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Preventing Legionellosis

By William F. McCoy, Ph.D., Member ASHRAE

Legionellosis is the condition of being infected by *Legionella* bacteria. Recent news has increased awareness about how important it is to prevent the hazard that causes legionellosis from harming people in health-care facilities.^{1–4}

In October 2005, a \$600 million class action lawsuit was filed on behalf of legionellosis victims at the Seven Oaks Home for the Aged, a long-term health-care facility in Toronto. Infectious *Legionella* bacteria in the building killed 23 people. At least 135 people were infected: 70 residents, 39 staff members, 21 visitors and five people who lived or worked near the health-care facility. The hazard is believed to have been in aerosolized water droplets transmitted throughout the building by the ventilation and cooling systems.³

Earlier in 2005, the New York State Department of Health (NYSDOH) cited the New York Presbyterian Health Care

System for violations related to the investigation of legionellosis cases at its Milstein Pavilion, Columbia Division in New York

City.⁴ The infections occurred from March to May 2005. At least seven patients were harmed. Two of those patients subsequently died while hospitalized. The investigation revealed that Columbia Presbyterian Hospital failed to effectively notify patients and visitors of water restrictions and follow policies and protocols to help detect, monitor and eradicate the *Legionella* hazard from the building potable water distribution system. The New York Presbyterian Hospital, Weill Cornell Division, was also cited by the NYSDOH for similar violations related to the monitoring of its potable water system. Lawsuits are pending.

The NYSDOH responded by issuing direct and specific guidance to health-care facilities in the state.⁵

In both of these 2005 news-making events, ASHRAE Guideline 12-2000,

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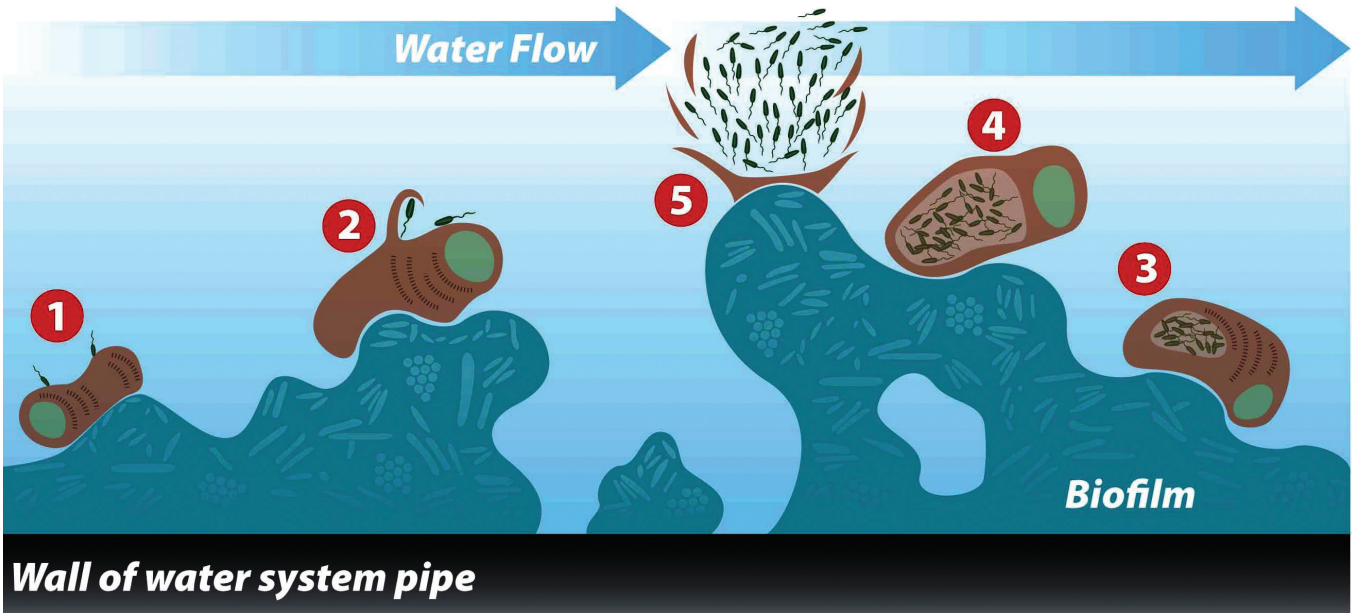


Figure 1: Life cycle of *Legionella* in a building water system. 1) Amoebae graze on biofilm consuming bacteria for food but are 2) infected by *Legionella* which 3) grows intracellularly and then 4) overwhelms its protozoan host cell, differentiates into motile cells and 5) causes lysis of the host cell releasing hundreds or thousands of infective progeny in search of new hosts to infect.

