The National Academies of SCIENCES ENGINEERING MEDICINE

Management of *Legionella* in Water Systems

CONCLUSIONS AND RECOMMENDATIONS FOR BUILDING AND FACILITIES MANAGEMENT

The leading cause of reportable waterborne disease outbreaks in the United States today is Legionnaires' disease, a pneumonia caused by the Legionella bacterium. This new Consensus Study Report from the National Academies estimates the number of U.S. cases of Legionnaires' disease ranges from 52,000 to 70,000 each year. Steps can be taken to limit the growth of this bacterium in building water systems to reduce incidence of the disease.

WHAT CAUSES LEGIONNAIRES' DISEASE?

Legionella bacteria reside in many natural environments including rivers, lakes, and soils. These bacteria are also found in a variety of engineered systems that support biofilm growth, including drinking water supplies, cooling towers, hot tubs, fountains, and building plumbing systems and their outlets like faucets and showerheads. These water systems are often characterized by warm temperatures, stagnant water, and a lack of chemical disinfectants—conditions that promote the growth of biofilms and their associated protozoa, which are the hosts for *Legionella* bacteria. Humans are primarily exposed to *Legionella* through inhalation of contaminated aerosols into the respiratory system from these contaminated water systems. Those at higher risk for developing Legionnaires' disease include the elderly, men, smokers, and the immune suppressed. The growth of some of these high-risk groups, along with increasing dependence on HVAC systems and warming climates, are factors likely to increase disease incidence.

Although the Safe Drinking Water Act has been effective in reducing U.S. disease rates of enteric waterborne organisms, it has had little impact on managing *Legionella* in water systems and buildings. In fact, the incidence of Legionnaires' disease has increased more than six-fold from 2000 to 2018. Facilities managers can play a major role in preventing the growth of *Legionella* in engineered environments like building water systems.

DETERMINING THE RISK OF *LEGIONELLA* IN A BUILDING

The principles to consider when determining whether a building water system presents a potential risk as a *Legionella* source and requires control are:

- Presence of *Legionella* in the system water (see below);
- Water temperature between 77–109°F (25–43°C);
- The system has the means to create and/or spread aerosols;
- The system stores and/or re-circulates water; and
- The system is likely to contain a source of food for *Legionella*, such as contaminants from the surroundings, including sludge, rust, scale, organic matter, or biofilm.

The Academies report reviewed dozens of *Legionella* studies from various building types from around the world. Available data suggest that cooling towers, hot tubs, showers, and wastewater treatment plants can be hot spots for growth of *Legionella* and exposures. Several studies that recorded concentrations of culturable *Legionella* were compiled to determine if and when concentration could be indicative of outbreaks of Legionnaires' disease. As

