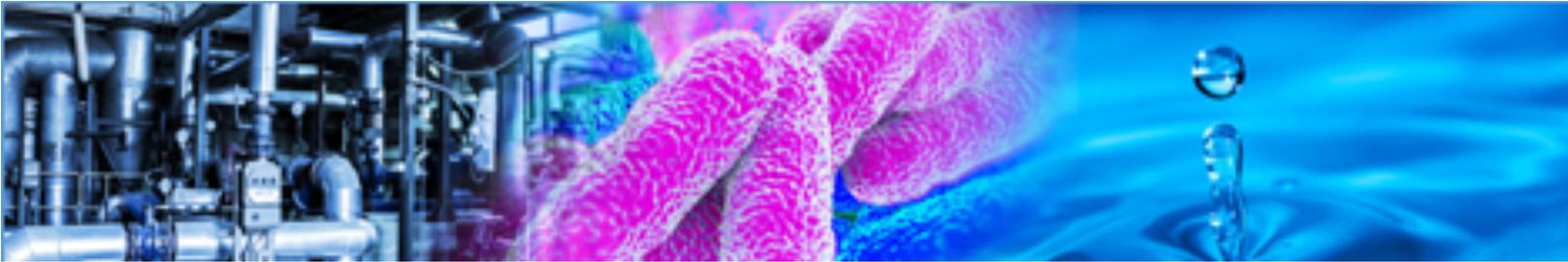


***Legionella* 2019:** A Position Statement and Guidance Document



Legionella 2019: A Position Statement and Guidance Document

(Approved by AWT Board of Directors, February 2019)

Special Acknowledgments

Legionella 2019: A Position Statement and Guidance Document is an update and revision to *Legionella 2003: An Update and Statement by AWT*. The 2019 document was produced by the AWT *Legionella* Task Force, chaired by Bill Pearson, CWT, and Andy Weas, CWT, in consultation with the AWT Technical Committee. Special thanks are given to the AWT board of directors for their review and approval of the document. Very special thanks are given to the AWT *Legionella* Task Force members for their gracious contributions of time, expertise, and knowledge toward the production and technical development of this document: John Caloritis, CWT; Michael Coughlin, Ph.D.; Jay Farmerie, CWT; Matt Freije; Diane Miskowski; Dick Miller, Ph.D.; Rich Moll; Kenneth Soeder, CWT; and Janet Stout, Ph.D.

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Forward and Purpose

The Association of Water Technologies (AWT) is a not-for-profit international trade association founded to serve the interests of regional water treatment companies and to advance the technologies of safe, sound, and responsible water treatment practice. AWT provides education and training, public awareness, networking, research, industry standards, and resource support. Association activities are directed toward promoting the growth and development of member firms and advancing the art and science of the water treatment industry.

Since the initial outbreak in 1976 that led to the discovery and identification of Legionnaires' disease, much has been learned about the bacteria (*Legionella*) that causes the disease and the disease itself. This includes how Legionnaires' disease is contracted and how to minimize risk of disease contraction, as well as effective medical treatments for Legionnaires' disease. Guidelines and standards provide substantial direction and information that can be adopted to manage building water systems and devices to control *Legionella* and minimize legionellosis; however, none can provide an absolute (100%) guarantee of disease prevention.

Much has changed since AWT drafted and published *Legionella 2003: An Update and Statement by AWT*. Surveillance data by the Centers for Disease Control and Prevention (CDC) for the United States shows an increase of more than 550% in the annual incidence of Legionnaires' disease cases reported from 2000–2017. With continuing high-profile disease outbreaks; the release of ASHRAE Standard 188-2015; and the issuance of laws by state, city, and local regulatory authorities, as well as directives and regulations by other authorities having jurisdiction, such as the Centers for Medicare and Medicaid Services (CMS), there is a responsibility and there are requirements for managing *Legionella* as a waterborne pathogen in associated building water systems. Many facilities are now required to have policies in place, implement appropriate risk management, and develop water management plans to control *Legionella* in their water systems to prevent disease. All these factors have greatly influenced the way facility owners and managers operate their buildings and building water systems, and how water treatment professionals design, implement, monitor, and document their water treatment and water management programs.

Legionella 2019: A Position Statement and Guidance Document is a revision of the 2003 AWT document. It provides current *Legionella* and related legionellosis information in a broad and useful format that can be easily utilized by water treatment professionals and their clients as a reference and guidance document to manage the risk of Legionnaires' disease from water systems under their care or supervision. It is a comprehensive update of collective information and data available from numerous research, investigative, and authoritative sources on *Legionella* and legionellosis. These include the CDC, OSHA (Occupational Safety and Health Administration), WHO (World Health Organization), EPA (Environmental Protection Agency), and various state public health agencies as well as associated technical trade organizations and recognized *Legionella* experts and commercial entities. Due to the multi-disciplined technical and medical nature of the subject, this document is directed at summarizing and presenting up-to-date *Legionella* information in a useful format to the water treatment professional and end-user as well as to the public and private sectors. Extensive references are cited to provide more detailed and in-depth information on legionellosis and related topics to benefit those with more specific interest and application or decision-making needs.

Legionella 2019:

A Position Statement and Guidance Document

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Figure 1: Legionella is a waterborne pathogen

I. Discovery of Legionnaires' Disease and Legionella

Legionnaires' disease acquired its name from the media reference given to a mysterious pneumonia-like illness that afflicted numerous attendees of an American Legion convention at the Bellevue-Stratford Hotel in Philadelphia during July 1976. An outbreak of illnesses occurred, presenting Pennsylvania Department of Public Health officials with a recorded 221 cases of a strange respiratory illness contracted by convention (hotel) attendees and by some pedestrians passing by the hotel. Symptoms included high fever, chills, muscle pain, headache, and eventual development of a dry cough with difficulty in breathing. Some patients developed patchy lesions in their lungs representative of severe pneumonia. More than two-thirds of the patients required hospitalization and 34 eventually died.

In January 1977, the discovery of the causative agent of the outbreak was made by the Centers for Disease Control and Prevention (CDC). It was a bacterium that was subsequently named *Legionella pneumophila* (pneumophila is Greek for lung-loving). It was determined that neither the bacterium nor the disease was new and that *Legionella* bacteria have been around and causing disease for many years. When reexamined, the CDC found *Legionella* bacteria in 50-year-old (archived) tissue samples of unsolved and similar-illness cases. So, Legionnaires' disease was not a new disease discovered in 1976—just an old one that was finally recognized and named.

II. Terms, Definitions, and General Facts

Legionella is the name of a genus of bacteria. *Legionellae* (the plural, referring to more than one *Legionella* bacterium) are aerobic, non-spore-forming, rod-shaped, typically flagellated, gram-negative bacteria. They are common to aquatic environments, especially warm water, and are found in some muds and soils. There have been at least 60 *Legionella* species identified, with approximately half being linked to human disease. Some species of *Legionella* are distinguished by serogroup or serotype, with more than 70 serogroups presently identified for the genus. Some species have serogroups that are further differentiated into subtypes.

Legionella pneumophila was the first *Legionella* species named upon discovery in 1977, following the 1976 disease outbreak in Philadelphia. *L. pneumophila* stands alone today as the single species responsible for more than 90% of legionellosis cases. More than 80% of these cases are attributed to only one serogroup—*L. pneumophila* serogroup 1—of the more than 15 identified *L. pneumophila* serogroups. This serogroup is the most common *Legionella* isolate recovered from environmental samples. Within this serogroup are more than 50 subtypes that can be identified by molecular typing methods. Serogroups and subtypes appear to differ in their degree of virulence—and thus, their ability to cause disease.

Legionellosis is a collective term describing the pneumonic and non-pneumonic forms of infection and disease caused by exposure to *Legionella* bacteria. Legionnaires' disease and Pontiac fever (disease) are two forms of legionellosis, with Legionnaires' disease, the pneumonic form, being the more serious and primary one of focus. Pontiac fever, the non-pneumonic form, presents with flu-like symptoms after an incubation period from less than 24 to 72 hours. It is a self-limiting illness, usually lasting less than two to five days, and it is not associated with death. Conversely, Legionnaires' disease presents as a serious and potentially fatal pneumonia. It is considered a non-communicable disease, as it requires transmission of the disease-causing bacteria (*Legionella*) from an environmental source (water or soil) and exposure to a susceptible host via inhalation or aspiration. It is not transmitted from person to person.

Legionnaires' disease is an acute bacterial infection of the lower respiratory tract that causes pneumonia. The disease is a potentially fatal, multi-system respiratory illness with an average mortality rate of 10%, according to the CDC; however, a significantly higher mortality of 25% is reported by the CDC when the disease occurs in healthcare facilities. Fortunately, only 2–5% of people exposed to an infectious form of *Legionella* will present with symptoms of disease.

Pontiac fever is a much milder, flu-like illness not involving pneumonia caused by *Legionella*. Cases of Pontiac fever

have been linked to *L. pneumophila*, *L. feelei*, and *L. anisa*. It attacks indiscriminately, uniformly infecting 90% to 95% of those exposed, and has a shorter incubation period of less than one to three days. Complete recovery usually occurs in two to five days without medical attention or antibiotics.

A. Legionnaires' disease is a serious illness and not rare.

Legionnaires' disease is a severe pneumonia with an estimated 8,000–18,000 hospitalized cases occurring annually in the United States, according to the CDC. *Legionella* is one of the top three causes of sporadic, community-acquired pneumonia. While approximately 95% of reported cases are sporadic, outbreaks can occur in almost any setting and are most frequently reported in association with travel and healthcare exposure. According to the CDC in *Morbidity and Mortality Weekly Reports*, June 10, 2016, Garrison et al., "The most frequent outbreak settings in this analysis were hotels and resorts, long-term care facilities, and hospitals. Although 44% of the outbreaks were travel-associated and 33% were healthcare-associated, healthcare-associated outbreaks were larger and resulted in more deaths than travel-associated outbreaks. Potable water was the most frequent source of exposure; however, outbreaks related to cooling towers were associated with larger numbers of cases."

Because it is difficult to distinguish from other forms of pneumonia, unless specifically investigated, many cases of disease go undiagnosed and unreported. However, the reported cases of Legionnaires' disease are on the rise in the United States, according to the CDC's National Notifiable Diseases Surveillance System data (see Figure 2)—with the incidence increasing more than 5.5 times during the reporting period of 2000–2017.