Minimizing the Risk of Legionellosis Associated with Building Water Systems, was cited as authoritative guidance by expert panels in the investigations.

The health-care facility related *Legionella* hazard is not a new problem.⁶ Public health departments have previously established proactive guidance in Allegheny County, Pa.,⁷ Maryland⁸ and Texas.⁹ The Centers for Disease Control and Prevention (CDC) has published guidance.¹⁰ In western Pennsylvania, 33% of all legionellosis cases were nosocomial (health-care facility related) and 71% of hospital water systems were colonized with *Legionella* bacteria (48 hospitals surveyed) prior to implementation of proactive guidance to control legionellosis.¹¹ In Texas, 73% of hospital water systems (15 surveyed) were positive for *Legionella*.⁹ A review of all the guidance published in the U.S. was published in the 2006 *ASHRAE Transactions*.¹²

Preventing legionellosis in health-care facilities is part of a much larger biological hazard control problem. In a review of waterborne nosocomial infections, an estimated 1,400 deaths occur each year in the United States from *Pseudomonas aeruginosa*, another waterborne bacteria commonly found in building water systems.¹³ A variety of bacteria, fungi and protozoa are prevalent in health-care building water systems and can cause disease by transmission through water and air. Clinically important bacteria, fungi and protozoa known to cause disease in health-care facilities include (bacteria) *Legionella*, *Pseudomonas*, and *Mycobacteria*, (fungi) *Aspergillus* and *Fusarium* and (protozoa) *Cryptosporidium*, *Giardia* and *Acanthamoeba*.

The Joint Commission for the Accreditation of Healthcare

Organizations (JCAHO) issued a standard that became effective Jan. 1, 2001. This standard, EC 1.7, requires all JCAHO-accredited health-care facilities to implement a risk management program to “reduce the potential for organizational-acquired illness.” It holds health-care facility management responsible for “managing pathogenic biological agents in cooling towers, domestic hot water, and other aerosolizing water systems.”

Prevention—Hazard Analysis And Control

The following information generally and collectively summarizes legionellosis prevention practices given in the various guidance documents referenced. Special emphasis was given in this summary to the New York State Department of Health guidance⁵ because it is the most recent and comprehensive published so far.

This summary should not be construed to supersede local guidance in your area. The reader is urged to check guidance directives readily available from the county or state health department in your area before implementing a prevention program at your health-care facility.

Teamwork

In almost all of the guidance documents referenced, directives establish a multidisciplinary team to address the problem on a site-specific basis. The team should consist of facility personnel, for example, from infection control, epidemiology and facility management, and the team should be prepared to include their suppliers and consultants, if necessary.



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Broadly speaking, the team should achieve the following seven goals: 1) analyze the hazards and characterize the risk of the hazards for the occupants of the building; using this analysis, the team should develop a site-specific plan which includes 2) hazard control measures, 3) location(s) at which the hazard control should be applied, 4) measurable limits for any hazard control measure applied, 5) record-keeping protocols, 6) a corrective action plan (to be implemented if something goes wrong with hazard control), and 7) an environmental sampling program to quantitatively assess under operating conditions the effectiveness of the hazard control applied and a review process to confirm the plan is being implemented properly.

