Consensus Study Report

August 2019

HIGHLIGHTS

Management of *Legionella* in Water Systems

Legionnaires' disease is the leading cause of reported waterborne disease outbreaks in the United States. Caused by Legionella bacteria, the disease ranges from a mild flu-like illness to a severe form of pneumonia that can be fatal. Legionella occur naturally in water from many different environmental sources, but grow rapidly in the warm, stagnant conditions that can be found in engineered water systems such as cooling towers, building plumbing, and hot tubs. This report addresses what is known about Legionella occurrence in water systems, and makes recommendations for managing bacterial growth in these environments in order to reduce the incidence of Legionnaires' disease.

Legionella grow within amoeba that colonize biofilms—sticky layers of microbes that accumulate on virtually all surfaces that contact water. Although the bacteria reside naturally in many rivers, lakes, and soils, *Legionella* can flourish in the pipes, tanks, and other components of human-made water systems, where the combination of stagnant water, warm temperatures, and loss of residual disinfectants can lead to explosive bacterial growth. When contaminated water from those systems is aerosolized, for example, by showerheads or hot tubs, people nearby can be exposed to *Legionella* when they breathe in the mist (see Figure 1).

Legionella infections (known as legionellosis) can lead to pneumonia with fever, cough, shortness of breath, aching muscles, gastrointestinal symptoms and altered mental state (classic Legionnaires' disease), or a milder, flu-like condition called Pontiac fever. Those at greatest risk of developing the disease are the immunocompromised, the elderly, men, and smokers. Between 3 and 33 percent of *Legionella* infections lead to death.

Since Legionnaires' disease was first identified in 1976, much has been learned about the disease and about *Legionella pneumophila*, the species of *Legionella* that has caused most reported cases of Legionnaires' disease. In contrast, less progress has been made in understanding other species of pathogenic *Legionella*, and there remains great uncertainty about how to control *Legionella* in water systems. Although the Safe Drinking Water Act has been effective in reducing disease rates of waterborne enteric organisms, it has had little impact on managing *Legionella* in water systems and buildings. In fact, incidence of Legionnaires' disease has increased more than five-fold from 2000 to 2017 in the United States (see Figure 2).

The National Academies of Sciences, Engineering, and Medicine were asked by the Centers for Disease Control and Prevention (CDC), the Department of Veterans Affairs, the U.S. Environmental Protection Agency, and the Alfred P. Sloan Foundation to address the state of the science with regard to *Legionella* contamination of water systems, including its ecology, disease diagnosis, amplification within water systems, quantification, prevention and control, policy and guidance, and research needs.

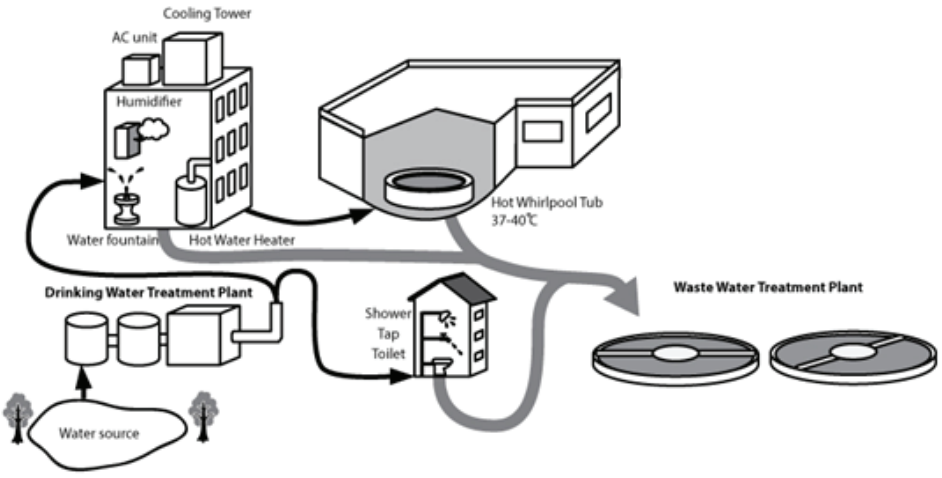

FIGURE 1. *Sites with both biofilm growth and potential for aerosolization are possible sources of Legionnaires' disease risk. Many such areas exist in the built environment, including components of heating, cooling, ventilation and air conditioning systems such as cooling towers and humidifiers; outlets like faucets and showerheads; and hot tubs. Fountains, misters, and industrial wastewater treatment plants can also be sources of Legionella. In this figure, the smaller dark arrows indicate water pathways to premise plumbing, and larger grey arrows pathways of wastewater. Source: Adapted by Kyoko Kurosawa from Exner (2018).*

