LEGIONNAIRES
How Safe Is the Water?

By Kevin Reinhart

SOME BUSINESSES IN THE U.S. may have a health hazard lurking in their water system and be unaware of it. This health hazard is known as *Legionella,* which is a significant health concern that can lead to substantial, yet avoidable, cost. *Legionella* is a bacteria that lives in water and includes more than 50 bacterial species. The main species connected to *Legionella* is *L. pneumophila*, which was the cause of a 1976 Legionnaires' disease outbreak among members of the American Legion and is still responsible for most cases of Legionnaires' disease in the U.S. and Europe. Legionnaires' disease is a form of pneumonia whose symptoms include fever, chills, cough, muscle aches, headaches, diarrhea and shortness of breath. The disease has not been proven to be transmitted from person to person (CDC, 2016).

While it was not discovered until 1976, *Legionella* has existed since about 1968 when the first cases of Pontiac fever were identified in Pontiac, MI. In 1976, public health officials demonstrated that both the Pontiac fever and newly discovered *Legionella* had the same bacterium (Montopoli, 1993).

Legionnaires' disease is on the rise, and CDC (2018a) says that the rate of reported cases of the disease has increased 5.5 times since 2000. In the U.S., waterborne disease outbreaks associated with *Legionella* have been tracked through the Waterborne Disease and Outbreak Surveillance System since 2001. According to CDC (2018c), Legionnaires' disease outbreaks occur when two or more people are exposed to *Legionella* in the same place and get sick at about the same time. The disease may be underdiagnosed due to the symptoms it mimics; the number of cases could be higher.

How, Who & Where *Legionella* Is Contracted

Legionella is contracted through the inhalation of small droplets (less than 5 µm) of water that is in the air (ASHRAE, 2000). For comparison, a human red blood cell is about 5 µm and the diameter of human hair is about 75 µm (Bacteria World, 2019). The naked eye cannot visually identify 5 µm, and exposure may exist without visual knowledge. Actions that can generate small droplets are those that help break up the water stream (e.g., shower nozzles, aerators, spray nozzles, water impacting on hard surfaces).

KEY TAKEAWAYS

- **Legionnaires' disease is a form of pneumonia whose symptoms include fever, chills, cough, muscle aches, headaches, diarrhea and shortness of breath.**
- **Legionnaires' disease is on the rise. The rate of reported cases has increased more than five times since 2000.**
- **The disease can be prevented. A properly maintained water system can eliminate the creation of *Legionella* bacteria that can cause Legionnaires' disease.**

Epidemiological studies suggest that *Legionella* infections can travel for a distance in an aerosol form and have been associated with sources at distances up to nearly 10 km (Prussin, Schwake & Marr, 2017). For example in May 2005, there was a large outbreak of *Legionella* in Norway, with an air scrubber being the source which was concluded may have contributed to a wide spread of *Legionella* species probably for more than 10 km (Nygård, Werner-Johansen, Rønsen, et al., 2008).

People can drink water that contains the bacteria and not get sick, but a person could contract *Legionella* if s/he inadvertently aspirates that water and it gets into the lungs (if it "goes down the wrong pipe"). Some people are more at risk of contracting *Legionella* than others, including people who:

- are 50 years of age and older;
- smoke or used to smoke;
- suffer from a chronic lung disease such as emphysema, asthma or chronic obstructive pulmonary disease;
- have a weakened immune system (e.g., people with cancer, diabetes or kidney failure);
- take medication that weakens the immune system.

The bacteria is typically found in water systems of buildings (e.g., hotels, hospitals, office buildings). It can grow and spread in a building's water system in areas such as hot tubs, hot water tanks/heaters, large plumbing systems, cooling towers and decorative fountains. Several internal and external factors can lead to its growth. Construction or water main breaks nearby that cause vibration or water pressure fluctuation can cause biofilm to dislodge, allowing the *Legionella* to flow into a building's water system. The bacteria grows best in temperatures between 77 °F and 108 °F, but has been known to grow outside of this range (CDC, 2017).

