Legionella: An Invisible Risk

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Ignoring this hidden hazard can put both the public and companies that operate cooling towers at risk.

More than 30 years after the first known outbreak of Legionnaires' disease, U.S. industry is stepping up its efforts to address the risks posed by *Legionella* bacteria in cooling water and refrigeration systems. The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) and the Cooling Technology Institute (CTI), both of which had previously published guidelines for controlling the growth of *Legionella*, are now developing formal standards that some people see as a possible first step toward the regulation of cooling towers. The U.S. Occupational Safety and Health Administration (OSHA) already requires employers to provide personal protection against *Legionella* under the General Duty Clause of the Occupational Safety and Health Act.

A comprehensive water treatment and tower maintenance program helps control the growth of *Legionella* in cooling towers. Photo courtesy of Ashland Water Technologies.

ASHRAE has been working on a standard for building water systems for about two years and plans to issue a draft for comment this summer. CTI announced the formation of a committee to develop a standard to control the bacteria in process-plant cooling systems at its annual meeting in February. Both are playing catch-up to developments in Europe, where *Legionella* legislation is already in place in France, Spain, the U.K., and the Netherlands, and in 2002 the European Working Group for *Legionella* Infections (EWGLI) introduced procedures for managing cases of travel-associated Legionnaire's disease.

So, why now? Loraine Huchler, president of MarTech Systems, Inc. (Lawrenceville, NJ), a water-management consulting firm, warns that there are dire consequences to ignoring the issue. "Look what happened to ExxonMobil in Harnes, France, in 2003. Their cooling tower infected 86 local residents, killing 17 people," she points out.

There is a growing understanding that legionellosis, the form of pneumonia caused by the bacterium *Legionella pneumophila,* is preventable. "It has taken a long time for hospital personnel to be able to recognize and correctly diagnose Legionnaire's disease. While many patients treated with standard antibiotics may have recovered, they often did not receive the most-effective drugs. More importantly, though, are the public health implications of this. By not asking 'where did this person get this infection and who else has been infected from that source?,' opportunities to clean up the contaminated source and prevent additional infections were lost," explains Janet Stout, director of Special Pathogens Laboratory (Pittsburgh, PA) and the microbiologist who discovered the link between the presence of *Legionella* bacteria in hospital water systems and the occurrence of hospital-acquired Legionnaires' disease.

Only recently has greater attention been focused on the fact that the water systems of hotels, commercial office building, and high-rise apartment buildings may also be sources of infection. While Legionnaires' disease must be reported to public health agencies, only outbreaks of two or more cases are investigated. For the majority of reported sporadic cases, the source remains unidentified.

"Identifying whether a water system is colonized with *Legionella* is straightforward — culture for the bacteria," Stout notes. "This is now being required of hospitals in the nationwide Veterans Affairs healthcare system if they treat patients at risk of getting Legionnaires' disease."

In addition, while hospitals have been known to be a source of legionellosis infection for some time, recognition that almost any building water system or cooling tower can be a source of infection is relatively recent. Some companies understand that cooling towers can cause legionellosis infections in the community; other plant managers are unaware of the risk.

According to Huchler, "manufacturers thought that industrial cooling towers were too far away for the drift to impact the local community … wrong. Many plant managers thought that if they protected their employees from infection, then they properly managed the risk … wrong. They thought that industrial cooling towers with good monitoring had good control of water chemistry, specifically microbiological populations … wrong."

"Unfortunately," she continues, "just because employees seldom get legionellosis doesn't mean that your cooling tower can't be the source of infection. It can. And it will if you ignore this invisible risk. Any leaks of process fluids (hydrocarbons) into the cooling system serve as food for the bacteria — they feast on it. A tower's basin is an excellent breeding ground for the bacteria, but many plants don't realize the need to clean out the accumulated sludge."

Huchler says that there have been several incidents where process cooling towers were implicated as the source of the *Legionella* bacteria that caused infections in employees. The event in Harnes, France, was the first incident where a process control tower was the source of bacteria that caused infections in the surrounding community. Investigators matched the DNA of the bacteria in two victims with the DNA of the *Legionella* bacteria in a cooling tower at the local industrial alcohols plant owned by Noroxo SAS, a subsidiary of ExxonMobil.

Such outbreaks are not surprising, considering that *Legionella* bacteria are found virtually everywhere — in rivers, lakes, ponds, and various make-up water sources. Any cooling tower is a risk for *Legionella* proliferation.