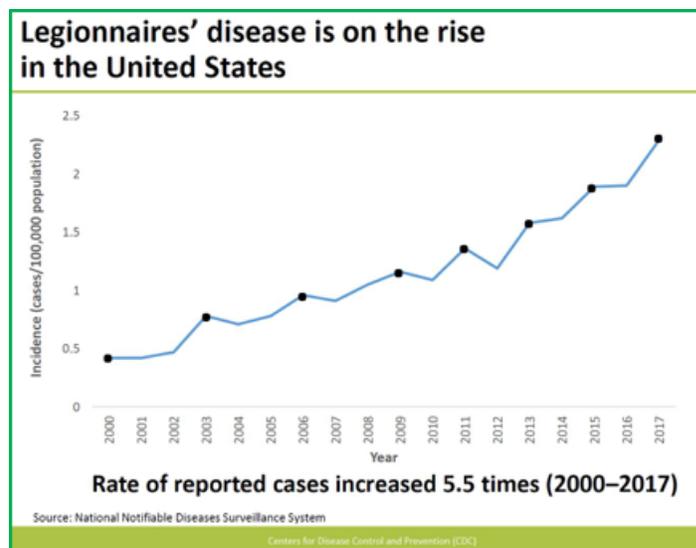


Figure 2: Courtesy CDC (Dec 2018)

The CDC confirms that U.S. health departments reported more than 7,000 cases of Legionnaires' disease in 2017. While over 7,000 cases were reported to the CDC for the year, it is estimated that more than 25,000 cases of the illness occur each year and cause in excess of 4,000 deaths. Dr. Paul Edelstein has estimated the actual number of annual cases in the United States ranges from 56,000 to 113,000 based on the incidence ratio of 180–360 cases per 1 million people reported in the German CAPNETZ (Competence Network for Community Acquired Pneumonia) study (von Baum et al. 2008). With the CDC's estimate of a 10% overall mortality rate, that would equate to 5,600 to 11,300 annual deaths in the United States due to legionellosis.

B. Disease exposure most likely occurs via two routes:

1. Inhalation of aerosols, fine sprays, mists, or other microscopic droplets of water or soil contaminated with *Legionella*—providing direct access into the lungs; and

2. Aspiration, which occurs when solids or liquids intending to be swallowed and make their way to the stomach, instead “go down the wrong pipe” and enter the respiratory tract (trachea) and are subsequently breathed into the lungs. (Aspiration is discussed in more detail in Section III.)

C. Disease sources may include almost any warm water system or device (manmade or natural) that disseminates water—particularly as aerosols, sprays, or mists—and provides favorable conditions for *Legionella* growth. The potable (domestic) water distribution systems of large buildings, including healthcare facilities, hotels, resorts, etc. are considered the primary source of *Legionella* and disease, as supported by the CDC and peer-reviewed research studies. These large buildings and facilities tend to have complex hot water systems and are commonly linked to occurrences and transmission of disease.

While cooling towers and evaporative condensers are also a potential source related to Legionnaires' disease, and long thought to be the major source of *Legionella*-causing disease, current data suggest that domestic (potable) water plumbing systems are responsible for an even larger number of cases of legionellosis.

Legionella can grow and has been found in the many parts of building water systems that are continually wet, including: hot-water and cold-water storage tanks, water heaters, water-hammer arrestors, expansion tanks, water filters, electronic faucets, aerators, faucet flow restrictors, shower heads and hoses, non-steam aerosol-generating humidifiers, ice machines, and infrequently used equipment, including eyewash stations and safety showers. *Legionella* is also known to grow in other stagnant lines and piping, such as future expansion lines as well as discontinued lines or underway construction and remodeling piping runs. All of these are

often referred to as dead-legs.

Other disease sources include: various heat-rejection devices, whirlpool baths and spas, home or other warm water birthing tubs/pools, hot springs, respiratory therapy equipment, dental water lines (*The Lancet* 2012), and even misting machines found in grocery store produce sections and outside misters in hot, dry climates.

D. Disease susceptibility is an important factor in disease contraction. The greatest host susceptibility to *Legionella* is found in the elderly and those with suppressed or compromised immune or respiratory systems. These include heavy smokers, alcoholics, HIV patients, cancer patients, bone marrow or organ-transplant patients, diabetics, and others with lung or respiratory diseases. Underlying disease and advanced age also contribute to a significantly higher risk of mortality with Legionnaires' disease. The most common risk factor found in Legionnaires' disease patients is heavy cigarette smoking, along with chronic lung disease. Bone marrow and organ transplants represent the most intense risk factor, since the medicines used to protect new organ transplants also compromise the body's immune defenses against infection. Patients taking corticosteroid medicines are also at risk.

E. Disease symptoms may include:

- High fever, chills, headache, muscle pain (flu-like symptoms)
- Dry cough and difficulty in breathing
- Diarrhea and/or vomiting
- Confusion and delirium

F. Disease incubation time (i.e., the time between exposure and onset of symptoms) for Legionnaires' disease is generally 2 to 10 days, but up to 16 days has been recorded in some outbreaks (WHO 2018). For several days, the patient may have flu-like symptoms and feel tired and weak. Most patients who are admitted to a hospital develop high fever, often greater than 39.5 °C (103 °F). A cough can be the first sign of a lung infection and may be sufficiently severe to cause sputum production (mucous with saliva). Gastrointestinal symptoms are seen in approximately 40% of patients, with diarrhea being the leading symptom. Many patients have nausea, vomiting, and stomach discomfort. Other common symptoms include headaches, muscle aches, chest pain, and shortness of breath.

G. Legionnaires' disease treatment requires the use of antibiotics. However, many antibiotics effective against other bacterial pneumonias are ineffective against *Legionella*, as they do not act to penetrate the pulmonary alveolar macrophage (cells) where infectious *Legionella* thrive. Fortunately, there are several newer antibiotics that are

effective against *Legionella*. The two most potent classes of these antibiotics are the **macrolides**, such as azithromycin, and the **quinolones**, including ciprofloxacin, levofloxacin, moxifloxacin, gemifloxacin, and trovofloxacin. Other agents that have proven effective against Legionnaires' disease include tetracycline, doxycycline, minocycline and trimethoprim-sulfamethoxazole. Erythromycin, the former antibiotic of choice, has been replaced by these more effective and less toxic antibiotics.

When patients are treated with appropriate antibiotics near the onset of disease, the outcome is usually excellent, especially if there is no underlying illness compromising the immune system. For patients with compromised immune

systems, including transplant recipients, any delay of appropriate treatment can result in complications, prolonged hospitalization, or death.

After successful treatment and hospital discharge, many patients will still experience fatigue, loss of energy, and difficulty concentrating. These symptoms may last for several months. Complete recovery within one year is usually the rule. Patients who were cigarette smokers should consider discontinuing smoking.

Because the contraction of Legionnaires' disease represents a much more serious condition than Pontiac fever, this document will focus on Legionnaires' disease.

III. *Legionella*: Infectious Growth, Transmission, and Host Susceptibility

Legionella is naturally occurring and is commonly found in surface waters (lakes, ponds, rivers and streams) and ground waters. Some *Legionella* species (e.g., *longbeachae*) have been found in natural soils as well as potting soils, and have been associated with disease. *Legionella* can exist as a sessile member in a complex biofilm community or as an independent and motile organism when it erupts from a biofilm to colonize new surfaces. *Legionella* can also thrive in a multitude of manmade water system devices, including premise plumbing (potable/domestic) cold, and hot water systems that approximate its natural environment. *Legionella* can infect the human lung and is responsible for a bacterial pneumonia known as Legionnaires' disease.

The ecology of *Legionella* is particularly interesting and important to its ability to persist in the environment as well as infect human hosts. *Legionella* not only thrives in biofilms but is an opportunistic parasite that can infect certain amoebae and ciliated protozoa. In this relationship, the protozoan is a cellular host in which *Legionella* grow and replicate. Not only does *Legionella* acquire necessary nutrients from its host, but the host also protects *Legionella* from toxic and unfavorable environmental conditions.

This endosymbiotic relationship with amoebae and other protozoa is an adaptation that allows *Legionella* to survive and, oftentimes, persist in water systems despite disinfection strategies to control or remediate it. The genetic mechanisms by which *Legionella* can parasitize and thrive within protozoa in the natural environment is related to how it can also parasitize and propagate within the human macrophage to cause Legionnaires' disease (infection). Macrophages are white blood cells that function as an integral part of our body's defense against disease by phagocytizing (ingesting) pathogens that are constantly entering our bodies.

Disinfection of a water source can lead to the eradication or reduction of *Legionella* populations; however, the majority of *Legionella* does not exist in an independent and solitary (planktonic) state. Instead, *Legionella* more often resides inside a protozoan host and/or biofilm community. When *Legionella* is released from a host, it is encapsulated within vesicles derived from the host's cell membrane. There can be hundreds to more than a thousand *Legionella* within a single vesicle. *Legionella* dispersed within these vesicles appears to be more virulent than *Legionella* not parasitized in a protozoan host.

A. The mere exposure to *Legionella* bacteria is not sufficient to cause disease. *Legionella* must meet the following criteria for an infection to occur: 1) grow and increase in population density; 2) have and present certain virulence factors; 3) upon transmission, gain access to the lungs; and 4) upon exposure, have a susceptible human host and an infectious dose to cause disease.

B. The dose of *Legionella pneumophila* (or other species of *Legionella*) required to infect humans is not known.

It is most probably influenced by host susceptibility and extent of exposure. Certain virulence factors are known to contribute to the pathogenesis of *Legionella*. For example, one gene (*rtxA*) was shown to be involved in the ability of *Legionella* to enter and replicate within host cells (Cirillo et al. 2001).

C. A susceptible host must inhale or otherwise aspirate (choke into their lungs) water or particulates colonized with a sufficient quantity of virulent *Legionella*.

The transmission of *Legionella* to the air sacs in the lung (alveoli) is a critical step in the infection process. Transmission can occur by inhaling aerosols of water or aspirating water contaminated with *Legionella*. If *Legionella*-contaminated droplets are of sufficiently small size (<5.0 microns), they can reach the alveoli. Once *Legionella* enters the alveoli, it will be ingested by pulmonary macrophage. However, if *Legionella* is not destroyed (digested) by phagocytosis, it will grow within the macrophages—in a manner similar to the growth of *Legionella* within amoeba and protozoa. At their optimum (human body) temperature for growth, *Legionella* will amplify to eventually cause cellular lysis (rupture) of the macrophage cells. This soon overwhelms the host's immune system, and disease will ensue.

Aspiration is a common way that bacteria enter lungs and cause pneumonia. Studies indicate that aspiration is also a mode of *Legionella* inhalation. Active aspiration occurs as a "choking process" during drinking, swallowing, clearing-of-the-throat, or respiratory therapy. When choking occurs, secretions or fluids in the mouth initiate a choking reflex, and instead of entering the esophagus, they enter the respiratory tract.

Passive aspiration is a form of dysphagia, which is the medical term for a difficulty in swallowing. It often occurs when the epiglottis is impaired, allowing a small amount of fluid or food to enter the lungs with every swallow. Dysphagia is characterized by difficulty with swallowing and often accompanied by nasopharyngeal regurgitation, aspiration, and a sensation of residual food remaining in the pharynx. It is a common condition after stroke and occurs with Parkinson's disease and Alzheimer's disease. It can also cause serious complications, including aspiration pneumonia. According to the World Gastroenterology Organisation's *Global Guidelines & Cascades for Dysphagia* (Update September 2014), within three days of experiencing a stroke, 42–67% of patients present with oropharyngeal dysphagia. Among these patients, 50% aspirate and one-third develop pneumonia that requires treatment. Despite its high prevalence among the elderly and associated serious complications, dysphagia is often overlooked and underdiagnosed in vulnerable patient populations.