A risk mitigation approach to controlling and preventing *Legionella* in plumbing systems can include thermal controls. Thermal controls consist of maintaining temperature in hot- and cold-water systems outside the range in which the bacteria can ideally grow. Cold-water systems are typically maintained at temperatures below 68 °F; however, during periods of low or no flow, the temperature can increase, especially during seasonal temperature fluctuations. Increasing the water temperature can help control the bacteria's growth; EPA (2016) suggests that the hot water temperature should be at least greater than 122 °F at the outlets (faucets).

To achieve a certain water temperature at the outlet, the hot water system itself must be raised to compensate for heat loss during the water transfer through the pipes to the outlet. Heating water temperatures to control *Legionella* can result in greater energy use and increased risk of scalding. For most adults, being exposed to 120 °F for 9 minutes can result in a

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second-degree burn, while at 124 °F it takes just 3 minutes (EPA, 2016). Those more susceptible to scalding include young children, the elderly, disabled individuals and those with sensory loss. It is important to consider the assessment of scalding risk in selection of hot water temperatures. A facility can install automatic compensating mixing valves on outlets to minimize the risk of scalding injuries.

Some facilities may treat water with a disinfectant to control *Legionella* (e.g., chlorine, sodium hypochlorite solution, dry calcium hypochlorite, monochloramine, chlorine dioxide, copper-silver ionization, ultraviolet light, ozone). Each of these methods has a unique potential impact on water quality; facility owners and operators should consult with their water supplier and primacy agency for specific requirements including plumbing requirements (EPA, 2016).

Disinfectants should be used with caution. Each has its own benefits and consequences. For example, in sufficient concentrations, chlorine is known to be effective against microorganisms, however, it must have adequate time to react. Chlorine can react with organics, inorganics and nonhalogens in water to form disinfection by-products, which have been shown to cause cancer. Use of monochloramine is effective but excess ammonia can cause biofilm growth (EPA, 2016). Copper-silver ionization is an alternative to using elevated levels of chlorine. In this method, a direct electric current is passed between anodes, releasing copper and silver ions into the water stream. NASA first developed the use of silver ionization for water disinfection for the drinking water and wastewater system on the Apollo spacecraft. Combined use of silver and copper ions for water treatment was mainly used to disinfect swimming pools instead of using elevated levels of chlorine. This method was later reported to be effective in controlling *Legionella* (EPA, 2016).

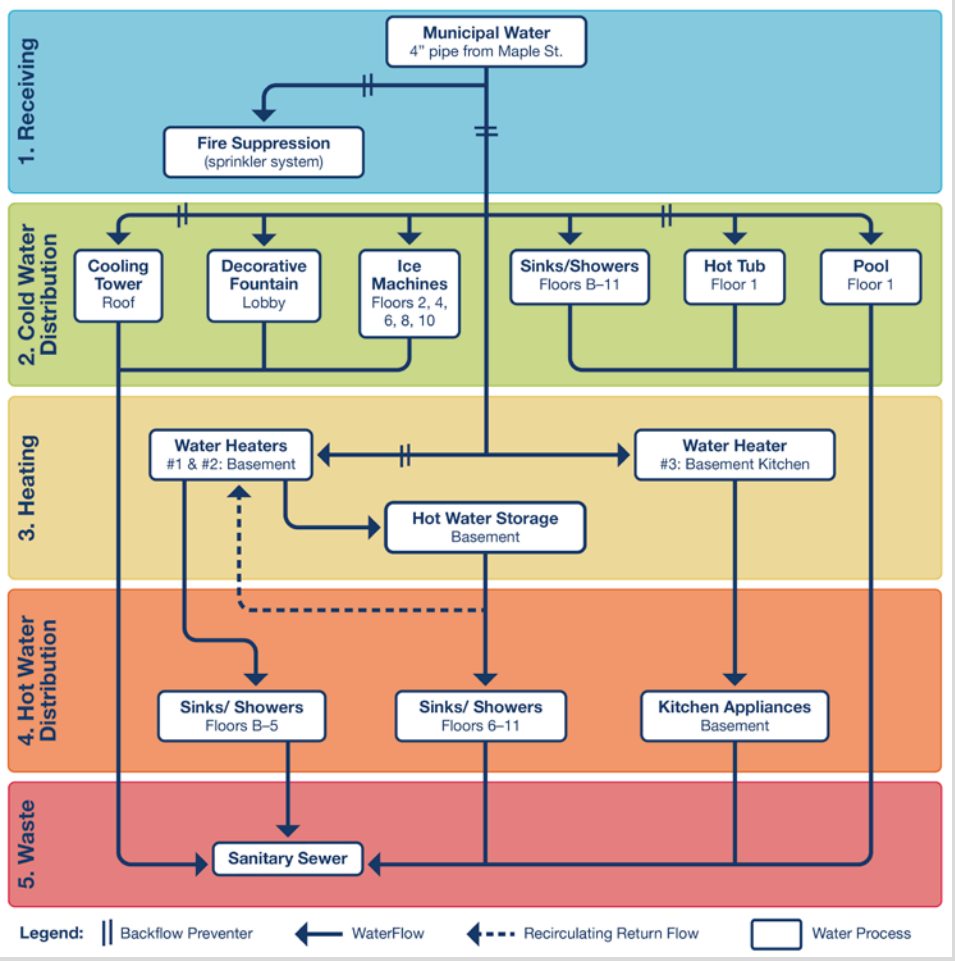
Environmental testing should be conducted to determine whether a facility is controlling *Legionella* within the water system. Environmental testing consists of collecting water samples from the facility's plumbing system to analyze it for *L. pneumophila* or other hazards as well as water quality parameters (e.g., pH, temperature, disinfectant residual) that may indicate effectiveness of treatment performance and overall water quality.