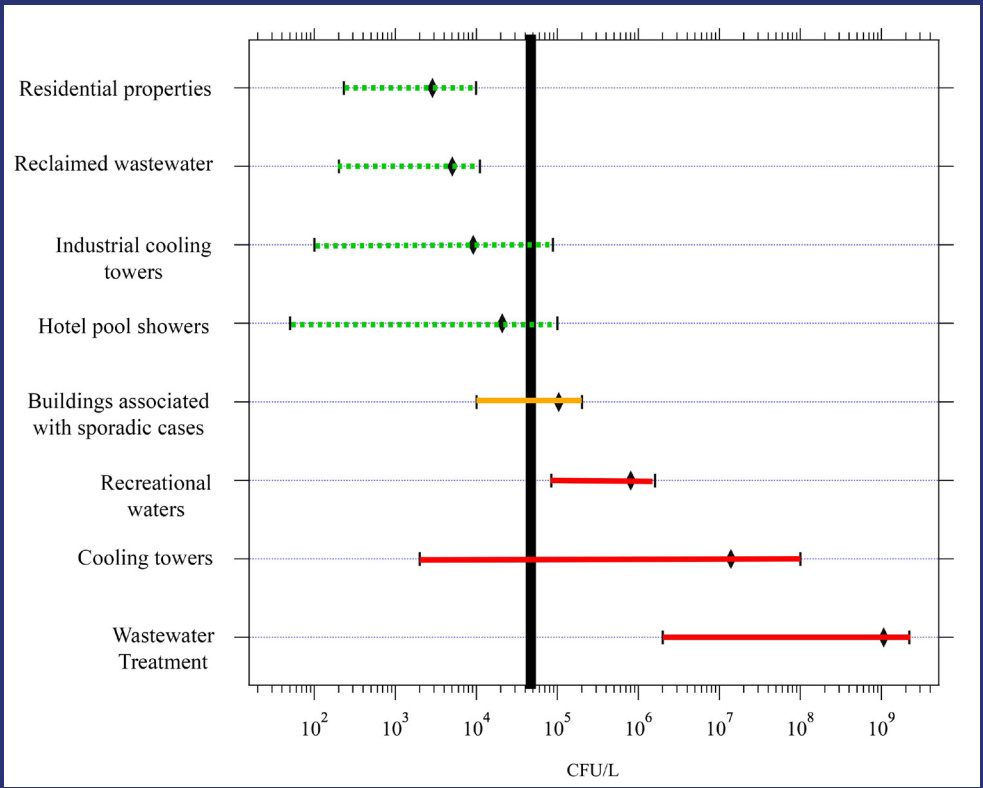


FIGURE 1 Concentrations of culturable *Legionella* during outbreaks and routine monitoring from various environments (ranges shown as bars, averages shown as diamonds). Red solid lines are data collected during outbreaks. Green dashed lines are routine sampling data. The orange solid line represents data collected from buildings associated with sporadic cases (i.e., cases not related to an outbreak). The solid black line is the 5 x 10^4 CFU/L action level identified by the Academies' authoring committee as a break between sporadic cases and outbreaks.

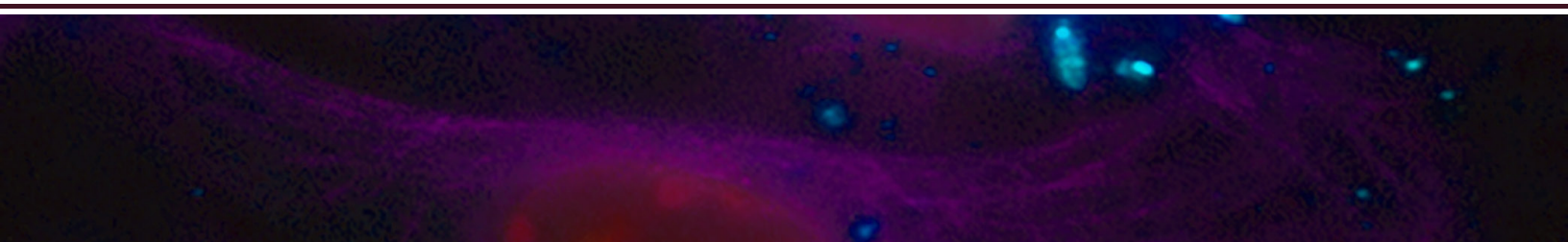
shown in Figure 1, the report concludes that **a *Legionella* concentration of 5 x 10^4 colony-forming units per liter (CFU/L) should be considered an "action level"—that is, a concentration high enough to warrant serious concern and trigger remediation.** A lower action level may be necessary to protect those at higher risk, such as hospital patients, particularly those in intensive care, cancer, and solid-organ transplant units.

FUNDAMENTAL FACTORS FOR *LEGIONELLA* CONTROL IN BUILDINGS

Design and commissioning of a large building are key opportunities to ensure that *Legionella* control is prioritized, including the appropriate design and implementation of hot- and cold-water systems that are part of the premise plumbing, and heating, ventilation, and air conditioning (HVAC) features including cooling towers. Furthermore, building water systems should be configured to facilitate the collection of water for *Legionella* monitoring and for the implementation of maintenance and remediation (such as sampling and injection ports on hot-water lines), particularly in hospitals where sensitive populations are housed. Unfortunately, the vast majority of existing large buildings were not designed in this manner and present numerous complex challenges for *Legionella* control. The following are fundamental factors that building managers, contractors, plumbers, and others should consider when making decisions about building design, construction, and operation to maximize control of *Legionella*.

Temperature

A fundamental control strategy is to keep hot- and cold-water systems at temperatures outside *Legionella's* preferred growth range. Numerous studies from large buildings around the world support **maintaining temperatures above 140°F at the hot-water heater and above 131°F to distal points across hot-water systems, for all building types.** In buildings with populations particularly sensitive to scalding, thermal mixing valves can be used to reduce the temperature of water experienced at the tap.



Disinfection

Many disinfection methods have demonstrated some efficacy toward managing *Legionella*, including chemical disinfection using oxidizing agents (e.g., chlorine, chloramines, and ozone) and ultraviolet radiation. Of the chemical disinfectants, monochloramine has gained traction in the United States as being the most effective for *Legionella* control because it is more stable in the water distribution system, minimizes the formation of disinfection byproducts, and can penetrate biofilms better than chlorine.

Managing Hydraulics

Neither heat nor chemical disinfection will be effective unless the water is properly circulated. The flushing of water in building water systems can have significant benefits. Flushing can reduce total *Legionella* cell counts in premise plumbing by many mechanisms, such as delivering disinfectants and hot temperatures and dislodging loose deposits and biofilm. Although there is no consensus on optimal flushing frequency, several guidance documents recommend minimum weekly flushing of low-use faucets and showers.

Plumbing Materials

The combination of plumbing materials and building-level water chemistry will uniquely shape the biofilms that grow in premise plumbing. However, it remains difficult to identify pipe material that limits *Legionella*. Although copper pipe has well-known antimicrobial properties, it does not universally control *Legionella*. Polyethylene and other heat-tolerant polymers are known to leach organic carbon and can stimulate bacterial growth. Iron pipe is extremely problematic because it enhances biofilm formation and negates the action of disinfectants.