D. Legionella growth and population amplification.

To better understand *Legionella* and its potential to cause disease, and to manage populations of *Legionella* in water systems, one must understand the conditions that promote *Legionella* growth and the resulting increase in population (amplification). The major factors include:

- 1.** Warm water temperatures to 50 °C/122 °F allow the survival of *Legionella*, with growth occurring and gradually increasing from 25 °C to 45 °C (77 °F to 113 °F) and peaking around and an optimum growth range observed at 35 °C to 40 °C (95 °F to 104 °F).
- 2.** Bulk water pH in the range of 5.0 to 8.5.
- 3.** The presence of scale, deposits, sediment, or debris, including mud and sludges, which provide surfaces for biofilm attachment and growth.
- 4.** The presence of increased corrosion byproducts, especially iron-based, which have yielded increased *Legionella* populations in domestic water systems.
- 5.** The presence of supporting microbiota, including algae and other biofilm bacteria that supply essential nutrients for *Legionella*.
- 6.** The presence of certain amoebae and other protozoan hosts that allow *Legionella* to survive in the midst of harsh environmental conditions, including chemicals and disinfectants, and to grow and multiply.
- 7.** Stagnant water conditions resulting from infrequent water use as well as the presence of dead-legs, low-flow, or otherwise poor circulation patterns. The dissipation and loss of chemical disinfectant is an important consequence

of these conditions—commonly referred to as the “aging of water” within the water system.

Many different types of water systems and devices serve as *Legionella* amplifiers and (aerosol) disseminators—and have been associated with disease. They include:

- Potable/domestic hot water systems via tap faucets, showerheads, and aerators
- Cooling towers and evaporative condensers
- Spas, hot tubs, and whirlpools (on display or otherwise in use)
- Humidifiers and misters
- Water fountains and decorative water features
- Supermarket (grocery store) produce or other water reservoir misters
- Respiratory therapy/CPAP equipment
- Home or other natural birthing tubs/pools
- Dental hygiene equipment*
- Ice machines

Accordingly, due care and concern should be exercised in the operation and maintenance of these and all water systems and related devices that have the potential to harbor, support the growth, and provide a means of transmission of *Legionella* and, consequently, pose a potential health risk upon exposure to at-risk individuals and populations.

*** Note:** *Dental equipment that uses potable water will generate water mists and should be considered a potential source of Legionella. Although Legionella has been isolated from dental equipment, only one known case of disease has been linked to such contaminated dental equipment. (Italy 2011)*

IV. Domestic (Potable) Water Plumbing Systems and Legionnaires' Disease

A. Domestic water systems are a primary source of Legionnaires' disease. Plumbing systems that supply water to faucets, showers, and other devices used by people in buildings are referred to as domestic or potable water systems. For the purposes of discussing *Legionella* prevention, the terms “domestic” and “potable” have the same meaning. “Domestic” will be used in this document because facilities management personnel typically refer to these systems by that term. Domestic also includes both the hot and cold water distribution systems that provide waters to these taps.

A domestic water system was first implicated in Legionnaires' disease in 1980 (Tobin et al. 1980), whereby a patient became ill during a hospital stay. Numerous cases have since been attributed to domestic water systems—in nursing homes, hotels, workplaces, apartment buildings, and even single-family homes.

It is not surprising that plumbing systems have been implicated in so many Legionnaires' disease outbreaks. They provide a good habitat for *Legionella* as well as many points of exposure. For example, people can be exposed to *Legionella* while washing their hands or face, brushing their teeth, or showering.

Of 20 hospital outbreaks of Legionnaires' disease reported in the United Kingdom from 1980 to 1992, 19 were attributed to domestic water systems (Joseph et al. 1994). Among 27 outbreaks investigated and studied by the CDC from 2000 to 2014 (Garrison et al. 2016), domestic water systems were implicated in 15 (56%), more than twice as many as cooling towers (6, or 22%). The number of cases per outbreak was about twice as many for cooling towers than for domestic water systems. However, since most Legionnaires' cases associated with domestic water systems occur sporadically, one or two at a time (CDC considers an outbreak if there is more than one case) rather than in multi-case outbreaks, they are less likely to be reported. The total number of cases associated with domestic water systems is likely much higher than the number associated with cooling towers.

Domestic water (premise plumbing) and cooling tower water systems are both potential reservoirs for harboring and transmitting *Legionella* and must therefore be properly managed to reduce the risk of disease.

B. Domestic water systems must be managed to reduce Legionella risk. In 1991, the U.S. Environmental Protection Agency (EPA) acknowledged that *Legionella* bacteria contaminate public water supplies at very low concentrations; however, the EPA also stated that the responsibility for managing the risk of Legionnaires' disease falls on building owners and/or operators. The EPA stated

that it is within building water systems that the bacteria generally find an environment where they can multiply to a more hazardous level.

After water from a public water distribution system enters a building's domestic water system, it typically encounters warmer temperatures and is subject to low flow or stagnant conditions and a residence time that can lead to the loss of disinfectant residuals. There is also a significant difference with the building (premise) piping having a much larger surface area to water volume relationship than within the public water distribution piping. It is on the surfaces of pipe walls, valves, and fittings that biofilm develops—and it is within biofilm that *Legionella*, along with other microorganisms, have a favorable environment for protection and colonization.

Proper treatment of public water systems is important in the utility plant as well as the distribution system. Domestic water systems in buildings supplied by water of high quality and relatively high disinfectant residuals are less likely to have hazardous levels of *Legionella* than buildings with water of poorer quality and lower disinfectant levels. However, buildings in areas served by public water utilities meeting all EPA standards have been associated with Legionnaires' disease. Building owners must take reasonable steps to manage their domestic water systems for *Legionella* control regardless of the treatment regimen and disinfectant type employed by the public water supplier.

In addition to the incoming water supply quality and disinfectant residual, factors that affect *Legionella* in a domestic water system include the size of the system; stagnation (whether due to design, operation, or use); complexity of the system; surface area relative to water volume; overall temperature range within the system; temperature variation among outlets; metallurgical makeup (e.g., galvanized, copper, PEX, plastic); equipment types (e.g., water heaters, water softeners); and whether or not the system was sanitized and cleaned before placing on line after construction or remodeling.

C. ASHRAE Standard 188 is the “industry standard” for managing disease risk. Since there are so many variables and combinations of variables in domestic water “ecosystems” that cannot be adequately described, it is not possible to unequivocally predict the degree to which a premise plumbing system might be harboring or colonized with *Legionella*. To manage and reduce the risk of disease, building owners should implement a Water Management Plan (WMP) that follows the framework outlined in ANSI/ASHRAE Standard 188. This standard includes measures to manage and control conditions that promote *Legionella* growth and transmission, as well as requires

procedures to validate the effectiveness of the WMP in controlling *Legionella*.

As the first *Legionella* standard in the United States, ANSI/ASHRAE Standard 188-2015 has received a great deal of attention and gained broad support. The CDC (CDC 2016, 2017) and the Centers for Medicare and Medicaid Services (CMS) (CMS 2017) as well as legal experts and supporting organizations such as AWT and CTI have stated that implementing a WMP per ASHRAE 188 is the industry standard for managing *Legionella* risk.

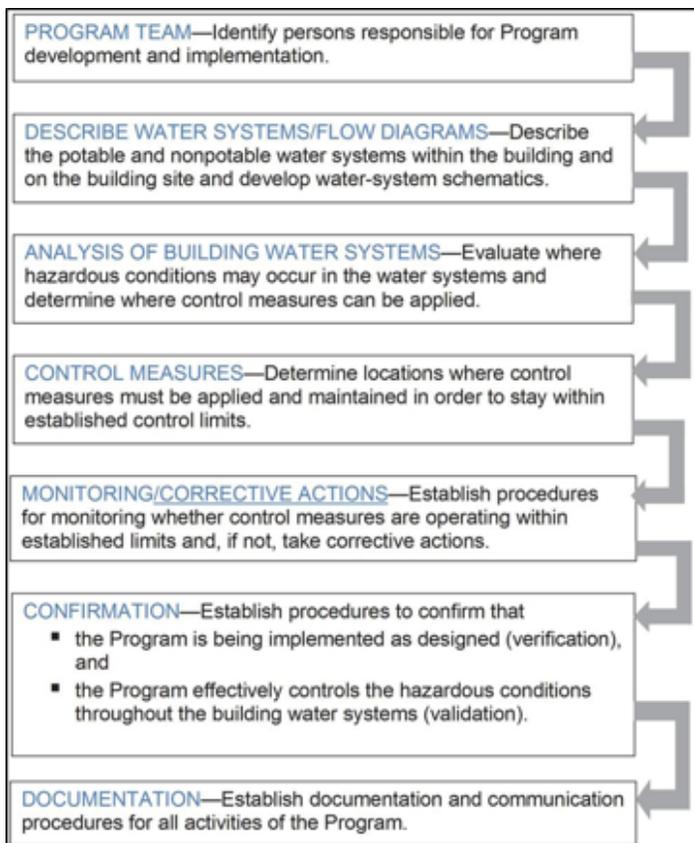


Figure 3: Courtesy ASHRAE Standard 188/Elements of a Water Management Program

WMPs should include the framework outlined in ASHRAE Standard 188, filled in with specific measures (“control measures”) for minimizing conditions that promote *Legionella* bacteria in domestic water systems. Control measures should be included and consideration given to the following:

- Operation and maintenance.
- Design and construction.
- Responding to Legionnaires’ disease should a case occur despite prevention efforts.
- Responding to incidents (e.g., water main breaks) and planning for events (e.g., temporary shutdowns) that can make a domestic plumbing water system (more) prone to *Legionella* contamination.

When the sampling, laboratory analysis, and interpretation of

test results are performed properly, testing water for *Legionella* provides the most direct and reliable validation of WMPs for domestic water.

D. Disinfection, filtration, and other intervention methods needed.

If validation test results indicate that *Legionella* will not be sufficiently controlled in a domestic water system simply by operating and maintaining the system to minimize conditions that promote *Legionella* growth, then additional measures will be needed. These measures often include a combination of chemical treatment with products approved for drinking water, along with equipment or piping changes and/or filtration.

Disinfection and filtration technologies continue to advance rapidly. The reader is advised to contact an experienced water treatment professional to provide the best solution for a given problem. Water treatment professionals who have the training and experience to help facility operators implement *Legionella* remediation strategies are an invaluable resource.

AWT provides extensive training to water treatment professionals and takes its role in improving public health very seriously, with endeavors to keep its members up to date on the latest technologies and best practices for disinfection and other intervention strategies in domestic water systems. This includes providing resources to evaluate and implement *Legionella* remediation technologies and procedures.