Environmental testing guidelines for *Legionella* vary between agencies such as CDC, World Health Organization (WHO), American Industrial Hygiene Association (AIHA) and American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). WHO and CDC both acknowledge using *Legionella* testing as one way to verify and validate a water safety plan. Under the ANSI/ASHRAE 188-2015 standard, Annex C provides guidance when *Legionella* testing is utilized. (*Note:* The references to ANSI/ASHRAE 188-2015 in this article are to a historical version of the standard. The current standard is 188-2018.) Annex C of the standard states:

> Laboratories performing microbiological culture testing of environmental water samples should be accredited by a regional, national or international accrediting body according to a nationally or internationally recognized standard, for example ISO/IED 17025:2005 *Legionella* culture testing must be included as well as the laboratory's scope of accreditation. (ANSI/ASHRAE 188-2015)

A laboratory should demonstrate proficiency in the detection of *Legionella* culture. The laboratory can use the CDC Environ-

FIGURE 1
EXAMPLE FLOW DIAGRAM



Note. From "Developing a Water Management Program to Reduce *Legionella* Growth and Spread in Buildings: A Practical Guide to Implementing Industry Standards (Version 1.1)," by CDC , 2017.

mental *Legionella* Isolation Techniques Evaluation program, the European external quality assessment/proficiency testing program through Public Health England or an equivalent nationally accredited test provider.

Establish a Risk Management Plan for Building Water Systems

It is important for a business or building owner/operator to develop a water management program (WMP), a written risk management plan to help prevent and control *Legionella* associated with a building's water system. ANSI/ASHRAE 188-2015 outlines the elements of a WMP as follows:

1) Program team: Identify persons responsible for program development and implementation.

2) Describe water systems/flow diagrams: Describe the potable and nonpotable water systems within the building and on the building site and develop water-system schematics.

3) Analysis of building water systems: Evaluate where hazardous conditions may occur in the water systems and determine where control measures can be applied.

4) Control measures: Determine locations where control measures must be applied and maintained in order to stay within established control limits.

5) Monitoring/corrective actions: Establish procedures for monitoring whether control measures are operating within established limits and, if not, take corrective actions.