The practical use of systematic hazard analysis and control for preventing waterborne pathogens from causing disease is concisely described by the World Health Organization and in publications from the International Water Association.^{14,15}

Hazard Analysis

Legionella bacteria are parasites that grow and multiply within protist host cells, most particularly, the aquatic and soil amoeba. Unlike most bacteria taken up by amoeba for food, *Legionella* defeat the phagocytic process of its host that would otherwise devour it. These bacteria do not grow, or they grow very inefficiently, outside their natural host. However, they are quite adapted to rapid growth within the host cells. When they grow intracellularly to such an extent as to produce a great number of vigorous progeny, the host cell ruptures, and releases infective bacteria into the aquatic environment. These great numbers of released bacteria are enormously eager to find new hosts to infect. *Figure 1* shows the life cycle of *Legionella*.

If *Legionella* happen to be inhaled deeply within the human lung, they can infect alveolar macrophage (white blood cells in the lung), which are the cells that engulf bacteria to prevent disease. This process is analogous to the means by which amoeba engulf bacteria for food. Unfortunately for us, *Legionella* can defeat the lytic process of white blood cells. They can grow inside white blood cells to achieve vast numbers of bacteria that can repeat the infective cycle within the lung. This can cause serious lung infections, leading to pneumonia, and also can cause disease in the kidney, heart and central nervous system.

Legionella can thrive in warm water, with ideal growth occurring between 77°F to 115°F (25°C to 46°C). Cooling towers and the hot water systems of health-care facilities typically operate in this temperature range. Above 122°F (50°C) *Legionella* can survive, but with difficulty, and they probably do not multiply. Even at 131°F (55°C), it takes several hours to kill *Legionella* but at 160°F (71°C), it is killed almost instantly.

Legionellosis results from inhalation or aspiration (inhalation of water during the choking reflex) of *Legionella*-laden water. No known person-to-person transmission occurs. A definitive link

has been established between disease transmission and potable water or aerosol-generating devices, such as cooling towers, showers, faucets, hot tubs, whirlpool spas, respiratory therapy equipment (e.g., nebulizers) and in-room humidifiers.

Immunocompromised patients at health-care facilities are at greater risk of infection compared to the general population. Therefore, cooling towers, hot water systems, and other equipment that may generate aerosols must be properly operated and maintained as outlined here.

Hazard Control

Emergency Thermal and Chemical Disinfection

If legionellosis is definitively linked to a health-care facility, the implicated systems must be disinfected immediately. Emergency disinfection is costly and potentially hazardous. Therefore, it should be avoided. The best way to avoid the need for emergency disinfection is to establish and implement an effective hazard analysis and control plan before a nosocomial case occurs. If emergency action must be taken, thermal and/or chemical disinfection should be performed as follows:

- Emergency thermal disinfection of building water systems can eliminate, reduce or prevent *Legionella* in building water systems from harming people. Each outlet should be flushed for more than 5 minutes with water at 160°F to 170°F (71°C to 77°C). Caution: Beware of the potential for serious scalding hazards.
- Emergency hyper-chlorination of building water systems can eliminate, reduce or prevent *Legionella* in building water systems from harming people. Free chlorine levels of at least 2 mg/L (ppm) but less than 4 ppm free residual oxidant from an EPA-registered chlorine product or from on-site electrolytically generated oxidant should be maintained for at least two hours but not to exceed 24 hours throughout the system. If a cold water storage tank is in the system, it may be necessary to add as much as 20 to 50 ppm free chlorine to the tank. Run all faucets and taps until the odor of chlorine is present. Control of pH between 6.0 and 8.0 is recommended to ensure disinfection efficacy. *Thoroughly flush the system after disinfection.* Caution: Chlorine is corrosive to pipes. Emergency disinfection should be avoided except in systems where high levels of *Legionella* have been observed or if an outbreak has occurred. Be aware that local regulations or codes of practice supersede the recommendations given in this article.

It is much safer and more cost-effective to have a hazard analysis and control plan in place at the facility prior to any implication of nosocomial disease.

Complete eradication of *Legionella* by emergency disinfection is difficult and regrowth of the biological hazard is likely to occur. Therefore, long-term control measures must be implemented after the emergency disinfection.

Perform environmental surveillance (collecting water samples or plumbing system swab samples for *Legionella* analysis) to ensure that emergency disinfection and long-term control measures have been effective under operating conditions. In bone marrow transplant and solid organ transplant units, the environmental sampling frequency must be at least quarterly and consistent with the recommendations discussed below in long-term hazard control. In the absence of disease, environmental surveillance in non-transplant units should be initiated as determined by the *Legionella* hazard control policy that was formulated by the multidisciplinary team at the facility.