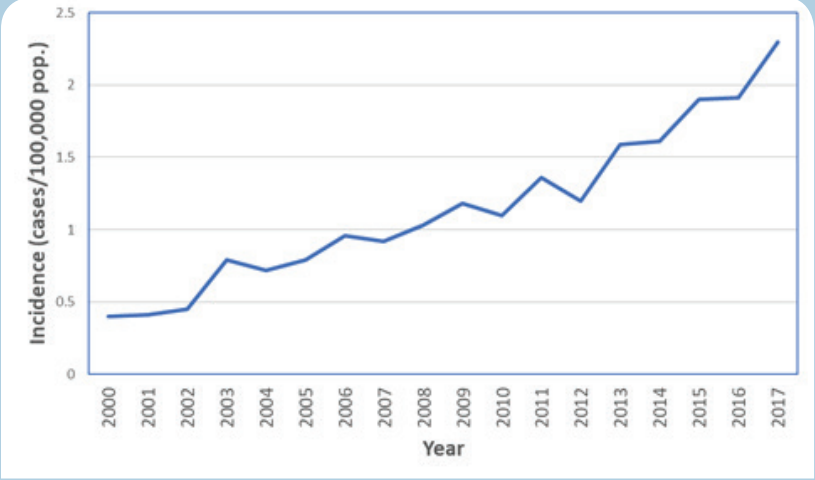

FIGURE 2. *The reported incidence of Legionnaires' disease in the United States has increased more than five-fold from 2000 to 2017. Many factors contribute to this increase: more people are at risk because of the aging population, increased use of immunosuppressant drugs, and higher prevalence of comorbid conditions such as diabetes and pulmonary disease. There is also a growing dependence on heating, ventilation, and cooling systems, and increasingly complex indoor plumbing systems in large buildings. In addition, efforts to conserve water within buildings are likely to result in increased risk of Legionella growth due to water stagnation, temperature changes, and loss of disinfectant residual. Higher water temperatures as a result of climate change may also play a role. Source: Adapted from Shaw et al. (2018) with 2016 and 2017 data from the National Notifiable Disease Surveillance System.*

QUANTIFYING *LEGIONELLA* AND LEGIONNAIRES' DISEASE

Monitoring levels of *Legionella* in water systems and determining how many people get sick with Legionnaires' disease are important for preventing outbreaks. However, both types of quantification are fraught with difficulties.

States report cases of Legionnaires' disease to the CDC, but many cases go unreported because the tests that diagnose the disease are not commonly provided to patients with pneumonia. Even when a case of Legionnaires' disease is reported, investigations to identify the source of the infection are infrequent. Most states do not have the capacity to investigate environmental sources of Legionnaires' disease, with few engineering experts on staff in public health departments. In the United States, environmental testing for *Legionella* bacteria is carried out in only a small subset of acute care hospitals.

Most of what is known about Legionnaires' disease has come from investigations of recognized disease outbreaks—where two or more people are infected at the same time, by the same source. However, recognized outbreaks account for only 4 percent of Legionnaires' disease cases in the United States, and it is not known whether the environmental exposures found in outbreak investigations are representative of the majority of cases. Using data from previous studies and from current surveillance systems, the report's authoring committee carried out its own analyses to estimate the incidence of Legionnaires' disease in the United States and quantify the relationship between levels of environmental *Legionella* and outbreaks of infection.

ESTIMATING THE TRUE INCIDENCE OF LEGIONELLOSIS

Surveillance data show that Legionnaires' disease rates have been steadily rising in the United States and Europe over the past 20 years (see Figure 2). These data are understood to be a substantial underestimate of the actual disease burden for a variety of reasons, including the fact that patients may not seek medical care, those who do may not be tested for *Legionella*, and those tested may be infected by a non-pneumophila species of *Legionella*. Worldwide, it is estimated the burden of Legionnaires' disease is underreported by as much as eight- to ten-fold.

To develop its own estimate of the incidence of Legionnaires' disease, the report's authoring committee started with a population-based CDC-led study that measured the incidence of Legionnaires' disease among 2,488 patients hospitalized with pneumonia in Nashville and Chicago from 2010 to 2012. The committee then used data from other studies to consider Legionnaires' cases that would not have been captured in the CDC study, including factors such as the accuracy of diagnostic tests, patients hospitalized with non-pneumophila disease, and cases of outpatient disease.

The report's authoring committee estimates that the number of persons with Legionnaires' disease in the United States ranges from 52,000 to 70,000 each year (or a rate of 20.5 to 27.4/100,000). This estimate is felt to be conservative as it considers only those cases of Legionnaires' disease for which treatment was sought.