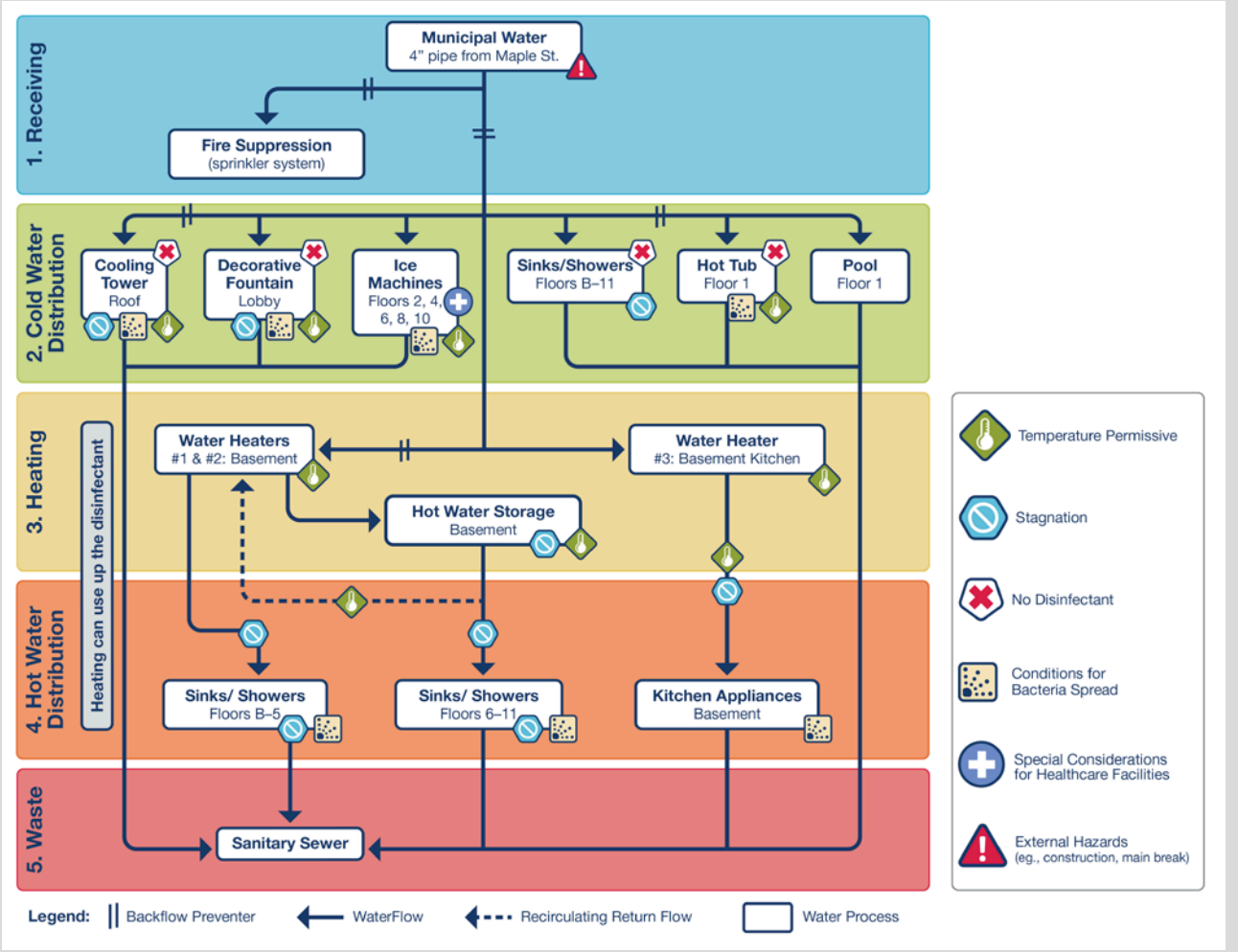
6) Confirmation: Establish procedures to confirm that:

•the program is being implemented as designed (verification);

FIGURE 2

EXAMPLE FLOW DIAGRAM DENOTING HAZARDOUS CONDITIONS

Example of a flow diagram denoting location and types of hazardous conditions.



Note. From "Developing a Water Management Program to Reduce *Legionella* Growth and Spread in Buildings: A Practical Guide to Implementing Industry Standards (Version 1.1)," by CDC , 2017.

