Peer-Reviewed

New Guidelines On *Legionella*

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ASHRAE Guideline 12[1] was issued in May 2000 following six years of committee effort and a January 2000 approval by the Board of Directors. The Guideline provides environmental and operational guidance that will contribute to the safe operation of building water systems so as to minimize the risk of Legionnaires' Disease. It is intended for use with non-residential building systems and centralized systems in multi-family residential buildings. While not specifically intended for single family residential building systems, at least some of the information is applicable to these systems. The Guideline is suitable for use by designers, installers, owners, operators, users, maintenance personnel and equipment manufacturers.

Legionella are bacteria. They are commonly present in natural and man-made aquatic environments. In natural water systems as well as municipal water systems, legionellae are generally present in very low or undetectable concentrations. However, under certain circumstances within man-made water systems, the concentration of organisms may increase markedly, a process termed "amplification." A system where such amplification can occur is likewise termed an amplifier.

Conditions favorable for the amplification of legionellae growth include water temperatures of 25°C to 42°C (77°F to 108°F), stagnant conditions, presence of scale, sediment, and biofilms and the presence of amoebae. Legionellae may be considered protozoonotic; i.e., they naturally infect free-living amoebae and incidentally infect the phagocytic cells within human lungs under certain conditions. Intracellular growth of legionellae within protozoa and/or within diverse microbial biofilms may be the primary means of proliferation.

Generally, *Legionella* thrive in diverse, complex microbial communities because they require nutrients and protection from the environment. Controlling the population of protozoa and other microorganisms may be the best method of minimizing *Legionella*.[2]

A chain of events must occur in order for Legionnaires' disease to result. As depicted in *Figure 1*,[3] the chain begins with a source of *Legionella*. This event is generally outside the scope of building engineering and management practices. However, the next three events in the chain—amplification, dissemination and transmission—can be influenced by engineering design and maintenance practices. Subsequent events are influenced by the individual's health.

The concept for the control of most diseases, including Legionellosis, is prevention of transmission at as many points as possible in the disease's chain of transmission. Guideline 12 presents information intended to allow readers to develop an understanding of the types of conditions that may allow amplification and transmission of *Legionella*. With this understanding, it should be possible to define strategies to break the chain and prevent the disease.

Amplifiers which are covered by Guideline 12 include potable and emergency water systems, heated spas, architectural fountains and waterfall systems, cooling towers and evaporative condensers, evaporative air coolers, misters, air washers, humidifiers and metal-working systems. Information is presented on operation, nutrient availability, operating temperature level, water droplet sizes and most importantly, recommended treatment.

A review of all of the amplifier systems is beyond the scope of this article. Rather, the discussion will be limited to potable water systems, and cooling towers/evaporative condensers. Readers are referred to ASHRAE Guideline 12-2000 for more detail on these amplifiers as well as information on amplifiers not covered here.

Potable Water Systems

Potable water systems include all piping from the point where the water enters the building as well as hot water heaters, storage tanks, faucets, nozzles, and any other distribution outlets. Water delivered to these systems from most municipal water systems has been chlorinated to control the presence of microorganisms. However, legionellae are more tolerant of chlorine than many other bacteria and are

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presumed present, in low concentrations, in municipal water supplies,[4] and thus the potable water system.

Potable cold water systems are generally below the 25°C (77°F), level required for amplification. Potable hot water temperatures typically range from 41°F (105°F) to 60°C (140°F). Temperatures below 42°C (108°F) are in the amplification range for legionellae. Both dead and living microorganisms, biofilms and debris may provide nutrient sources required for legionellae growth. Water droplets of the very small size (less than 5 micrometers) that can be inhaled deeply into the lungs can be created by shower heads, aerators, spray nozzles, water impacting on hard surfaces and bubbles breaking up.

Many reports link legionellae in hospital tap water to outbreaks of nosocomial (hospital-acquired) Legionnaires' disease, often with immunosuppressed patients.[5] Potable hot water systems are an important potential source of Legionellosis in all buildings and are of particular importance in hospitals, nursing homes and other health care facilities.[6]

The principal treatment strategy for potable water systems is control of the water temperature level. Cold water should be stored and/or delivered at temperatures below 20°C (68°F). In health care facilities, including nursing homes, the hot water should be stored at or above 60°C (140°F) and where it is recirculated, the minimum return temperature should be 51°C (124°F).