DETERMINING A THRESHOLD FOR ENVIRONMENTAL *LEGIONELLA*

Monitoring of *Legionella* bacteria in various water systems is done for several reasons, including to locate the source of the bacteria after an outbreak of Legionnaires' disease, to verify that a water management plan including remediation is working, and to determine background levels of *Legionella* in various systems. In order to quantify the relationship between levels of *Legionella* bacteria and outbreaks of Legionnaires' disease, the report's authoring committee reviewed dozens of studies on the occurrence of *Legionella* in various building types during outbreaks and routine monitoring (see Figure 3). The committee found that **a *Legionella* concentration of 5 x 10^4 Colony Forming Units (CFU)/Liter should be considered an "action level", i.e.,**

a concentration high enough to warrant serious concern and trigger remediation in a building water system. A lower action level may be necessary to protect those at higher risk for legionellosis such as hospital patients, particularly those in intensive care, cancer, and solid-organ transplant units.

WATER TEMPERATURE AS A STRATEGY FOR *LEGIONELLA* CONTROL

Environmental conditions such as water temperature, disinfectant type and levels, pipe materials, and the extent of aerosol formation are all known to influence the rate of *Legionella* growth in water systems and its transmission to people, and therefore could be the targets of strategies to control *Legionella*. The report compares and contrasts several different control strategies, from the use of particular disinfectants to managing the hydraulics of building plumbing to installing point of use devices on faucets and showerheads. Maintaining water temperature outside of *Legionella*'s growth range of 25°C to 43°C is the paramount control strategy for all buildings that provide hot water, and has been proven successful by numerous longitudinal field studies (see Figure 4). The report's authoring committee recommends that, in order to limit the growth of *Legionella*, **hot-water heater temperatures should be maintained above 60°C and the hot-water temperature to distal points should exceed 55°C for all types of buildings.** In buildings with sensitive populations, the scalding risk of 55°C can be reduced with the use of thermal mixing valves.

REGULATIONS AND GUIDELINES ON *LEGIONELLA* CONTROL IN WATER SYSTEMS

Unlike many European countries, Australia, and Canada, the management of *Legionella* in water systems in the U.S. occurs on an ad hoc basis, ranging from no requirements at all to regulations that require some buildings to have holistic water management plans including *Legionella* monitoring.

U.S. regulations that affect *Legionella* management (by requiring water management plans and/or monitoring of water systems for *Legionella*) currently cover healthcare facilities in New York State, cooling towers in New York City and New York State, healthcare facilities within the Veterans Health Administration, and hospitals and

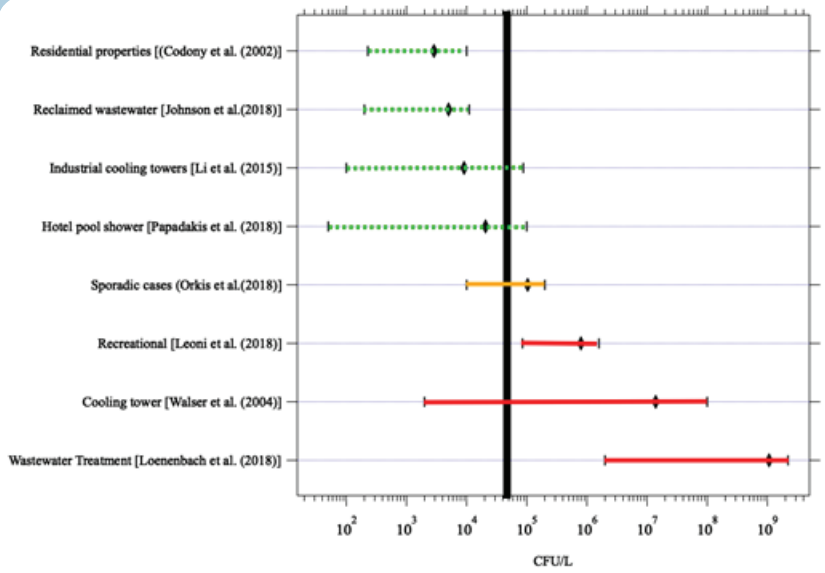

FIGURE 3. *This graph shows the concentrations of culturable Legionella during outbreaks and routine monitoring from various environments. Ranges are shown as bars, averages shown as diamonds. Red solid lines are outbreak data, green dashed lines are routine sampling data, and the yellow solid line represents data from sporadic cases. The solid black line is the action level identified by the Committee as a break between sporadic cases and outbreaks (5 x 10^4 CFU/L).*