Disinfection

- Disinfection should be done routinely (e.g., at least semi-annually). To disinfect a hot water distribution system, each outlet should be flushed for more than 5 minutes with water at 160°F to 170°F (71°C to 77°C), and/or with water containing more than 2 ppm free chlorine residual. If thermal anti-scald valves are used, then thermal disinfection cannot be used.

- These hazard control methods may require enhancement, prompted by either disease occurrence or results of environmental sampling as specified by the site-specific *Legionella* hazard prevention, surveillance and control policies at the facility. For instance, ASHRAE Guideline 12-2000 suggests that:

- The optimal thermal disinfection flush time is not known. Multiple 30 minute flushes were required to significantly reduce the hazard for certain systems.
- For chlorine disinfection, 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. This may require chlorination of the water heater or tank to 20 to 50 ppm free residual.

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- Store and distribute potable cold water at less than 68°F (20°C).

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- Hot water heating systems and cooling towers should be maintained according to the manufacturer's recommendations and current industry guidance (ASHRAE Guideline 12-2000). Hot water storage tanks and cooling towers should be drained, cleaned and disinfected at least annually.
- The operation and maintenance of cooling towers should be conducted with the guidance of a water treatment professional, preferably with experience in cooling tower design, operation, hazard analysis and control methodologies.
- A daily operation log and maintenance manual reflecting the latest industry guidance must be developed and maintained for all cooling tower and hot water systems. These should include written details regarding the proper use of anticorrosives, biocides, and disinfectants, and records on repairs, alterations, operating times, monitoring, routine disinfections, and inspections.
- If the necessary mixing valves and/or anti-scald valves are installed in the building, hot water should be stored above 140°F (60°C) and circulated with a minimum return temperature of 124°F (51°C). Mixing valves and/or anti-scald valves are necessary on such systems to reduce the final water temperature in patient areas to prevent scalding. Anti-scald valves need to be operated according to manufacturer's recommendations, which include periodically testing outlet temperatures.
- Facilities without the necessary mixing valves and/or anti-scald valves to operate according to the temperatures described previously, or have not implemented other long-term control measures, should disinfect their distribution system using a high temperature or a chlorination flush at least semi-annually (see the sections on disinfection and long-term hazard control). Precautions should be taken to prevent scalding or exposure to chlorine levels greater than 4 ppm.
- Recirculation loops in the hot water distribution system should be used to minimize stagnation. Dead-legs or capped lines should be eliminated. Water lines in patient areas that have been dormant should be disinfected and flushed before being placed back into service.
- When planning new construction, anti-scald valves should be installed on all hot water outlets, so water temperatures in the distribution system may be set high enough to control *Legionella*.
- When the hot water distribution system is opened for repair/construction or subject to water pressure changes, the system should be thoroughly flushed before being returned to service. The need to disinfect using a high temperature or a chlorination flush before being returned to service should be evaluated on a case-by-case basis. If only a portion of the system is involved, disinfection may be used on only that portion of the system. Precautions should be taken to prevent patient exposure to aerosols during flushing.

- For bone marrow stem cell and solid organ transplant units, the following additional measures should be implemented:
 - Remove, clean, and disinfect shower heads and tap aerators monthly by using a chlorine-based, EPA-registered product, or a chlorine solution of about 500 mg/L (ppm) total residual oxidant.
 - Remove aerators from patient room sinks if environmental sampling yields positive results.

Long-Term Hazard Control

(This especially closely follows the NYSDOH guidance.⁵)

Long-term control is complex and must be individualized for each facility.