Operating at these temperature levels requires that great care be taken to avoid scalding problems. One means of accomplishing this is to install preset thermostatic mixing valves. Where this is not practical, consider periodically increasing the temperature to at least 66°C (150°F) or chlorination followed by flushing. Inspect systems annually to ensure that thermostats are functioning properly.

Where practical in other situations, store hot water at temperatures of 49°C (120°F) or above.

Elevated holding tanks in hot or cold water systems should be inspected and cleaned annually. Lids should fit closely to exclude foreign materials.

Insulated recirculation loops should be incorporated as a design feature in high-risk applications. For all situations, the pipe runs should be as short as practical. New shower systems in large buildings, hospitals, and nursing homes should be designed to permit mixing of hot and cold water near the shower head. The warm water section of pipe between the control valve and the shower head should be self draining.

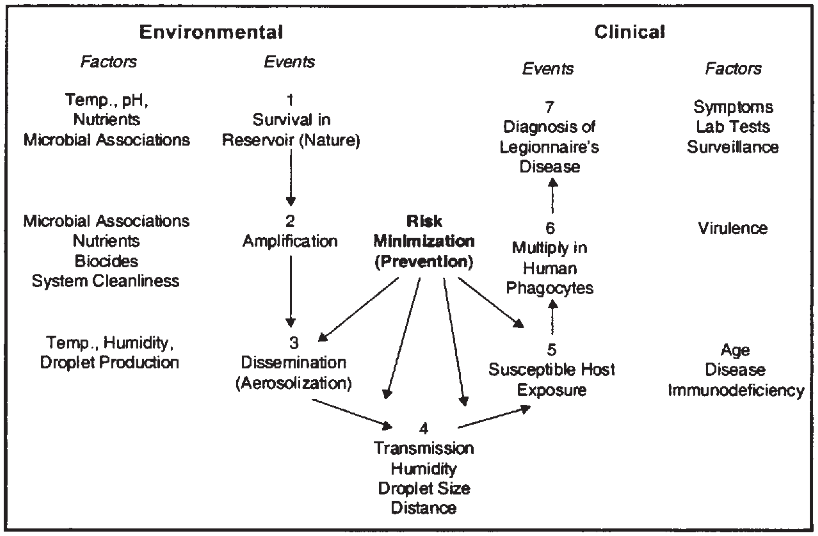

Figure 1: *Legionella* transmission.

An optional treatment strategy involving copper-silver ionization is a relatively new approach to controlling *Legionella* in hot water distribution systems and has been used successfully in a number of hospitals.[7–9] Copper and silver ions are generated electrolytically and build up in the hot water recirculating system to levels effective in eradicating *Legionella*, typically in the range of 0.2 to 0.8 mg/L copper and 0.02 to 0.08 mg/L silver. The optimum concentration of copper-silver ions for controlling *Legionella* in hot water systems is not known. Also, a specific concentration may not be universally effective due to variables in water quality and system design. It also is important to note that the efficacy of copper-silver ions, like chlorine, is adversely affected by elevated pH.[10]

In high-risk applications, monthly removal of shower heads and top aerators to clean out sediment and scale and then cleaning them in a chlorine bleach solution is recommended.

Where decontamination of hot water systems is required (typically due to implication of an outbreak of Legionellosis), this can be accomplished by either thermal shock treatment or by shock chlorination. Thermal shock treatment requires raising the hot water temperature to 71°C to 77°C (160°F to 170°F) and then progressively flushing each outlet around the system. Of course, appropriate safety precautions to prevent scalding are essential. A minimum flush time of five minutes has been recommended by the Center for Disease Control Hospital Infection Control Practices Advisory Committee.[11] However, the optimal flush time is not known and longer flush times may be necessary.

In the original report describing this method, multiple 30-minute flushes were required to significantly reduce *Legionella* colonization.[12] The number of outlets that can be flushed simultaneously will depend on the capacity of the water heater and the flow capability of the system. Local building and sanitary codes should be checked for any temperature limits on water discharged to the sewer.