For domestic water systems in which *Legionella* is not under control, despite the WMP’s implementation of control strategies as well as maintenance and operating procedures, then one or a combination of the following options can also be considered:

1. Continuous chemical disinfection

Continuous chemical disinfection includes the selection and continuous use of a supplemental disinfectant in the domestic water system to control *Legionella*. It involves maintaining a residual disinfectant at safe levels and in compliance with EPA or other government regulatory authority, throughout the system, on a continuous basis. Some of the current technologies include the application of the following: chlorine, chlorine dioxide, copper/silver ionization, monochloramine, ozone.

Note 1: Any chemical additive used in drinking water systems must conform to the regulatory body governing drinking water for the area in which the facility resides. The regulatory body can restrict or control the use of additives in order to make sure the public is protected and supplied a safe drinking water in accordance with the U.S. Safe Drinking Water Act (SDWA).

Note 2: Continuous chemical disinfection is not the one-time or short-term application of using chlorine or any other

disinfectant at an elevated or “hyper-feed” level to the domestic water system, alone or in conjunction with heat and flush procedures. These are considered noncontinuous or temporary remediation procedures. Legionella remediation of a potable water system can be very complicated and very specific for a facility. It can require the use of significant manpower and can lead to serious consequences of corrosion and other issues. This type of remediation should be carefully considered and conducted by an experienced water treatment professional.

2. Filtration

Filters can be installed on faucets, showers, and other point-of-use (POU) sites, either temporarily or permanently, to prevent *Legionella* from flowing through the outlet. Filters can also be installed at or near points of building entry (POE) to minimize particles and *Legionella* entry to the system. The efficacy of POE filters in *Legionella* control has not been thoroughly studied. Some types of media (e.g., carbon) should not be used in POE filters because they may reduce or eliminate residual disinfectant in the water. POE filters must be well maintained to keep from promoting *Legionella* growth.

3. Physical changes

Changes in piping or types of equipment are sometimes necessary or beneficial in making a remediation strategy successful.

The following should be considered in selecting an intervention strategy (Freije 2013):

- Chemistry of the incoming water supply
- *Legionella* test results for the hot and cold water systems
- Safety of storing and handling any required chemicals
- Domestic water system materials of construction (e.g., metallurgy, coatings)
- EPA, state, and other applicable regulations
- Age and fouling of the system
- Health effects from exposure to the disinfectant and its byproducts
- Corrosiveness of the chemical disinfectant
- Availability and capability of an onsite crew to handle the maintenance
- Initial and ongoing costs

In addition to an effective disinfectant, the following are important factors for success in domestic water continuous disinfection (Freije 2013):

- The disinfection equipment must be properly selected, sized, and controlled. The equipment must be able to generate the amount of chemical required for the peak demand, considering both the water consumption and the quality of the incoming water supply. Underfeeding disinfectant can lead to *Legionella* concerns, while overfeeding can lead to corrosion and deposit issues.
- The chemical must be injected at the proper locations. If the chemical is injected at too few locations, or less than optimum locations, disinfectant residuals will likely be too high in some parts of the system and too low in others. Levels too high can promote either plugging or excess corrosion, and low levels will not be effective in controlling the bacteria.
- The disinfection equipment must be well maintained and operated properly. Simple as that sounds, it often does not happen. The facilities staff and water treatment vendor must work together, each doing their part, to ensure the equipment is operating properly.
- The domestic water system must be properly designed, operated, and maintained. Even if the disinfectant is injected at the optimum dose and locations, it will not likely be successful in controlling *Legionella* unless it maintains constant or frequent contact with all parts of the domestic water system. The WMP must include operation and maintenance procedures to ensure that the disinfectant has a chance to be effective.

Scientific literature is replete with reports of reasonable control measures and disinfection technologies that successfully reduced *Legionella* in domestic water systems and subsequently prevented new cases of Legionnaires' disease associated with those systems (Sidari et al. 2004; Shelton et al. 1993; Stout 2003; Zhang et al. 2009). Although more effective procedures and technologies will be discovered, enough information is available now to control and significantly reduce Legionnaires' disease by properly managing domestic water systems.

V. Cooling Towers: Water Treatment and Legionnaires' Disease

Cooling towers and evaporative condensers can provide favorable conditions for the growth and amplification of many microorganisms, including *Legionella*. Tower drift (water loss) becomes the mist or aerosol that can transmit potentially infectious *Legionella*. The evaporative (cooling) process causes makeup waterborne constituents as well as system water constituents to concentrate and accumulate in the tower loop according to cycles of concentration. The recirculating water's retention (residence) time in the water loop allows for increased growth and reproduction of organisms. Warm water temperatures, along with the presence of corrosion byproducts, sediment debris, and other deposits, further promote biofilm development and provide *Legionella* an ideal environment for growth and amplification.

A. Water chemistry and system maintenance should be well controlled in these systems. The chemical treatment objectives of any prudent water treatment program are to reduce corrosion, deposits, and microbiological fouling. These same practices will also significantly contribute to the control of *Legionella* growth and amplification. Nearly all cooling towers that have been linked to outbreaks of *Legionella* infections have been found to be poorly treated and maintained. However, *Legionella* has been found in cooling towers that appeared to be properly maintained and operated. (Bentham and Broadbent 1995) Therefore, efforts to prevent transmission (e.g., via efficient drift eliminators) and tests to validate *Legionella* control are important.

1. Biocide treatments

Biocide treatments play a major role in microbiological control programs, including the control of *Legionella*. However, biocide treatments do not generally target specific microbial organisms, nor are they 100% efficacious. In the case of *Legionella* control, it must be stressed that the efficacy of any specific biocide can only be determined by testing for the presence of *Legionella* in the field under actual operating conditions. Laboratory trials should not be relied upon exclusively for proof of a biocide's efficacy against *Legionella*. In addition, Total Bacterial Counts (TBC) of a cooling water system should not be relied upon for any definitive correlation to *Legionella* counts, control, or disease risk. Legionnaires' disease has been associated with systems where the total bacterial count was very low yet *Legionella* counts high. Systems have also been found to have very high total bacterial counts yet very low and even zero *Legionella* counts. Common practice as well as numerous guideline and regulatory recommendations suggest that biocide regimens incorporate the use of halogen or oxidizer chemistries to provide more effective microbial control.

2. Dispersants

Dispersants can play an important role in microbiological control programs. These chemicals act to loosen microbial deposits (e.g., slime, sludges) and promote system cleanliness. Dispersants promote biocide penetration of biofilm and enhance the effectiveness of biocides. Biofilm is often seen as the slime layer on surfaces in contact with water. *Legionella* flourishes within biofilm since it is nutrient-rich and contains a diverse population of microbiota, including algae, amoebae, and other protozoa. As opposed to being freely suspended (planktonic) in the bulk water, biofilm *Legionella* and *Legionella* within protozoa are protected from concentrations of biocide and/or other environmental conditions that would otherwise kill or inhibit them.

Dispersants should not be used alone in microbiological or *Legionella* control programs without also using biocides. In their various modes of action, dispersants may loosen and free large amounts of biofilm related bacteria (including *Legionella*) into the bulk water. These bacteria may be viable and (now in the bulk water) have the potential to be transmitted from the tower and pose a Legionnaires' disease health risk. Dispersants are meant to supplement and enhance the performance of biocides, not replace or serve as an alternative to the use of biocides.

3. Filtration

Filtration is considered a useful support tool for ongoing removal of suspended matter which could otherwise contribute to the proliferation of the *Legionella* organism. There are many devices capable of removing suspended matter (dirt and debris). These include media, sand, bag, cartridges, screens, and separators. Reducing suspended solids to below 10 microns is considered acceptable operational control for cooling towers. Filters also can entrap bacteria during their operation and become a feeding ground for the bacteria. Manufacturer's guidelines should be followed to successfully purge trapped debris from the filter, which might mean backwashing, filter bag or cartridge changes, manual cleaning of screens, etc. However, bacteria can collect in the depths of media and sand filters, preventing removal by simple backwashing. Thus, monitoring the filter inlet and outlet for bacterial characteristics is always recommended, and conducting regular sanitizations of the media can be required so as to prevent *Legionella* growth inside the media bed.

B. Cooling tower disinfection for the purpose of *Legionella* control and disease prevention is generally recommended for:

- Maintenance actions for startup, post lay-up, or regularly scheduled cooling tower cleaning.

- Corrective control actions following system *Legionella* sampling with elevated counts.
- Required actions following a confirmed or suspected system's Legionnaires' disease case.

The following is an abbreviated version of the emergency cooling tower disinfection method described by the CDC, 1997. This procedure is often recommended if there is suspicion that the tower may have been the source of exposure for a case of Legionnaires' disease. The complete methodology should be previewed for a full understanding of the CDC procedure. It should be noted, however, that most experts differ with respect to the chlorine levels recommended and the frequency of using this type disinfection due to the potential damage by chlorine to system materials of construction. Guidelines established by ASHRAE (2000) and by CTI (the Cooling Technology Institute) (1996) should also be consulted.

1. Shut off the cooling tower fans.
2. Keep makeup water valves open and the circulation pumps operating.
3. Close outdoor air intake vents located within 30 meters of the cooling tower.
4. Achieve an initial free residual chlorine (FRC) of at least 50 ppm; some states require application of an EPA-approved chlorine product only at levels not higher than 5–10 ppm initially.
5. Add a dispersant to tower water within 15 minutes of chlorine addition, then maintain 10 ppm FRC for 24 hours; pH testing and adjustment is needed to ensure that pH is maintained between 7.0 and 8.0 during chlorine circulation. Some have also found it useful to incorporate chlorine dioxide as an effective penetrating agent at this step.
6. Drain and refill the system, then repeat steps 4 and 5 at least once to remove all visible algae-like film.

7. Using a brush and water hose, thoroughly clean all water-contact areas, including the basin, sump, fill, spray nozzles, drift eliminators, and fittings, and manually remove all dirt and debris.

8. Circulate 10 ppm FRC for one hour, then flush the system until free of all sediment.

9. Refill the system with clean water and return to service.

10. Following any disinfection cleaning, perform validation testing for *Legionella* approximately 3-5 days after the work was completed, allowing time for the system to stabilize.

Note 1: *It is recommended that proper safety protocols be followed for dealing with hazardous chemicals and respiratory protection before conducting the above procedure. Also, local, state, governmental or other AHJ's may require certified applicator licenses or have other regulatory requirements for conducting this protocol.*

Note 2: *It is generally recommended that dispersant-chlorination disinfection procedures for Legionella also include a final step maximum dosing (per EPA label) of a nonoxidizing antimicrobial combination—either a synergistic combination in one product or two separately applied products.*

Note 3: *If this procedure is used in response to an event associated with Legionnaires' disease, then the entire procedure may need to be repeated.*

C. Cooling tower inspections are an important part of successful maintenance. Operations departments should incorporate visible inspections of tower internals, distribution decks/nozzles, fill, pans, and drift eliminators into routine PM operations. Doing so on a prescheduled basis will certainly support discovery of adverse conditions that could lead to *Legionella* growth. It is also advisable to inspect the cooling tower following any disinfection.