•the program effectively controls the hazardous conditions throughout the building water systems (validation).

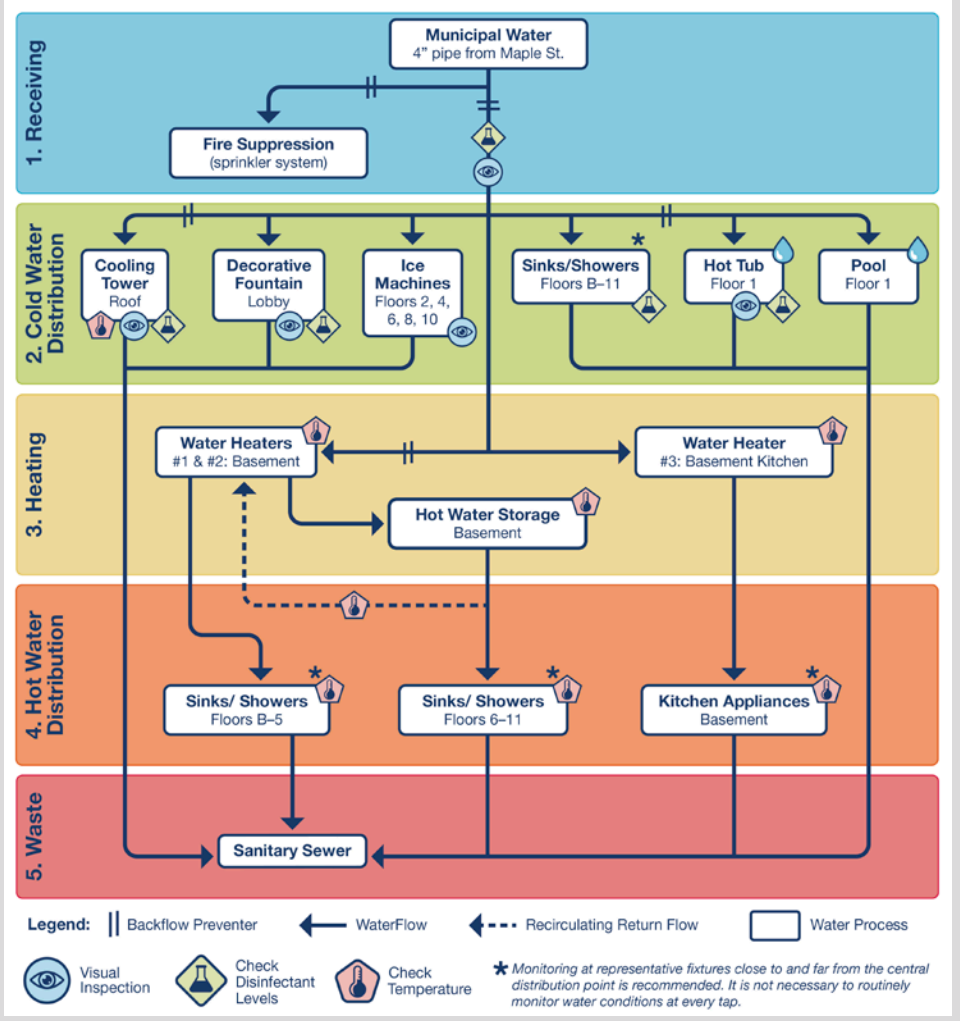
7) Documentation: Establish documentation and communication procedures for all activities of the program. (ANSI/ASHRAE 188-2015)

The first step should be to establish a WMP team that will develop and implement the program. The WMP team should consist of individuals with different skill sets. This could include personnel such as the building owner/manager/administrator or maintenance/facilities engineer, or outside experts, such as equipment or chemical suppliers, water treatment consultants, industrial hygienist, microbiologist, environmental health specialist or a state/local health official. The WMP team should have knowledge of water management and the building's water system as it relates to *Legionella*.

