Equipment Size/Cost	Small/Low	Large/High
Chemical Use	Low	High
Occupant exposure to disinfectant and by-products	Low	High

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Evidenced Based Approach

INFECTION CONTROL AND HOSPITAL EPIDEMIOLOGY NOVEMBER 2014, VOL. 35, NO. 11

ORIGINAL ARTICLE

Evaluation of A New Monochloramine Generation System for Controlling *Legionella* In Building Hot Water Systems

Scott Duda, MS;[1] Sheena Kandiah, MD, PhD;[2] Janet E. Stout, PhD;[1,3] Julianne L. Baron, BS;[4]

Office of Water
EPA 810-R-16-001
September 2016

FRANK P. SIDARI III, JANET E. STOUT, SCOTT DUDA, DOUG GRUBB, AND ALAN NEUNER

Maintaining *Legionella* control in building water systems

THIS ARTICLE REVIEWS HOW *LEGIONELLA* AND OTHER WATERBORNE PATHOGENS CAN PRESENT A RISK TO CONSUMERS OF POTABLE WATER. SECONDARY

Legionella and other waterborne pathogens can present a risk to consumers of potable water. In particular, building hot water systems have been established as the primary reservoir for bacteria linked to cases of Legionnaires' disease (LD). These systems provide ideal conditions for *Legionella* proliferation because of their elevated temperature and lack of disinfection residual. Control of *Legionella* in potable water systems has become a focus for health care facilities because they serve a population that is particularly susceptible to LD from underlying health conditions, such as suppressed immune systems. In

4) 1193-6

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aymond Shafer[c],

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Evidenced Based Approach

ELSEVIER
journal ho

Point-of-use filtration met
of hospital water

Charity Holmes, RN, BSN
Laguna Beach, Calif

Infections with *Pseudom*
mortality in hospitals. W
tion in the subacute car
and cost-effectively redu

INFECTION CONTROL AND HOSPITAL EPIDEMIOLOGY MARCH 2014, VOL. 35, NO. 3

ORIGINAL ARTICLE

Long-Term Effects of Hospital Water Network Disinfection on *Legionella* and Other Waterborne Bacteria in an Italian University Hospital

Beatrice Casini, BSc, MS;[1] Andrea Buzzigoli, BSc;[1] Maria Luisa Cristina, BSc, PhD;[2] Anna Maria Spagnolo, BSc, PhD;[2] Pietro Del Giudice, MD;[3] Silvio Brusaferro, MD;[3] Andrea Poscia, MD;[4] Umberto Moscato, MD;[4] Paola Valentini, BSc, MS;[1] Angelo Baggiani, MD;[1] Gaetano Privitera, MD[1]

Preventive efficacy and cost-effectiveness of point-of-use water filtration in a subacute care unit

APPLIED AND ENVIRONMENTAL MICROBIOLOGY, Mar. 2010, p. 2032–2035 Vol. 76, No. 6
0099-2240/10/$12.00 doi:10.1128/AEM.02174-09
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Efficacy of Copper-Silver Ionization in Controlling Biofilm- and Plankton-Associated Waterborne Pathogens[▽]

Hsiu-Yun Shih and Yusen E. Lin*
Graduate Institute of Environmental Education, National Kaohsiung Normal University, Kaohsiung, Taiwan

Received 9 September 2009/Accepted 6 January 2010

Example…
Evidenced Based Approach

- Copper Silver Ionization
  - Legionella – very effective
  - Mycobacterium avium – not as effective
  - Pseudomonas – could be effective

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Example…
Evidenced Based Approach

- Chlorine
  - Legionella – not very effective
  - Mycobacterium avium – not very effective

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Chlorine, Chloramine, Chlorine Dioxide, and Ozone Susceptibility of *Mycobacterium avium*

ROBERT H. TAYLOR,[1] JOSEPH O. FALKINHAM III,[1]* CHERYL D. NORTON,[2] AND MARK W. LECHEVALLIER[2]

Fralin Biotechnology Center, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061-0346,[1] and American Water Works Service Co., Inc., Belleville Laboratory, Belleville, Illinois 62220[2]

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Resistance of *Legionella pneumophila* serotype 1 biofilms to chlorine-based disinfection

I.R. Cooper*, G.W. Hanlon

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Regulatory Context

- Regulatory Context
  - Adding treatment in the facility could impact chemical and microbial water quality

- Certain federal and state regulatory requirements may apply
  - Different states with different interpretations on permitting