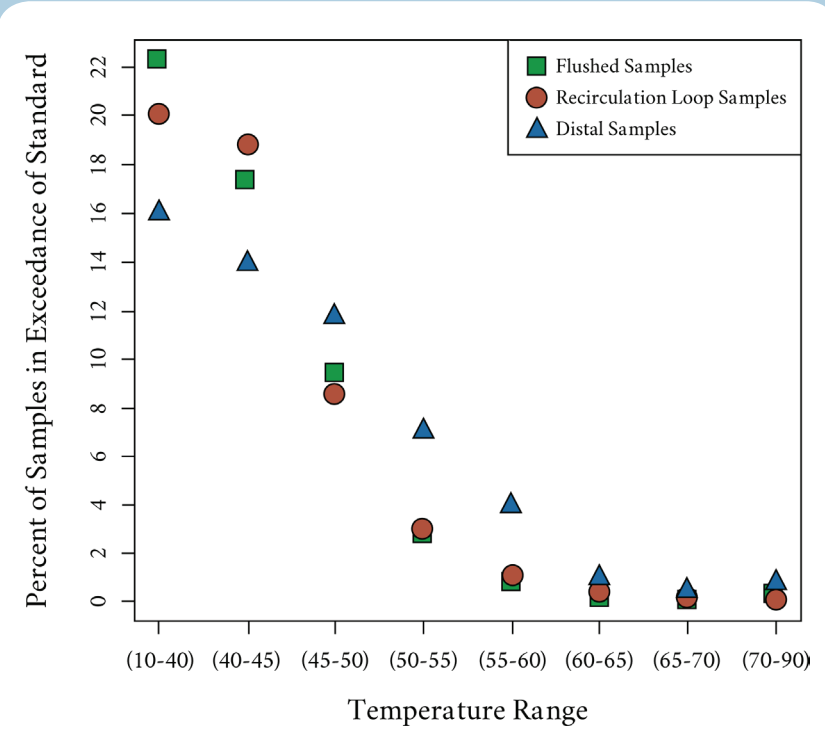

FIGURE 4. *This chart shows the relationship between water temperature (x-axis) and the percent of samples exceeding the German standard of 100 CFU/100mL for Legionella spp. (y-axis) from public buildings in Germany over a seven-year period. Squares indicate flushed samples, circles indicates samples from the recirculation loop of the hot-water system, and triangles are samples taken from the distal ends of the plumbing. SOURCE: Kistemann and Wasser (2018).*

healthcare facilities receiving Medicare or Medicaid funds. The following recommendations are made to develop a more comprehensive policy for *Legionella* management in the United States.

Expand the Centers for Medicare and Medicaid Services (CMS) memorandum to require monitoring for *Legionella* in environmental water samples. Routine quantitative *Legionella* monitoring programs would enable these institutions to assess the effectiveness of their water management programs, and the data collected could help refine the data thresholds needed for prevention.

Register and monitor cooling towers. Cooling tower registries would allow for rapid public health response to community clusters of legionellosis cases, including timely remediation of possible sources of infection, and could also be used to assess the contribution of cooling towers to overall disease incidence.

Require water management plans in all public buildings such as hotels, businesses, schools, apartments, and government buildings. The standard of care specified for water management plans should be considered best management practice for all public buildings. The recommendation is to codify what are currently voluntary standards for managing public buildings. ASHRAE 188, AIHA (2015), and other guidance documents are available to help create a water management plan that can meet this requirement.

Require a temperature of 60°C at hot-water heaters and 55°C to distal points. These temperature requirements could be codified by changing building and plumbing codes or by modifying the CMS memo. There is also the possibility of these requirements being incorporated into guidance documents as they undergo revision in the near future.

Require a minimum disinfectant residual throughout public water systems and concomitant monitoring for *Legionella*. *Legionella pneumophila* has been shown to grow in public water systems where chlorine residuals were less than 0.1 mg/L. The EPA should require a minimum disinfectant residual throughout public water systems to prevent the growth of *Legionella*, and validate treatment performance by routine monitoring.

COMMITTEE ON MANAGEMENT OF *LEGIONELLA* IN WATER SYSTEMS

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For More Information . . . This Consensus Study Report Highlights was prepared by the National Academies of Sciences, Engineering, and Medicine based on the Consensus Study Report *Management of* Legionella *in Water Systems* (2018). The study was sponsored by the Alfred P. Sloan Foundation; Centers for Disease Control and Prevention; the Department of Veterans Affairs; and the Environmental Protection Agency. Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of any organization or agency that provided support for the project. Copies of the Consensus Study Report are available from the National Academies Press, (800) 624-6242; http://www.nap.edu or via the Water Science and Technology Board web page at http://www.nationalacademies.org/wstb.

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