VI. Cooling Towers and *Legionella*: Objectives and Guidelines

A. Cooling tower *Legionella* objectives—minimizing counts and transmission.

Because of the potential for any cooling tower to harbor, amplify, and disseminate *Legionella*, control measures need to be considered for all cooling tower and evaporative condenser operations. *Legionella* control measures should emphasize both controlling the growth and colonization of *Legionella* within the tower system as well as the transmission or dissemination of *Legionella* within the drift from the tower system.

1. Minimizing *Legionella* growth in cooling towers and evaporative condensers

Keeping *Legionella* below detectable levels in every cooling tower system at all times is not feasible and should not be expected; however, practices and precautions to control and reduce *Legionella* in cooling towers should be an ongoing water management program effort. Many of the measures that are generally recommended for *Legionella* control in cooling towers are also recommended for the efficient operation and proper maintenance of a cooling tower system and include:

- Periodic cleaning
- Regular maintenance
- Effective water treatment

When applied collectively, these measures generally minimize *Legionella* counts in a tower but cannot be expected to eliminate them entirely in every system. Even seemingly properly maintained and operated cooling towers have been found to have high *Legionella* counts. Whenever high concentrations of *Legionella* are encountered and in lieu of any regulatory guidance, a full review of the entire program should begin immediately. Actions should include retesting and possibly an online disinfection. These actions are especially appropriate at healthcare facilities that house large numbers of at-risk individuals. In cases where local, city, state, or federal regulations are already in place, high *Legionella* counts will automatically trigger further actions. Depending on the regulations, actions may include a program review, retesting, and/or online decontamination.

2. Operational guidelines for minimizing *Legionella* counts in cooling towers and evaporative condensers

The following guidelines and procedures are the basis of a WMP and are described in more detail in ASHRAE Standard 188 and numerous other government and industry laws or guidelines designed to minimize *Legionella* counts in the tower and minimize transmission of *Legionella* from the tower to people:

- a. Clean tower and disinfect before startup, especially

with a new system, and after any long shutdown period (greater than two weeks).

- b. Treat water for control of corrosion, scale, fouling, and microorganisms.

- c. Establish a maintenance plan and log all activities, including the chemical treatment program's dosages, services, and results.

- d. Maintain all drift (mist) eliminators in efficient and proper operating condition as well as the operations of fans that affect drift productions.

- e. If dead-legs in the piping system exist and cannot be removed, blow them down regularly—particularly after biocide treatments and cleanings. Dead-legs are not always obvious or easy to clean.

- f. Exercise all valves in the system periodically by opening and closing them fully.

- g. Clean the basin when slime, algae, or dirt are visible.

- h. Blow down direct free cooling (chilled water) risers weekly.

- i. Thoroughly flush and clean the entire system at least once (preferably twice) a year, and include an oxidizing (or nonoxidizing) disinfection before and after each cleaning.

- j. Where a cooling tower is out of use, it should be drained and kept dry. If it is used intermittently, then dosing it with a nonoxidizing biocide might be more realistic.

- k. In cases where local, city, state, or federal regulations (e.g., New York City, New York State) are already in place, more specific procedures may supersede the guidelines listed above.

3. Minimizing *Legionella* transmission from cooling towers (to people)

Minimizing transmission from the tower to a host is the second responsible measure necessary in reducing risk of Legionnaires' disease, again, recognizing that there are no guarantees for keeping a tower system completely free of *Legionella*. The following considerations should be taken:

- a. Minimize tower drift with proper and well-maintained eliminators.

- b. Locate tower to keep drift and plume away from air intakes.

- c. If necessary, relocate building air intakes away from the cooling tower or vice versa.

- d. Workers or others who have exposure working around cooling towers should use appropriate personal protective equipment (including respirators). One should follow all regulatory requirements for medical evaluation and fit testing if using respiratory protection.

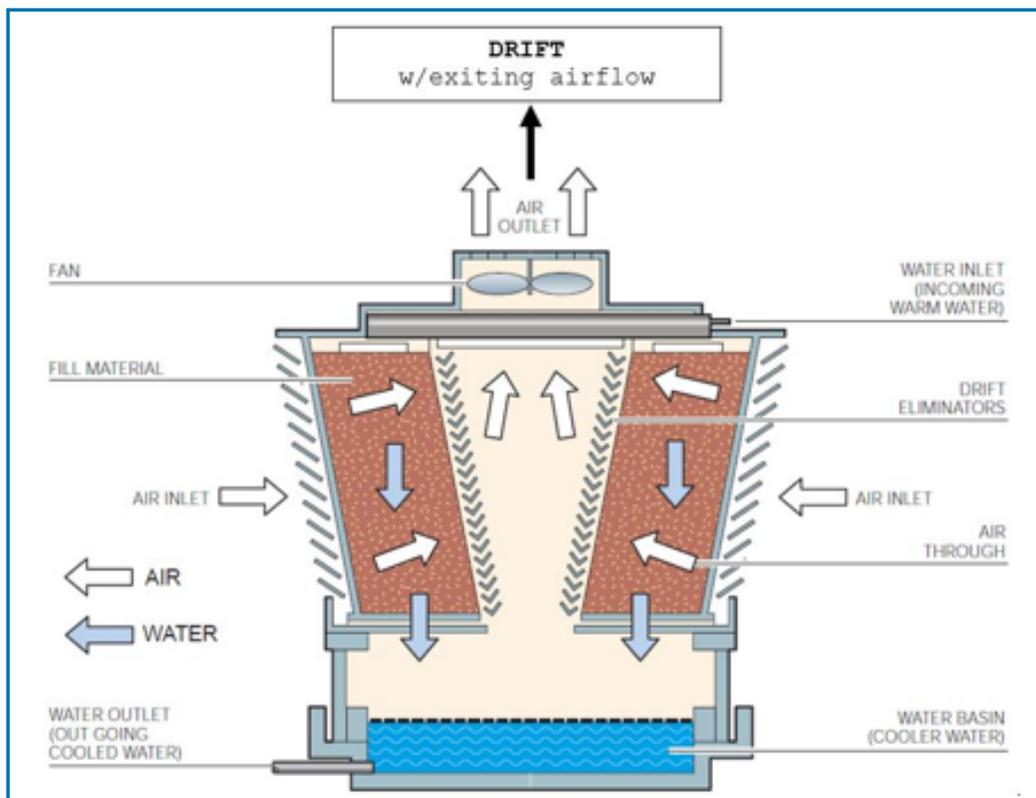


Figure 4: Cooling towers and drift eliminators

The graphic in Figure 4 shows the physical structure and mechanical design of a typical cooling tower where aerosols of the recirculating water can be produced and “leave” the tower system as “drift” with the exiting airflow. Drift eliminators are thus a very important part (structure) of the cooling tower system to limit this water loss and the potential transmission of *Legionella* from the tower. As such, their consideration and maintenance are important aspects of the cooling tower or evaporative condenser water management program for the control of potential disease transmission.

B. Design guidelines for cooling towers and evaporative condensers.

The following actions should be taken into consideration to minimize *Legionella* counts in the tower and minimize transmission of *Legionella* from tower to people. In cases where local, city, state, or federal regulations (e.g., New York City, New York State) are already in place, more specific procedures relating to some or all of the following will supersede the guidelines listed below. Please refer to the appendix for the New York City/New York State regulations and the CDC toolkit.

1. Tower location should consider prevailing winds and proximities with respect to potential populations of people (particularly at-risk populations), including air intakes, picnic areas, and other high-density population areas, such as smoking-permitted areas near the proposed cooling tower.
2. Tower location should consider prevailing winds and proximities that could introduce bacterial nutrient sources into the tower (e.g., kitchen exhausts, industrial processes).

3. Shield or cover cold-water basins, distribution decking, and other wet surfaces from sunlight to prevent algae growth.
4. Materials of construction should be smooth and nonporous.
5. Water distribution piping should:
 - Be as simple as possible, avoiding dead-legs, low-flow, stagnant lines, and loops that are difficult to drain.
 - Promote effective flow through the entire system, utilizing equalization lines when necessary
6. Towers should be easily accessible for inspection, sampling, cleaning, and disinfecting.
7. The system should be designed to be completely drained or pumped out.
8. Provisions should be made to effectively dose, monitor, and control a water treatment program, including: a) inhibitor and biocide/s chemical injection, b) water sampling, c) corrosion coupon sampling, and d) effective bleed and control points.
9. High-efficiency drift eliminators should be used and maintained.
10. Multiple-cell tower basins should be designed such that each cell and basin can be isolated, while the other cells remain in operation.
11. The tower system’s total operating volume should be known for proper chemical dosing, (e.g., biocide and dispersant treatments).
12. Stagnant or intermittent-flow zone areas within the cooling system loop should be periodically circulated (generally recommended at least twice a week).

VII. Sampling and Testing for *Legionella*

A. Preface 1: *Legionella* testing—logic. Sampling and testing for *Legionella* can be useful in assessing risks and in determining whether preventive and corrective measures are working. Having an action plan based on test results from *Legionella* sampling can alert you to increased risks and as to whether disinfection procedures should be implemented. This logic is an integral part of ASHRAE Standard 188, which requires that a WMP contain a confirmation/validation step to document that the plan “establish procedures to confirm that the program effectively controls the hazardous conditions throughout the building water systems.” While the WMP team is responsible for providing validation evidence of the WMP, it is given the latitude to choose how to validate the WMP. However, *Legionella* testing is the only direct or “active” way (currently) to validate program effectiveness, short of proving there is no Legionnaires’ disease associated with the WMP systems.

Testing for *Legionella* is discussed in virtually all *Legionella* guidance documents, such as ASHRAE Standard 188; federal, city, and state regulations; OSHA; and New York City, State of New York, and public health guidance (from the CDC).

B. Preface 2: Guidance if *Legionella* testing is utilized.

Testing of environmental water samples for *Legionella* should be conducted by a laboratory with demonstrated proficiency evidenced by certification by a national, regional, or local government agency or by an accredited nongovernmental organization (NGO), such as the American Association for Laboratory Accreditation or the Environmental Microbiological Laboratory Accreditation Program. Laboratories performing *Legionella* culture testing of environmental water samples should perform these tests according to a nationally or internationally recognized standard (e.g., ISO/IEC 17025:2017). At a minimum, proficiency of *Legionella* culture testing should be demonstrated by achieving certification by one of the following:

- a. The CDC Environmental *Legionella* Isolation Techniques Evaluation (ELITE) program
- b. The European external quality assessment/proficiency testing program for *Legionella* isolation through Public Health England
- c. Accreditation by the American Industrial Hygiene Association (AIHA) for the Environmental Microbiological Laboratory Accreditation Program (EMLAP)
- d. Certification by New York State (required by all labs that analyze environmental samples for the presence of *Legionella*)

A more current and informative discussion of *Legionella* sampling and testing is found in ASHRAE Guideline 12-2000R,

Managing the Risk of Legionellosis Associated with Building Water Systems, First Public Review (July 2017). This guideline is intended to supplement Standard 188 with more procedural details.