- Expert advice should be sought when developing long-term control measures. Consultants must assess corrosion, scaling, biofilm, pH, temperature profile and other physical parameters that may negatively affect treatment.
- Treatment methods used for long term control of *Legionella* in hot water systems may include some or all of the following: 1) installing anti-scald valves on all outlets and maintaining a minimum return temperature of 124°F (51°C); 2) continuous chlorination to achieve a free chlorine residual of 1 to 2 ppm at the outlets; 3) periodic superheating and flushing; 4) silver/copper ionization; 5) chlorine dioxide; or 6) use a combination of the preceding treatment methods. All drinking water treatments should be EPA-registered or approved and NSF certified to NSF/ANSI Standard 60, *Drinking Water Treatment Chemicals* (www.nsf.org/business/water_distribution/index.asp?program=WaterDistributionSys).
- In addition to evaluating treatment methods, consultants should determine whether other preventative measures are needed for long-term control. These measures may include replacing or disinfecting shower heads, installing mixing or anti-scald valves to allow higher temperatures in all or part of the system, replacing hot water tanks with instantaneous heaters, removing shock absorbers, replacing rubber washers with synthetic washers, removing aerators, periodically flushing to improve treatment at distal outlets, modifying the hot water recirculation system, etc.
- After long-term control measures have been implemented, facilities must develop, and regularly reevaluate, an environmental surveillance plan for *Legionella* (routine water monitoring) along with their plan for active case surveillance.

Environmental Surveillance for *Legionella*

The purpose of environmental sampling should be to quantitatively confirm that hazard control has been achieved during operating conditions. In hazard analysis and control terminology, this activity is called "validation." Verification is

the process of checking documentation and records to confirm that the hazard control plan is being implemented.

Culturing the Environment in the Absence of Disease

Culturing for *Legionella* spp. in potable water samples from bone marrow or solid organ transplant units should be performed at least quarterly as part of a comprehensive strategy to validate that hazard control has been effective during operating conditions.

Facilities should convene the multidisciplinary team to assess the need for environmental sampling in non-bone marrow or solid organ transplant units using available empiric literature and site-specific hazard analysis and risk characterizations to guide a decision. If the decision is made to perform environmental testing, the NYSDOH recommends that the following issues are addressed before sampling:

- Methodology for collecting samples should be consistent with current guidance. See the Guidelines for Environmental Infection Control in Health-Care Facilities: Recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee, June 2003, Appendix p. 43, and Box 2 p.18.
- Culture is the gold standard for environmental testing for *Legionella*. The laboratory chosen should be proficient in culturing environmental samples for *Legionella*.
- Polymerase Chain Reaction (PCR) and Direct Fluorescent Antibody (DFA) methods are not useful for environmental sampling (this statement is directly from the NYSDOH guidance; see *Culturing the Environment in the Presence of Disease* later for further details).
- The multidisciplinary team should decide what measures will be taken at the facility for positive environmental results in the absence of disease. The CDC does not give specific guidance on this issue and the Allegheny County, Pa., guidelines recommend that the facility consider disinfection of the water system if more than 30% of outlets sampled yield positive results. The U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) provides a set of actions based on empirically derived limits for viable *Legionella* concentrations (as Colony Forming Units/ml water sampled) for cooling water, potable water and humidifiers.¹⁶

Note that the multidisciplinary team selects the validation criteria (e.g., concentrations of viable Legionella CFU/ml or %positive indications of viable Legionella above a certain detection limit) based on the site-specific circumstances for its facility and any local or regional guidelines. This places the burden on facility management with advice from its independent consultants to select the validation criteria based on its reasoned analysis of conditions at their site.

Culturing the Environment in the Presence of Disease

Recommendations regarding environmental sampling for *Legionella* spp. is far more directive in the case of known disease in New York State. Decisions about details of sampling frequency and actions will be made in consultation with the NYSDOH if a case of possible or definite health-care facility associated legionellosis disease is identified.

Environmental culturing must be performed by a laboratory experienced in culturing *Legionella* spp. from environmental samples. The NYSDOH does not certify laboratories for environmental *Legionella* analysis. The laboratory chosen to perform environmental culturing must be able to serogroup *L. pneumophila*. If the organism causing disease is a species other than *L. pneumophila*, the laboratory must be able to speciate *Legionella*. All positive environmental cultures with the same species and serogroup as the patient isolate must be preserved for molecular analysis.

Polymerase chain reaction (PCR) and differential fluorescent antibody (DFA) methods alone should not be used for environmental sampling as they may detect nonviable organisms.