Once a team is assembled, the next step is to describe the building's water system, which would include both potable and nonpotable water systems within the building and on the building site (e.g., decorative fountain in front of the building). Describing the building's water system should be documented and include details such as where the building's water line connects to the municipal line and how water is distributed through the building. The description of the water system should also point out the location of water processing equipment and components (e.g., pools, hot tubs, cooling towers, hot water heaters, boilers) in the building. The description should also include how water is received and processed (e.g., conditioned, stored, heated, cooled, recirculated or delivered to an end-point use). A diagram of the plumbing system and location of the fixtures can be useful in developing a written description of the building's water system and can be included in addition to the written description.

FIGURE 3

EXAMPLE FLOW DIAGRAM DENOTING CONTROL MEASURES MONITORING LOCATIONS



Note. From "Developing a Water Management Program to Reduce *Legionella* Growth and Spread in Buildings: A Practical Guide to Implementing Industry Standards (Version 1.1)," by CDC , 2017.

Once a written description of the building's water systems has been documented, it should then be transferred into a step-by-step process flow diagram (Figure 1, p. 27).

After the process flow diagram has been established, the WMP team must identify where *Legionella* could grow and spread, and indicate those locations on the process flow map. Figure 2 is an example of a flow diagram marked to denote where permissive temperatures exist, where water is in stagnation, where there are no disinfectants and areas where conditions exist for bacteria to spread.

Once potentially hazardous conditions have been determined, the WMP team should identify control measures currently in place by location and establish control limit parameters (range of values from minimum to maximum). Control measures include treatment methods, technical and physical processes and procedures (e.g., activities/actions such as visual inspection, checking disinfectant levels and checking temperature) that monitor the physical/chemical condition of the water within established control limits. Monitoring is part of the control measures and can consist of conducting a visual inspection, checking disinfectant levels and checking temperature.

Using the flow diagrams, the WMP team can mark

what type of monitoring occurs at which locations within the water system. Figure 3 (p. 29) illustrates an example flow diagram that identifies suggested monitoring locations within the water system, which is an additional step to the example in Figure 1.

Determine whether the appropriate control measures are currently in place (location and limit parameters). If no control measures are in place, the team must implement corrective actions to establish what those control measures should be. If control measures are already established and monitoring is being performed, determine the procedures in place that address when monitoring identifies control measures that do not meet the control limits. In advance, the WMP team should document written procedures as to what corrective actions must be implemented when control measures are found to be outside of the control limits. The written corrective action procedures must also identify the individual responsible for taking the corrective action, the required response time for implementing the corrective action and who should be notified.

ASHRAE Guideline 12-2000 provides recommendations, guidance on design, maintenance and operation of building water systems including:

- potable water systems;
- cooling towers and evaporative condensers;
- whirlpool spas;
- ornamental fountains and other water features;
- aerosol-generating misters, atomizers, air washers and humidifiers.

Buildings vary in characteristics (e.g., size/dimensions, location) as well as purpose. A risk management approach to controlling *Legionella* in a premise plumbing system includes superior design and engineering to ensure a comprehensive preventive method is followed to address potential health risks.

Conclusion

With Legionnaires' disease on the rise and cases being unreported due to symptoms that mimic other illnesses, most businesses and building owners/operators overlook or are unaware of the bacteria species that causes the disease. CDC states that 9 out of 10 outbreaks were caused by problems preventable with more effective water management. One reason for ineffective water management may be that businesses and building owners/operators do not understand the factors that encourage the survival and growth of *Legionella* within water systems. Businesses and building owners/operators also may be unaware of what, where, when and why to test for *Legionella*. Understanding how *Legionella* survives and grows within a water system can help stakeholders better know what controls to put in place to mitigate *Legionella* exposure and help protect human health in the process. It is important for businesses and building owners/operators to have a written water management program developed by a team that understands *Legionella* and has knowledge of the building's water system.

Several resources can be used to help develop a water management program. The ANSI/ASHRAE 188-2018 standard, Legionellosis: Risk Management for Building System Systems, establishes minimum requirements from design and construction to operation, maintenance and expansion of new and existing buildings and their associated (potable and nonpotable) water systems and components. Another useful resource is ASHRAE Guideline 12-2000, Minimizing the Risk of Legionellosis Associated with Building Water Systems. PSJ

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