C. Testing for *Legionella*. Testing for *Legionella* should be performed to answer specific questions. The results are then interpreted within this framework. For example, testing may be performed in the context of a case investigation. In these situations, selection of sampling locations must include the locations in the immediate vicinity of the exposed individual or patient. Testing may also be performed to confirm that the risk of exposure to *Legionella* from building water systems has been managed and controlled by a WMP. According to ASHRAE Standard 188, the WMP shall establish that the program successfully controls the conditions that contribute to the potential for harmful human exposure to *Legionella*. The selection of sampling locations for evaluating effectiveness of a WMP should include representative locations throughout the building water systems (potable and nonpotable and devices).

Testing may also be useful for routine monitoring to evaluate potential growth and transmission of *Legionella*, confirming the effectiveness of remedial treatments and the investigation of potential sources of disease. Facilities with higher risk of disease may find information from *Legionella* testing useful (Section 4). Examples of such facilities are:

- Healthcare facilities (hospitals, critical access hospitals, and long-term care) that treat at-risk patients.
- Facilities where control measures, such as water temperatures and disinfectant residual levels, are not being maintained consistently within target limits throughout the building water system.
- Facilities with a recent history of legionellosis associated with the building water systems.

Interpretation of *Legionella* test results for assessing disease potential (probability of acquiring legionellosis) is influenced by many factors. These factors include, but are not limited to, the species and serogroup of *Legionella* (strain virulence), host susceptibility, and the extent of exposure to *Legionella*. The concentration of *Legionella* in a given sample and the proportion of samples that test positive can be used along with other risk factors in assessing the risk of disease; however, no single factor has been found to be predictive of disease, and the infectious dose of *Legionella* for a susceptible human host is unknown.

1. Sample selection, collection, and transport

Failure to collect samples properly may compromise and

invalidate test results. The testing laboratory's instructions for sample collection and transport, as well as chain of custody and sample identification information, should be meticulously followed.

Sampling plans for *Legionella* testing should consider the entire building water system and include, at a minimum, the entrance of potable water into the building, storage tanks, distribution points, process steps that have low-flow conditions, and points-of-use that are close to and far from distribution sites. A water distribution diagram or process flow diagram as specified in ASHRAE Standard 188 is useful in determining the points at which to collect samples for *Legionella* testing. The drawing of a building water system also includes the location of all water processing steps, including conditioning, storing, heating, cooling, recirculation, and distribution. An example of such a diagram can be found in ASHRAE Guideline 12-2000R, *Managing the Risk of Legionellosis Associated with Building Water Systems*, First Public Review Draft 70.

The CDC document *Sampling Procedure and Potential Sampling Sites* may also be helpful in determining representative sample points and establishing sampling criteria, such as the volume of a water sample collected for *Legionella* testing; types of samples to be analyzed (e.g., potable, cooling tower, whirlpool spas); and the method of analysis (e.g., culture, PCR).

For potable water, a first draw water sample is collected immediately after the tap or fitting is opened. A first draw sample represents the water the user is likely to be exposed to and is the water held within the tap or fitting and the adjacent connected piping. Ideally, the sample should be taken when the tap has not been recently used. A first draw sample may have little or no residual disinfectant and may include water that has been open to the environment. These hazardous conditions could result in significantly higher *Legionella* concentrations. Flushing outlets prior to sample collection is likely to reduce the positivity and concentration of *Legionella* recovered. Immediately after collecting a water sample, temperature and/or disinfectant residuals are often determined if remedial steps are anticipated.

Hot water systems are the most likely source of exposure from the potable (domestic) building water systems and therefore should be the focus of sample collection unless specific circumstances suggest otherwise. Cold water sources such as ice machines should also be investigated, however, since water in ice machines can achieve warm water temperatures.

Swab samples from building water systems typically are collected during disease or environmental investigations to obtain biofilm samples that may harbor *Legionella*. Surfaces should be swabbed before water is collected from any device.

Before a swab is taken, it may also be necessary to remove the device (e.g., an aerator) to obtain an adequate sample of biofilm. It is important to make sure the surface to be swabbed is moist so that the sampled material adheres to the collection swab. Moistening of the swab with a couple of drops from the device outlet may be necessary. Cotton swabs should not be used because cotton inhibits the growth of bacteria.

For nonpotable water systems or equipment, sample locations are dependent upon system configurations and should be representative of system water.

Follow the testing laboratory's instructions to treat water samples. These instructions usually include the use of a sodium thiosulfate additive, a reducing agent that neutralizes oxidizing biocides (chlorine, bromine, iodine, monochloramine, and chlorine dioxide) and some nonoxidizing biocides. Unless these biocides are neutralized at time of sample collection, *Legionella* growth and death may be affected during transportation of the sample. Samples should be transported to the laboratory at ambient room temperature in insulated containers within 24 hours from the time of collection. Consistent sample collection and transport procedures are essential for making useful comparisons from one set of test results to the next. Samples should be received by the laboratory as soon possible after the time of collection. If the time must exceed 48 hours, then consult with the laboratory for instructions.

2. *Legionella* test methods

A variety of test methods are available for evaluating the presence and distribution of *Legionella* in building water and associated water systems that include culture and nonculture analysis. The selection of a suitable test method should be a decision made by individuals knowledgeable in microbiology, including the strengths and limitations of test methods, as well as individuals with knowledge of building water systems design and water management as it relates to legionellosis. This knowledge may or may not be within the WMP team. Consult with a testing laboratory that is accredited for *Legionella* testing for guidance on testing methods. In legionellosis case investigations, the method should be capable of detecting all *Legionella* species so as to provide the isolated organism for future molecular and epidemiological typing.

The method selected may depend on both the type of building water system tested and the reason for testing. For example, a method for detecting viable cells, such as culture testing, may be preferred when evaluating *Legionella* growth trends in a building water system and the validation of WMPs, even though culture test results are not quickly available. Alternatively, when evaluating whether remediation of a building water system was successful, it may be more useful to use a test method with quick turnaround time, such as PCR

testing. If a comprehensive examination of building water systems is needed, it may employ more than one test method. Consult with a qualified expert to assist with selection of the most appropriate test method, proper sample collection, and transportation procedures as well as for an explanation and interpretation of test results. Each testing method has both strengths and limitations that should be considered.

a. Culture

Culture is the most frequently used test method to determine whether there are detectable levels of viable *Legionella* bacteria in a sample. Culture testing has advantages over other microbial test techniques because it can discriminate between live and dead organisms, and it can detect all *Legionella* species and serogroups, including those not previously recognized. Most laboratories use some variation of the CDC or “ISO11731:2017, Water Quality—Enumeration of *Legionella*” method, but details such as sample volumes, plate types, and re-suspension methods may differ among laboratories. The ability to detect *Legionella* in a given sample is dependent on factors that go beyond the actual method of analysis and include the method of collection, time to transport the sample, processing methods, and laboratory experience.

Legionella culture test results are highly dependent upon the skill, experience, and procedural rigor of the laboratory. The generally accepted limit of detection for cooling water is about 10 CFU/ml, but this will vary depending on how and how much sample was processed. Final results from culture tests typically are reported in colony-forming units (CFU) per volume (milliliter or liter) and available 7–10 days after samples are processed. Colonies large enough to be visible to the naked eye are typically present within three or four days, so preliminary results may be available prior to seven days.

b. Polymerase chain reaction (PCR)

The most common non-culture methods used to evaluate environmental samples of *Legionella* are variations of the PCR procedure using *Legionella*-specific DNA or RNA templates. PCR holds the potential to detect all known *Legionella* species and forms, including dead and viable but non-culturable (VBNC) organisms, with a high degree of sensitivity and selectivity. Results from PCR tests are typically reported in genomic units (GU) and can be available the same day the laboratory receives the sample. GUs cannot be equated with CFUs. Currently, PCR methods are limited because viable organisms that may be able to cause infection cannot be differentiated from nonviable *Legionella*. Other limitations of PCR include the inability to discriminate between strains,

cross-reaction with non-*Legionella* bacteria (i.e., a false positive result), and chemicals in the sample that inhibit the PCR reagents. Although PCR results may be available in a matter of hours, the results should be interpreted with these limitations in mind. Notwithstanding these limitations, PCR testing is useful for negative screening of microbial samples for *Legionella*, especially when used in conjunction with culture methods.

c. Other detection methods

Other methods of detecting *Legionella* in environmental samples may utilize antibodies, liquid culture and bacterial enzymes, colorimetric indicator dyes, or even electrostatic potential. Unlike culture and PCR testing, such methods typically detect only a particular species or serogroup of *Legionella*. However, the “target testing” for the dominant disease-causing species, *Legionella pneumophila*, is gaining global recognition as a sensible approach in water safety and management program validation testing plans, as supported by the World Health Organization (WHO) and recognized by the EPA. The European Center for Disease Protection and Control (ECDC) releases an annual *Surveillance Report* that covers more than 25 European countries. The most recent reporting covers a seven-year period from 2009–2015 and includes more than 4,700 reported Legionnaires’ disease cases that were confirmed by culture testing. The results show that 95–99% of the cases in every year of the reporting were attributed to *Legionella pneumophila*.

The specificity and sensitivity of other detection methods may vary and must be considered. As well, the performance criteria for some methods may not have been standardized, so their utility for either positive or negative screening may not have been validated in well-designed studies; however, there are evolving and new technologies on the horizon in *Legionella* detection methodology that should be appropriately evaluated.

3. Interpretation of *Legionella* test results

Test results represent the concentration of *Legionella* in the sample at the time the sample was tested, including any increases or decreases due to factors such as sample handling, preparation, and transport testing variability. There can also be considerable fluctuation in the concentration of *Legionella* between different sample locations within a building water system as well as fluctuations due to changes in building use patterns and seasonal conditions. Reporting the results of *Legionella* testing to the public or to environmental health authorities is not generally required when it is not linked to a case of disease; however, it is important to confirm reporting requirements with the authority having jurisdiction.

In the absence of cases of disease, viewing trends in *Legionella* test results is one method for validating a WMP. Test results can also be useful in confirming that system control measures are working as intended and can be used in conjunction with known hazardous conditions when assessing the risk of disease. Results of *Legionella* testing alone do not provide a complete measure of risk assessment and should not be the sole basis for initiating remediation procedures. Corrective actions in response to *Legionella* test results should be incorporated in the WMP and results discussed with the WMP team.

4. Responses to *Legionella* test results

If results from testing for *Legionella* indicate that the *Legionella* control has not been met as per the objectives set forth in the WMP, the following actions need to be taken:

- a. Review the sample collection, handling, and testing procedures to confirm that the results are not due to errors.
- b. Confirm that system equipment is in good working order and functioning as intended.
- c. Review records to confirm that the WMP was implemented as designed.
- d. Review assumptions about operating conditions, such as the physical and chemical characteristics of the water supplied to the building.
- e. Reevaluate fundamental aspects of the WMP, including the analysis of hazardous conditions, cleaning and maintenance procedures, chemical treatment, and other aspects of the WMP that could affect results of *Legionella* testing.
- f. If review or re-evaluation of the WMP indicates deficiencies, adjust the WMP as necessary.
- g. After careful review, re-evaluation and possible adjustment of the WMP, consider whether remedial treatment is needed. In all cases, if the root causes of *Legionella* growth are not identified and controlled, growth of *Legionella* is likely to reoccur.