For systems where thermal shock treatment is not possible, shock chlorination is an alternative approach.[13,14] However, there is less experience with this method of decontamination. Users should also realize that the required levels of free chlorine residual can cause corrosion of metals. Chlorine should be added to achieve a free chlorine residual of at least 2 mg/L throughout the system, which may require chlorination of the water tank to levels of 20 to 50 mg/L. The pH of the water should be maintained between 7.0 and 8.0. Each outlet should be flushed until the odor of chlorine is detected. The chlorine should remain in the system for a minimum of two hours (not to exceed 24 hours), after which the system should be thoroughly flushed.

Once the decontamination is complete, recolonization is likely to occur unless steps are taken to prevent this. Such steps could involve maintaining the recommended temperatures, using continuous supplemental chlorination or using an alternative approach such as copper-silver ionization.

For potable water systems that were opened for repair or construction or systems that were subjected to water pressure changes associated with construction (which may cause water to become brown and the concentration of *Legionella* to dramatically increase),[15] it is recommended that at a minimum the system be thoroughly flushed. High temperature flushing or chlorination may be appropriate, and that judgment should be made on a job-specific basis.

Cooling Towers and Evaporative Condensers

Conventional open cooling towers are evaporative heat transfer devices in which atmospheric air mixes with and cools warm water by evaporating a portion of the water. Air movement through the tower is generally achieved by fans. Cooling towers typically use some media, referred to as "fill" to provide improved contact between the water and the cooling air.

Cooling towers associated with building water systems are typically used for rejection of waste heat from the chiller providing air conditioning for the building, though it could also be rejecting process heat.

Closed-circuit cooling towers and evaporative condensers are also evaporative heat transfer devices. Both are similar to conventional open cooling towers, but there is one significant difference. The process fluid (either a liquid such as water, an ethylene glycol/water mixture, oil, etc., or a condensing refrigerant) does not directly contact the cooling air. Rather, the process fluid is contained in a tubular coil assembly.

Water that is evaporated as part of the heat rejection process is replaced by makeup water, generally from the municipal water supply. Since this water is likely to contain legionellae,[4] in low concentrations, it is reasonable to presume that some concentration of legionellae will be present in the cooling tower or evaporative condenser.

Cooling towers (both conventional open designs as well as closed circuit designs) and evaporative condensers frequently, if not generally, offer conditions that are favorable to the growth of legionellae. The operating temperature is likely to be in the range of 25°C to 42°C (77°F to 108°F) that is favorable to amplification although temperatures can be above 49°C (120°F) or below 21°C (70°F) depending on system heat load, ambient temperature, and system operating strategy.

Because cooling towers and evaporative condensers are highly efficient air scrubbers and also move large volumes of air, organic material and other debris can accumulate. This material may serve as a nutrient source for legionellae growth. Diverse biofilms, which can support the growth of legionellae, may be present on heat exchanger surfaces, structural surfaces, sump surfaces and other miscellaneous surfaces.

Cooling towers and evaporative condensers incorporate inertial stripping devices called drift eliminators to remove water droplets generated within the unit. While the effectiveness of these eliminators can vary significantly with the design (new state-of-the-art eliminators are significantly more efficient than older designs) and with the condition of the eliminators, it should be assumed that some water droplets in the size range of less than five micrometers leave the unit. In addition, some larger droplets leaving the unit may be reduced to five micrometers or less by evaporation.

The key treatment recommendations of Guideline 12 are that the system be maintained clean and that a biocidal treatment program be used. Further, it is recommended to use a qualified water treatment specialist to define and oversee the treatment.

Maintaining a clean system reduces the nutrients available for *Legionella* growth. Regular visual inspections of the equipment should be made and the cold water basin should be cleaned when any buildup of dirt, organic matter or other debris is visible or found through sampling. Mechanical filters or centrifugal-gravity-type separators can be useful in assisting to control such buildup. The drift eliminators also should be inspected regularly and cleaned or replaced as needed.