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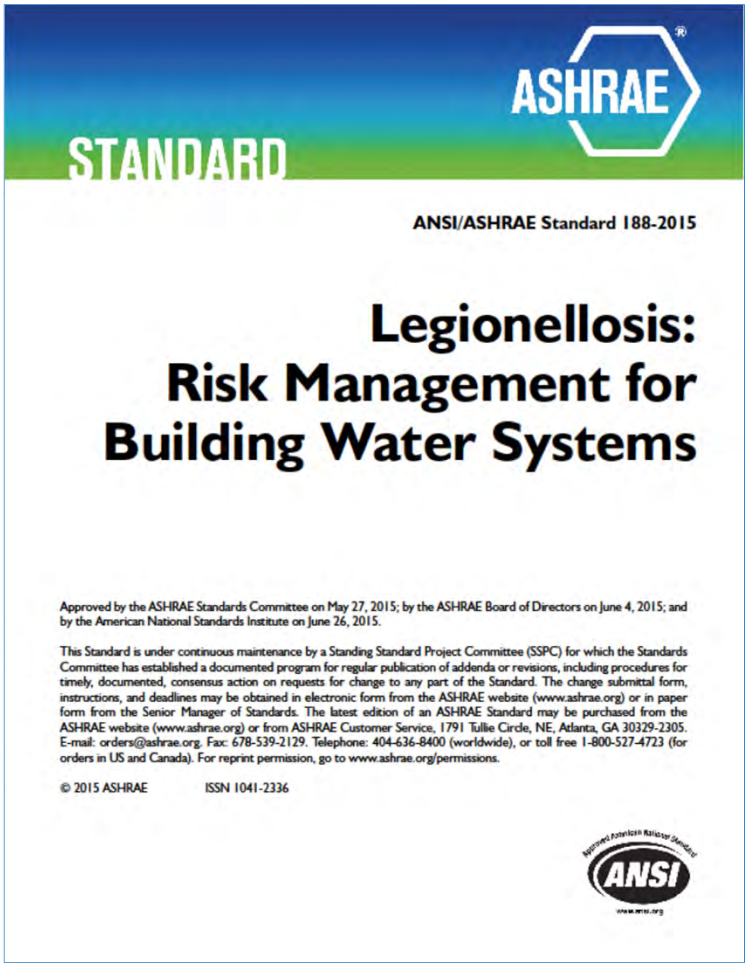
Water Safety and Management Program

- ASHRAE Standard 188
- First *Legionella* standard in the United States
- Establish minimum Legionellosis risk management requirements for building water systems.



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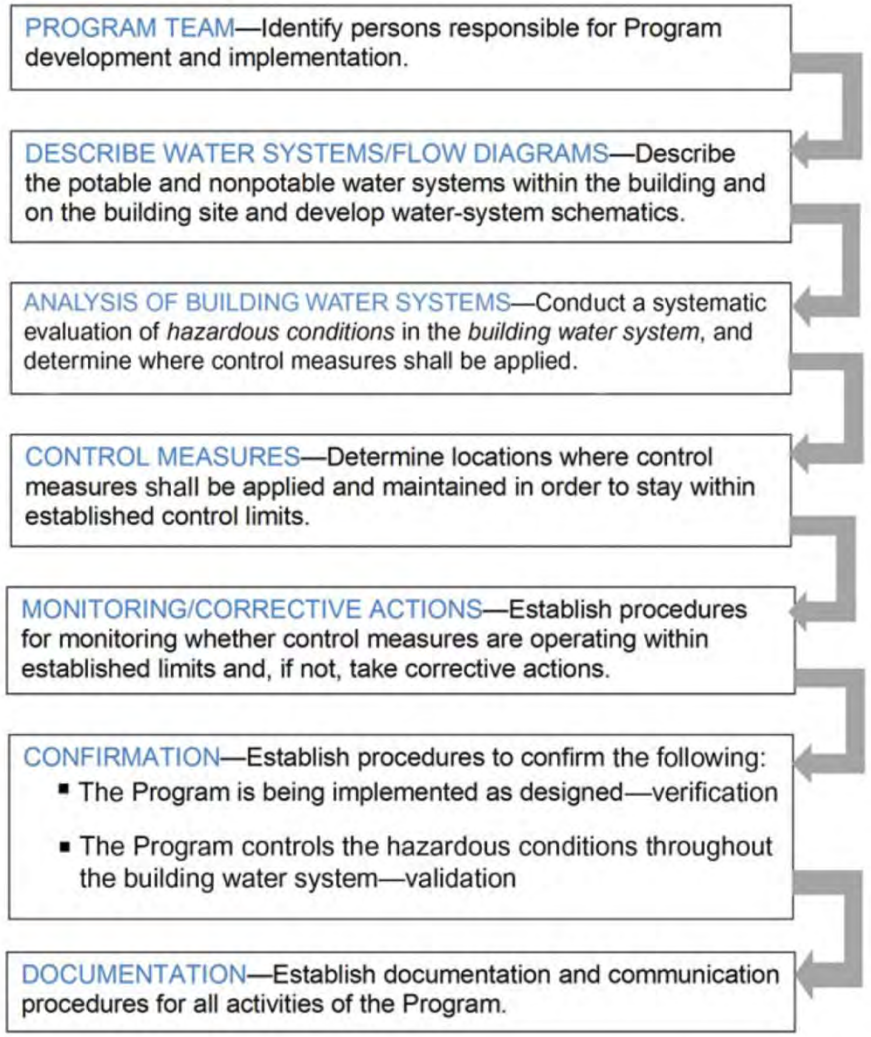
ASHRAE Standard 188



- Written for
  - Legionella
  - Building Water System
- Different Control Measures
  - Temperature
  - Disinfectant
  - Circulation
- Different Mitigation Approaches

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Other Pathogens and Water Safety

- Special attention to address both Legionella and Other Pathogens
- Water Safety needs to be in conjunction with infection prevention practices

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Take-Aways

1. Drinking Water Microorganisms
    a. Regulatory Perspective
    b. Drinking Water Microbiology

2. Risk Management
    a. Risk Assessment
    b. Mitigation Approaches
    c. Water Safety Plan

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THE LEGIONELLA EXPERTS®

THANK YOU

Frank Sidari III

fsidari@specialpathogenslab.com

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