Results of testing for have been interpreted based upon concentration, the extent of colonization, and the type of *Legionella*. For instance, recovery of low concentrations of bacteria from several representative sites may indicate that *Legionella* growth in the building water system is not well controlled. When considering remedial efforts, evaluation of low concentrations of *Legionella* strains known to be more likely to cause disease, such as *Legionella pneumophila*, may indicate a greater risk than equivalent concentrations of *Legionella* strains known to be less likely to cause disease, such as *Legionella anisa* and *Legionella bozemanii*. Whenever a case of disease is associated with a building water system, whether the association is only possible or is confirmed, WMP confirmation activities (verification and validation) should be reviewed and the WMP re-evaluated and revised. *Legionella* test results should never automatically trigger actions such as remedial treatment. Actions should be taken only after careful review and re-evaluation of the WMP.

5. *Legionella* test results, interpretations, and action plans

Test results must be interpreted comprehensively and analyzed with respect to applicable regulations. There are various guidelines and action plans that are publicly available, such as from OSHA, AIHA, CDC, VA, New York State, New York City, and others shown in the Appendix. The WMP team may want to refer to the latest scientific findings and technical papers.

The goal of a *Legionella* WMP is to prevent cases of Legionnaires' disease and legionellosis. Achieving zero detectable *Legionella* in a water source is nearly impossible. Finding some *Legionella* in a water source must be carefully interpreted and does not constitute an emergency.

VIII. Healthcare Facilities—A Special Legionnaires' Disease Risk Environment

Potable water plumbing systems of healthcare facilities present a favorable habitat for *Legionella* and pose an associated risk of disease to the susceptible host populations within the healthcare community. These facilities are often required by state regulatory agencies to maintain the hot water at lower temperatures to avoid the risk of scalding. Unfortunately, these temperatures are often favorable for *Legionella* growth. *Legionella* bacteria are not found in all healthcare facility water systems. Depending on the report, anywhere from 12 to 70% of healthcare facilities may be colonized by *Legionella* (Stout and Yu 2003).

Among outbreak investigations conducted by the CDC between 2000 and 2014, hospitals and long-term care facilities were the implicated sources of 34% of outbreaks and 57% of the deaths (Garrison et al. 2016). Among the 2,809 cases of Legionnaires' disease reported to the CDC in 2015, approximately 20% were healthcare associated (CDC 2016 and 2017). Thus, there is a major emphasis on the risk assessment and control and management of these systems and their associated water-disseminating equipment or systems in healthcare facilities.

In accordance with this concern, the Centers for Medicare and Medicaid Services (CMS) issued a policy memorandum for healthcare facilities about facility requirements to prevent *Legionella* infections. This policy memorandum applies to hospitals, critical access hospitals (CAHs), and long-term care (LTC) facilities. CMS further states that this policy memorandum is also intended to provide general awareness for all healthcare organizations. Medicare certified healthcare facilities must develop policies and procedures that reduce the risk of growth and spread of *Legionella* in building water systems. Documentation of water management implementation will be reviewed by surveyors to verify that facilities:

1. Conduct a facility risk assessment to identify where *Legionella* and other opportunistic waterborne pathogens could grow and spread in the facility's water system.
2. Implement a water management program that considers the ASHRAE industry standard and the CDC toolkit, and includes control measures such as physical controls, temperature management, disinfectant level control, visual inspections, and environmental testing for pathogens.
3. Specify testing protocols and acceptable ranges for control measures and document the results of testing and corrective actions taken when control limits are not maintained.

The CMS memorandum is much more specific and potentially punitive than a previously issued Joint Commission for the Accreditation of Healthcare Organizations (JCAHO) Environment of Care instruction (EC1.7). Now known as The Joint Commission (TJC), the 2001 JCAHO instruction vaguely required accredited

healthcare facilities to have a management program to "reduce the potential for organizational-acquired illness" and for "managing pathogenic biological agents in cooling towers, domestic hot water, and other aerosolizing water systems" (i.e., *Legionella*, among others). TJC now fully requires that the CMS memorandum of June 2017, updated in July 2018, be followed.

A. Healthcare facilities—risk assessment and management plans. Healthcare facility surveyors now clearly expect healthcare facility managers to have a risk assessment and management plan in place. Basic considerations are outlined below:

1. Risk Assessment

- a. Work with the Water Management Team to assess the clinical risk of the patient population to identify and review:
 - The treatment and care areas of patients at greatest risk.
 - Any cases or current history of infections, including legionellosis, resulting from waterborne pathogens.
- b. Assess the environmental risk from potential amplification factors such as:
 - Domestic hot water systems.
 - Design (e.g., dead-legs, low-flow conditions).
 - Operation (e.g., water temperature).
 - Maintenance (e.g., flushing and cleaning of hot water tanks).
- c. Assess cooling and humidifying systems that produce aerosols:
 - Design (e.g., drift eliminators).
 - Operation (e.g., sterile water in room humidifiers).
 - Maintenance (e.g., cleaning cooling towers and using an effective biocide).

2. Risk Assessment

- a. If susceptible patients are identified, work with the infection control practitioner to determine what aerosolizing systems are present in that patient's environment (e.g., showers) and limit their access to these systems.
- b. Develop a WMP as a result of the assessment (step 1) that includes standard operating procedures (SOPs) for maintenance and operation of water systems. ASHRAE requires an annual survey to assess changing conditions.
- c. Develop a system to document and log activities and findings such as temperatures, blow down of hot water tanks, and cooling tower inspections.

d. Include a maintenance and audit program for any systems that are currently installed to limit *Legionella* amplification in aerosolizing systems such as cooling towers and/or potable water treatment systems (e.g., copper-silver or chlorine dioxide biocides).

e. Inspect cooling towers/evaporative coolers to ensure that they are in proper condition and operate as designed.

B. Corrective actions and remediation (if required).

Work with the WMP team and other experts to establish and follow corrective actions in the WMP.

IX. Online Legionella Information

A great deal of information on *Legionella* and Legionnaires' disease, both international and multidisciplinary, is accessible via the internet. The following websites are listed as resources for additional information. The list is certainly not all inclusive but provides an excellent collection of on the subject matter and includes other linked sites for additional information. The list is restricted to government, authorities having jurisdiction,

academia, professional organizations, and otherwise noncommercial, not-for-profit entities.

Note: Many AWT member companies, particularly associate member (supplier) companies that offer Legionella testing and consulting services, have websites that are rich resources for information on the subject matter. They can be accessed by the Legionella Reference and Resources link on the AWT website.

1. Laws

<http://regs.health.ny.gov/content/part-4-protection-against-legionella>

New York State Department of Health regulations for *Legionella* in cooling towers and potable water in healthcare facilities.

<http://www1.nyc.gov/assets/doh/downloads/pdf/notice/2016/noa-chapter8-title24.pdf>

New York City government website; download Chapter 8 (Cooling Towers) of Title 24 of the Rules of the City of New York.

<http://www.hse.gov.uk/legionnaires/>

HSE (Health Safety Executive), U.K. website that provides practical advice and guidance to control the risks from exposure to *Legionella* in manmade water systems and the U.K. requirements (duties) under regulation.

<https://www.canada.ca/en/employment-social-development/services/health-safety/prevention/legionella.html>

Government of Canada website; download the "*Legionella* in heating, ventilation and air conditioning systems" document and link to the Canada Occupational Health and Safety Regulations (COHSR), Part II, Division III titled "HVAC Systems," which contains requirements regarding HVAC systems, such as standards, records, operation, inspection, cleaning, testing, maintenance, and investigations.

2. Guidelines

<https://www.ashrae.org/technical-resources/bookstore/ansi-ashrae-standard-188-2015-legionellosis-risk-management-for-building-water-systems>

ASHRAE (American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc.) website; download ANSI/ASHRAE Standard 188-2015, "Legionellosis: Risk Management for Building Water Systems" and latest position and guideline papers on Legionellosis.

<http://www.awt.org>

AWT (Association of Water Technologies) website; download information about water treatment and *Legionella*.

<https://search.cdc.gov/search/?query=Legionella&utf8=%E2%9C%93&affiliate=cdc-main>

CDC (The Centers for Disease Control and Prevention) website; links to over 2,500 results for *Legionella*, including the latest revision of the Model Aquatic Health Code.

<http://www.cti.org>

CTI (Cooling Technology Institute) website, formerly the Cooling Tower Institute; download the latest position papers on *Legionella*.

<http://www.osha.gov>

OSHA website; search and get OSHA Legionnaires' disease information, including the latest manual (Section III, Chapter

7) on Legionnaires' disease.

3. Healthcare Guidelines

<https://www.cms.gov/Medicare/Provider-Enrollment-and-Certification/SurveycertificationGenInfo/Downloads/Survey-and-Cert-Letter-17-30.pdf>

CMS (Centers for Medicare and Medicaid Services) website and the "Requirement to Reduce *Legionella* Risk in Healthcare Facility Water Systems to Prevent Cases and Outbreaks of Legionnaires' Disease."

<https://phpa.health.maryland.gov/IDEHSharedDocuments/Legionella-Scientific-Working-Group-Guidance.pdf>

Maryland Department of Health and Mental Hygiene "Report of the Maryland Scientific Working Group to Study *Legionella* in Water Systems in Healthcare Institutions" (June 14, 2000)

http://www.va.gov/vhapublications/ViewPublication.asp?pub_ID=3033

Department of Veterans Affairs (Veterans Health Administration) website; see VHA Directive 1061.2014: Prevention of healthcare-associated *Legionella* disease and scald injury from potable water distribution systems.

<https://www.aiha.org/about-aiha/Press/2015PressReleases/Pages/AIHA-Provides-Preventative-Guidance-in-New-Legionella-Guideline.aspx>

AIHA (American Industrial Hygiene Association) website; download the 2015 guideline on *Legionella* titled, "Recognition, Evaluation, and Control of *Legionella* in Building Water Systems."

4. Additional Resources

<https://www.epa.gov/ground-water-and-drinking-water/legionella>

U.S. EPA (Environmental Protection Agency) website; the latest *Legionella* (Ground Water and Drinking Water) information 2016 publication: "Technologies for *Legionella* Control in Premise Plumbing Systems: Scientific Literature Review."

<https://www.ncbi.nlm.nih.gov/pubmed/25203696>

PMC (PubMed Central) free full-text archive of biomedical and life sciences journal literature at the U.S. National Institutes of Health's National Library of Medicine (NIH/NLM). Journal of Public Health Management and Practice article, "Legionellosis on the Rise: A Review of Guidelines for Prevention in the United States." (2015)

http://www.who.int/water_sanitation_health/emerging/legionella.pdf

WHO (World Health Organization) website; download the 2007 publication "*Legionella* and the prevention of legionellosis" as well as any updates and current information ("Key Facts") on the subject matter.