Operating and maintenance records should be maintained. These records should include manufacturers operating and maintenance manuals, description of the water treatment program, dates of all inspections and maintenance, material safety data sheets for all chemicals used, dates of any repairs, records of the system water volume and names of persons responsible for system start-up, shut down and operation.

A water treatment program should be used to minimize scale and corrosion, to control microbial growth and to minimize the deposition of solids (organic and inorganic). Scaling is minimized through the use of inhibitors (phosphonates, phosphates and polymers) aimed at keeping minerals such as calcium in solution. Corrosion control is accomplished through the use of inhibitors such as phosphates, azoles, molybdenum and zinc. Microbial fouling can influence scaling and corrosion processes and can affect the performance of inhibitors. Microbial biofilms can consume certain inhibitors (phosphates, phosphonates and azoles), prevent access of inhibitors to surfaces, create localized oxygen-depleted zones, change the pH near surfaces and accumulate or trap deposits onto surfaces.

Surfactants are used to minimize deposition on surfaces (particularly heat transfer surfaces). It is important that the surfactant be appropriate for the type of dirt, oil or other material that is present as well as compatible with the scale and corrosion inhibitors that are used.

Growth of legionellae within protozoa may be one of the primary means of proliferation and because protozoa are relatively resistant to both oxidizing and non-oxidizing biocides, it is important that they be controlled by limiting the microbial biofilms that serve to provide them with nutrients.[16]

Microbial fouling is controlled through the use of biocides, which are compounds selected for their ability to kill microbes while having relatively low toxicity for plants and animals. Some biocides react with components of some scale and corrosion inhibitors to render both compounds less effective. Both oxidizing and non-oxidizing biocides are used. Oxidizing biocides function in one of two primary ways. Halogen biocides (chlorine, bromine and iodine) react with the protein in the cell membranes to cause the protein to become dysfunctional, thus killing/controlling the organism. Ozone and chloride dioxides are believed to oxidize other components of the microbial cell. On the other hand, non-oxidizing biocides function in a number of ways, including reacting with intracellular enzymes, solubilizing cell membranes and precipitating essential proteins in microbial cell walls.

Alternation of biocides is generally sound practice. The alternating biocide approach has been emphasized with the rationale that the population that survives the biocide treatment one week is susceptible to the alternate biocide a week or two later. Alternating the dose and the frequency of the same biocide also is used to achieve this goal.

Properly used, both oxidizing and non-oxidizing biocides can be effective for control of the microbial fouling process in cooling water systems. However, due to the previously mentioned interaction between scale and corrosion inhibitors, surfactants and biocides as well as the influence of system water chemistry (pH, etc.), it is recommended that the water treatment program is overseen by a qualified water treatment consultant. This individual should have a knowledge of water chemistry, a basic understanding of water microbiology and specific information about the system (including knowledge of what the system is cooling and sources of contamination).

Systems that have been inactive for a period of more than three days require special attention before being returned to service.[17] Specific actions vary according to whether the system was drained or not and whether a remote storage tank is used or not. The general scheme is to clean any accessible solid debris from the cooling tower and any remote storage tank and execute one of two biocidal treatment programs (either sodium hypro-chlorite or the biocide used prior to shutdown) while operating the water pump(s). The cooling tower fan(s) must remain inactive during this period. Once the biocidal pretreatment has been completed successfully (nominal time period of six hours according to Guideline 12), operation of the fan(s) may be resumed.

Where a system is known to be contaminated and is to be decontaminated, Guideline 12 recommends that the CTI "Emergency Protocol" for decontaminating cooling towers and evaporative condensers be used.[18] This procedure must not be used routinely because it can be very corrosive and produces toxic fumes.

Guideline 12 recommends that attention be given to the following considerations in locating cooling towers.

- Locate as far as possible from fresh air intakes and windows that can be opened.
- Do not locate in areas that could contribute sources of organic matter (such as near kitchen exhaust fans).
- Consider the direction of prevailing winds and do not locate upstream of any outdoor public areas.
- Consider future construction, including that on nearby sites.

Summary

Information on potable water systems and cooling towers/evaporative condensers is provided with the goal that these systems be operated in a manner to minimize the risk of Legionnaires' disease. Additional details on these systems plus similar information on many other amplifiers is found in Guideline 12.

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