Managing the Distal Portion of the Plumbing

There is strong evidence that concentrations of *Legionella* in the distal sites of premise plumbing (near the point of use) can be significantly higher than in more centralized sections of the plumbing. Devices such as faucets and showerheads provide many surfaces for biofilm growth, and the water in these devices is subject to recurring stagnation. Various actions to prevent *Legionella* growth include efforts to minimize water volumes at distal points, for example, by using small diameter piping, and maximizing water circulation through improved design and preventive flushing procedures. Low-flow fixtures should not be allowed in hospitals and long-term care facilities due to their high-risk occupant populations.

Cooling Towers and Humidifiers

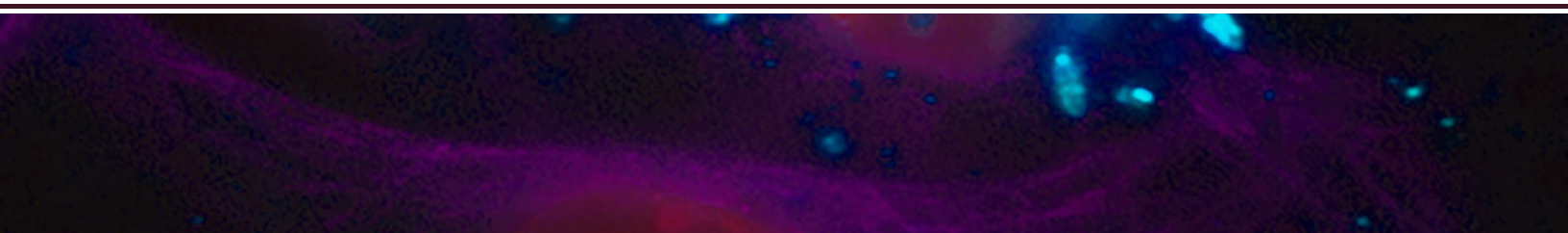
New designs are needed to help advance control of *Legionella* in cooling towers and humidifiers. Humidifier designs that produce water droplets within the temperature range conducive to *Legionella* growth should be avoided for use in new buildings, and existing units of these types should be replaced during building renovations. Strategies relying on disinfectants should consider using alternate types of biocides at regular intervals, since bacteria can regrow in cooling towers when biocide use is infrequent and irregular. Finally, cooling tower manufacturers should collectively design new systems that can operate at condenser water temperatures whereby the temperature going to the cooling tower will be greater than 60°C.

Green Buildings

Green buildings have exacerbated many of the problems with *Legionella* by lengthening water residence times (which leads to loss of disinfectant residual) and lowering hot-water temperatures in premise plumbing. Criteria for certifying green buildings, energy-conserving features, and water conservation features should be modified to take into account risk factors for *Legionella* growth. Substantial water conservation can still be potentially achieved while protecting public health with more overt management of water age, for example, through routine flushing.

WATER MANAGEMENT PLANS

The report recommends that Water Management Plans be required in all public buildings including hotels, businesses, schools, apartments, and government buildings. Today, only hospitals in New York State, those in the Veter-



ans Health Administration network, and those that receive Medicaid and Medicare funding are required to have such plans. The seven elements of a Water Management Plan include:

1. Establishing a program team to carry out all elements of the plan.
2. Describing each building water system.
3. Analyzing where potential hazards may exist, develop, or propagate in building water systems.
4. Identifying control measures and where they should be applied to stay within limits.
5. Monitoring certain parameters, which can include *Legionella*, to determine if control measures are working. (The report provides guidance on how to interpret *Legionella* monitoring results.)
6. Confirming that the program is being implemented as designed and that the program effectively controls the hazardous conditions.
7. Documenting the above steps.

Guidance documents from the American Industrial Hygiene Association, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, and others are available to help create a Water Management Plan that can meet this requirement. Ideally, this requirement would be codified by either local jurisdictions with authority (such as building inspectors) or state authorities (such as departments of environmental protection or health). Once codified, the requirements could be supported by insurance companies; that is, without a Water Management Plan, a building would not qualify for insurance.

REGISTER AND MONITOR COOLING TOWERS

Cooling towers provide a favorable environment for proliferation of *Legionella* due to not only their warm water temperatures but also the large surface area available for biofilm colonization. In addition, cooling towers can broadly disperse aerosols, from hundreds of meters to kilometres away. Hence, it is no surprise that cooling towers have been implicated in many outbreaks of Legionnaires' disease. Regulations and guidelines requiring the registration of cooling towers provide a demonstrable public health benefit with minimal regulatory burden to building owners and managers. Cooling tower registries enable a rapid public health response to community clusters of legionellosis cases, including timely remediation of possible sources of infection, and can also be used to assess the contribution of cooling towers to overall disease incidence. In addition, regulations requiring ongoing *Legionella* monitoring of cooling towers have been shown to reduce cooling tower colonization rates in jurisdictions where they have been implemented (e.g., Quebec, Singapore, and Garland, Texas).

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