The Bigger Picture

Proactive hazard analysis and control to prevent legionellosis will significantly improve safety of building water systems in health-care facilities. To prevent disease from other waterborne pathogens transmitted to people from contaminated water systems in health-care facilities (e.g., *Pseudomonas*, *Mycobacteria*, *Aspergillus*, *Fusarium*, *Cryptosporium*, *Giardia* and *Acanthamoeba*), these same hazard analysis and control activities also can be helpful. Generally, improving the safety of building water systems is important.

But, doing important tasks costs money. Experience since the first recorded outbreak in 1976 has taught us that the best way to motivate facility managers is to help them optimize utility operations, save money and time, and then apply some of the savings to improving safety. In most cases, optimizing operations to eliminate wasteful activity and conserve water also are those operational activities that improve the safety of the system. In many cases, the overall water-related costs in a health-care facility can be reduced while biological hazards in the system are effectively controlled.¹⁵

References

1. CTV.ca. 2005. Legionnaires' class action suit seeks \$600M. Oct. 27. www.ctv.ca/servlet/ArticleNews/story/CTVNews/20051025/legionnaires_lawsuit_051024/20051025?hub=Health.
2. Canadian Broadcasting Corporation. 2005. Legionnaires' lawsuit seeks \$600 million. www.cbc.ca/toronto/story/to_lawsuit20051025.html.
3. Government of Ontario, Canada. 2005. Report of the Expert Panel on the Legionnaires' Disease Outbreak in the City of Toronto—Sept./Oct. www.health.gov.on.ca/english/public/pub/ministry_reports/walker_legion/rep_final_120505.pdf.



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4. New York State Department of Health. 2005. "State Health Department Cites Two New York Presbyterian Hospitals for Violations in Legionnaires' Disease Investigation." August 26, 2005. www.health.state.ny.us/press/releases/2005/2005-08-26_presby_legionnaires.htm.

5. New York State Department of Health. 2005. Hospital-associated Legionnaire's disease – Guidelines. July 14, 2005. www.health.state.ny.us/press/releases/2005/2005-08-26_legionnaires/hospital_guidelines legionella.pdf.

6. McCoy, W.F. 2006. "Legionellosis: Why the problem continues." *ASHRAE Journal* 48(1):24–27.

7. Allegheny County Health Department. 1997. "Approaches to Prevention and Control of *Legionella* Infection in Allegheny County Healthcare Facilities."

8. State of Maryland. 2000. "Report of the Maryland Scientific Working Group to Study *Legionella* in Water Systems in Health-care Institutions." Dept. of Health and Mental Hygiene. www.dhmd.state.md.us/html/legionella.htm.

9. Texas Department of State Health Services. 2002. "Report of the Texas Legionnaires' Disease Task Force Recommendations." Last update Oct. 2005. www.dshs.state.tx.us/idcu/disease/legionnaires/.

10. Centers for Disease Control and Prevention. 1997. Guidelines

for Prevention of Nosocomial Pneumonia. *Morbidity and Mortality Weekly Reports*. 46(RR-1):1–79 www.cdc.gov/mmwr/preview/mmwrhtml/00045365.htm.

11. Squier, C.L., et al. 2005. "A proactive approach to prevention of healthcare-acquired Legionnaires' disease: The Allegheny County (Pittsburgh) experience." *American Journal of Infection Control* 33(6):360–367.

12. Fields, B.S., and M.R. Moore. 2006. "Control of *Legionellae* in the environment: A guide to the U.S. guidelines." *ASHRAE Transactions* 112(1):691–699.

13. Anaissie, E.J., et al. 2002. "The hospital water supply as a source of nosocomial infections: a plea for action." *Archives of Internal Medicine* 162(13):1483–92.

14. World Health Organization. 2004. *Guidelines for Drinking Water Quality*, 3rd ed., Chapter 4.

15. McCoy, W.F. 2005. Preventing Legionellosis. Chapters 5–8. International Water Association. London: IWA Publishing.

16. U.S. Department of Labor, Occupational Health and Safety Administration (OSHA). *Legionnaires' Disease*. www.osha.gov/dts/osta/otm/legionnaires/disease_rec.html#risk. ●

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