X. AWT Legionella and Legionellosis Position Statement

AWT makes the following recognition and position statements regarding *Legionella*, legionellosis, water treatment, and the related practices of water treatment professionals. They are based on the significant and prevailing information from ASHRAE, the CDC, CTI, EPA, OSHA, WHO, academia, and the medical community, subject matter experts, and other authoritative agencies that study, investigate, and deal with *Legionella* and legionellosis prevention.

1. AWT supports the ANSI/ASHRAE Standard 188 (Legionellosis: Risk Management for Associated Building Water Systems) and the importance of following a risk management process that has a WMP to control and manage *Legionella* in building water systems to prevent legionellosis.

2. AWT emphasizes that potable water, especially in healthcare facilities, but also in other large buildings, hotels, resorts, and facilities with complex hot water systems, is the most common and important source of *Legionella* and disease transmission.

- The domestic (potable) water system must be properly designed, operated, and maintained to not provide *Legionella* or other opportunistic microorganisms with a favorable environment for growth and proliferation.
- During new construction and renovations is a critical time to make sure domestic (potable) water systems are properly cleaned and flushed as well as provided and maintained with adequate disinfectant levels to control *Legionella*.
- Low flow, stagnant, and other conditions that result in extending the resident time of water and the loss of disinfectant in domestic plumbing systems and the formation of biofilm must be managed to control *Legionella*.
- Secondary or supplemental disinfection may be required in domestic (potable) water systems where other control strategies fail to keep *Legionella* from colonizing the systems.

3. AWT recognizes the potential hazard for *Legionella* contamination in cooling towers and evaporative condensers as well as other water systems and water-disseminating devices or equipment that may or may not be a part of a traditional water treatment program but can produce aerosols and provide a favorable microbial environment for *Legionella*.

4. AWT supports that prudent operational and water treatment practices for cooling towers, evaporative condensers, fluid coolers, and other recirculating water systems are consistent with reducing *Legionella* contamination within them and include:

- Corrosion, scale, and deposit control programs that promote operational efficiency and system cleanliness and reduce microbial breeding areas.

- Dispersant and antifoulant programs that reduce biofilm, sludge, debris, and nutrient accumulations, thus reducing microbial breeding areas.
- Biocide programs, including oxidizing and nonoxidizing chemistries that are applied according to proper labeling to control microbial growth and proliferation.
- Maintaining best available mist (drift) elimination technology in evaporative systems and eliminating or minimizing stagnant (dead-leg) zones and cross-connections.
- Minimum annual (twice annual preferred) thorough washout and cleaning of cooling towers and evaporative condenser cooling water systems, including an oxidizing disinfection before and after each cleaning.
- Filtration and solids separation devices for cooling water systems to remove airborne dirt and debris, thus maintaining system cleanliness and reducing nutrient conditions that support microbial growth.

5. AWT supports that the microbiology and environmental ecology of *Legionella* includes many variables that determine organism virulence and survival, disease transmission and contraction, and human host susceptibility. As such, even prudently applied WMPs cannot guarantee 100% *Legionella* eradication or disease prevention.

6. AWT supports the sampling and testing for *Legionella* in potable water systems, cooling towers, evaporative condensers, and other nonpotable or potable water systems that have been appropriately risk-assessed, evaluated, and determined to pose disease risk or are otherwise required by regulation. Such recognized systems would include those that have a likelihood of harboring *Legionella* and pose a risk of transmission and exposure to at-risk populations.

Legionella testing within a facility or water system may also be appropriate or required to:

- Validate effectiveness of *Legionella* control strategies in a WMP.
- Evaluate or determine potential disease transmission sources, or otherwise as part of disease outbreak investigations.
- Validate the effectiveness of *Legionella* remediation or decontamination procedures.
- Test within certain healthcare facilities or settings that have patients at high risk for disease.

7. AWT supports that *Legionella* sampling and testing should be considered for all potential *Legionella*-source water systems. An ultimate decision to test or not should be

determined and based on an assessment and review of the specific water system (site and operations) for disease risks. This includes an understanding of the science and relevant facts for *Legionella* sampling and testing, *Legionella*, and Legionnaires' disease, and having an action plan to respond to testing results. Accordingly, AWT does not recommend the routine sampling and testing of all systems without appropriate assessments—or as mandated by federal, state, provincial, or local laws or AHJs.

8. AWT will continue to investigate and evaluate, as well as promote and report, the latest findings, research, and technologies relevant to the control of *Legionella* and the prevention of Legionnaires' disease. This includes independent research as well as liaison and joint exchanges with government agencies, other organizations, associations, and related professional entities.

9. AWT further commits to sharing with the water treatment industry, the healthcare community, and the industry at large, as well as the public and private sector, any relevant information gathered and produced from its resources addressing *Legionella*, legionellosis, and disease prevention.

10. AWT also further commits to educating its member companies, their clients, and others on the potential hazards of *Legionella* in water systems and the proper protocols to be followed to limit the disease. AWT provides a *Legionella* subject matter curriculum in its educational training seminars and annual convention programming.

APPENDIX A: Legionella Control Measures

Overview

Regulatory agencies in the United States and abroad have various control measures for *Legionella*. Below is a compilation of *Legionella* control measures from various countries and organizations.

Table 1. Legionella Control Programs: Potable Water

Regulatory Authority	Test Frequency	Legionella Concentration (CFU/ml)	Remediation
NYC	No data.		No data.
NYS	Every 90 days first year, annually thereafter.	<30% positive results of sites tested.	Maintain WMP.
		≥30% positive results of sites tested.	Immediate short-term control levels. Retest. Persistent ≥30% results—institute long-term control levels.
AIHA	2x/year.	1-9	Continue monitoring and review WMP.
		10-100	ID infection source and online disinfection.
		>100	ID infection source and offline disinfection.
OSHA	Not stated.	10-99	Online disinfection.
		>100	Offline disinfection.
PW & GSC Canada	2x/year.	1-100 Lp sg 2-15	Online disinfection within 48 hrs.
		1-10 Lp sg 1	Online disinfection within 48 hrs.
		>100 Lp sg 2-15	Offline disinfection within 48 hrs.
		>10 Lp sg 1	Offline disinfection within 48 hrs.
HSE UK	Start monthly and adjust as per test results.	>0.1, <1.0; <50% positivity.	Review WMP.
		>0.1, <1.0; >50% positivity.	Review WMP and consider disinfection.
		≥1.0	Review WMP and consider disinfection.
MSS France	No data.	>1.0	Action required in non-healthcare facilities.
		>0.1	Action required in healthcare facilities.
		>0.025	Action required in healthcare facilities with severely immunocompromised patients.
DVGW Germany	No data.	1.0	No data.
VROM Holland	No data.	0.1	No data.
Australia and New Zealand	No data.	No data.	No data.

- NYS: Protection Against *Legionella* (2016)
- AIHA: American Industrial Hygiene Association. Recognition and Control of *Legionella* in Building Water Systems (2015)
- OSHA: Occupational Safety and Health Administration. Technical Manual, Legionnaires' Disease, Section III, Chapter 7
- PW and GSC Canada: Public Works and Government Services Canada. Control of *Legionella* in Mechanical Systems, Mechanical Design 15161 (2013)
- HSE UK: Health and Safety Executive, UK. Legionnaires' disease. The control of *Legionella* bacteria in water systems, Approved Code of Practice and Guidance (2009)
- MSS France: Ministère de la Sante et des Solidarités (2005)
- DVGW Germany: Deutscher Verein des Gas-und Wasserfaches, W551 (2004)
- VROM Holland: The Netherlands Ministry of Housing, Modelbeheersplan Legionellapreentie in Lidingwater Distribution No 16827 (2002)

Table 2 . Legionella Control Programs: Cooling Towers and Evaporative Condensers

Regulatory Authority	Test Frequency	Legionella Concentration (CFU/ml)	Remediation
NYC	At system startup and every 90 days thereafter.	<10	Maintain water chemistry and biocide levels.
		≥10 - <100	Online disinfection within 24 hours. Retest.
		≥100 - <1000	Online disinfection within 24 hours. Retest. Review WMP.
		≥1000	Online disinfection within 24 hours. Offline disinfection within 48 hours. Retest. Notify DOH within 24 hours of results.
NYS	At system startup and every 90 days thereafter.	<20	Maintain water chemistry and biocide levels.
		≥20 - <1000	Online disinfection immediately. Retest. Review WMP.
		≥1000	Online disinfection immediately. Retest. Review WMP. Any retest >1000 offline disinfection immediately.
AIHA	Monthly.	10-99	Review WMP and retest until <10 CFU/ml.
		100-1000	Review WMP and conduct an online disinfection until consistently <10 CFU/ml.
		>1000	Review WMP and conduct an offline disinfection until consistently <10 CFU/ml.
OSHA	Not stated.	100-999	Online disinfection.
		>1000	Offline disinfection.
PW & GSC Canada	Every 2 months.	1000-10,000 non-Lp	Online disinfection within 48 hrs.
		1-100 Lp sg 2-15	Online disinfection within 48 hrs.
		1-10 Lp sg 1	Online disinfection within 48 hrs.
		>1000 non-Lp	Offline disinfection immediately.
		>100 Lp sg 2-15	Offline disinfection immediately.
		>10 Lp sg 1	Offline disinfection immediately.
HSE UK	Quarterly.	0.1-1.0	Review WMP and resample.
		≥1.0	Review WMP, resample and disinfect.
MSS France	No data.	No data.	No data.
DVGW Germany	No data.	No data.	No data.
Holland	No data.	No Data	No data.
AS/NZS 366.3 Australia and New Zealand	Quarterly.	10-99	Online disinfection and add biodispersant. Retest 3-7 days.
		10-1000	Online disinfection with oxidizing biocide. Retest 3-7 days.
		>1000	Offline disinfection with oxidizing biocide. Retest 3-7 days.

- NYC: Chapter 8 (Cooling Towers) of Title 24 of the Rules of the City of New York (2015)
- NYS: Protection Against *Legionella* (2016)
- AIHA: American Industrial Hygiene Association. Recognition and Control of *Legionella* in Building Water Systems (2015)
- OSHA: Occupational Safety and Health Administration. Technical Manual, Legionnaires' Disease, Section III, Chapter 7
- PW and GSC Canada: Public Works and Government Services

Canada. Control of *Legionella* in Mechanical Systems, Mechanical Design 15161 (2013)

- HSE UK: Health and Safety Executive, UK. Legionnaires' disease. The control of *Legionella* bacteria in water systems, Approved Code of Practice and Guidance (2009)
- AS/NZS 366.3 Australia and New Zealand: AS/NZS 366.3 Code of Practice, Prevention and Control of Legionnaires' Disease (2010)

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