In a recent study of 2,590 samples from comfort-system cooling towers, Richard Miller, vice president of Environmental Safety Technologies, Inc. (Louisville, KY) and an associate professor in the department of microbiology and immunology at the Univ. of Louisville, found that 13% tested positive for *Legionella*.

"Of course, being ubiquitous in surface waters, *Legionella* could be present at much lower concentrations in more cooling towers, but there seems to be a very low risk associated with this," he says. His work used the culture method of analysis ("the gold standard," he says), which has a sensitivity limit of 10 colony-forming units (CFU) per mL. "Direct microscopic techniques have shown higher percentages of *Legionella* in towers, but these techniques detect both living and dead *Legionella*, and also have a high rate of false positives. For purposes of risk assessments, everyone agrees that only the culture method should be used."

Of more relevance to the chemical process industries, though, is the prevalence of the bacteria in industrial cooling towers. According to the 2006 CTI guideline document, studies have shown that 40% to 60% of process cooling towers tested contained *Legionella*.

Joanne Kuchinski, marketing manager at Ashland Water Technology (Dublin, OH), a division of Ashland, Inc., notes that "any water-handling system can harbor microorganisms, including *Legionella* as well as other organisms and pathogens. The important considerations are 'what levels of *Legionella* organisms are present in the cooling tower, what strains of *Legionella* are present, and what is the potential for growth, dissemination and transmission?'"

Regardless of the number of cooling towers that harbor the bacteria, "it's important for a plant to take a total, comprehensive focus, and to put together a comprehensive treatment and maintenance program, based on best practices, in order to maintain system cleanliness," Kuchinski says.

CTI's existing guideline (see box, p. 8) outlines a series of such best

What is Legionnaires' Disease?

Legionnaires' disease, or Legionellosis, is a form of pneumonia caused by the bacterium *Legionella pneumophila,* one of more than 50 species of the genus *Legionella*. It got its name after a 1976 outbreak among people attending an American Legion Convention in Philadelphia, PA. The disease, which sickened 221 people and caused 34 deaths, was attributed to a previously unknown bacterium that was later named Legionella.

According to the U.S. Centers for Disease Control and Prevention (CDC), between 8,000 and 18,000 people are hospitalized with Legionnaires' disease in the U.S. each year. However, many infections are not diagnosed or reported, so the actual number is believed to be higher. Most cases of Legionnaires' disease are sporadic (meaning that the source of the infection is not traced); 23% are the result of treatment in a hospital or other healthcare facility but secondary to the patient's original condition (known as nosocomial infections), and 10%–20% can be linked to outbreaks (i.e., when two or more people become ill in the same place at about the same time). Legionnaires' disease can be very serious, and can cause death in 5% to 30% of cases. Most cases can be treated successfully with antibiotics, and healthy people usually recover from infection; smokers and those who have cancer, chronic respiratory diseases and other immuno-suppressed conditions are most susceptible to serious complications and death.

Legionella bacteria are found naturally in the environment, usually in water and moist soil. The bacteria grow best in warm water, such as in cooling towers, hot water tanks, large plumbing systems, and air-conditioning systems of large buildings. Legionnaires' disease is contracted by breathing in a mist or vapor that has been contaminated with the bacteria; it is not transmitted by person-to-person contact.

practices and recommendations for minimizing the risks associated with *Legionella*. It focuses on chemical control, primarily by halogenated disinfectants, but emphasizes that chemical control is only one aspect of risk minimization, and that design, operation and maintenance practices are crucial to reducing risks associated with cooling systems.

Whether CTI's forthcoming standard will have the same form remains to be seen. Because members of the standard-writing committee are still being recruited, those involved did not want to comment on the direction they might take.

Microbiological control is key

The heart of a *Legionella* control program is the proper use of effective biocides. Various biocides are available, and many biocide combinations can work well against *Legionella*, Miller says.

He analyzed 2,590 water samples from approximately 1,000 cooling towers, and evaluated 28 combinations of eight biocides [bromine; quaternary ammonium compounds (quats); carbamate; isothiazoline; glutaraldehye; hydroperoxide; 2-2-dibromo 3-nitrilopropionamide (DBNPA); and tetrakis (hydroxymethyl) phosphonium sulfate (THPS)]. He found that none of the 28 treatment regimes were 100% effective in preventing *Legionella* colonization, nor were there any that always

CTI's Recommended Best Practices

"Guideline: Best Practices for Control of *Legionella*," published by the Cooling Technology Institute (CTI; Houston, TX; cti.org) in July 2006, offers recommendations aimed at promoting and maintaining clean heat-transfer surfaces and a healthy work environment around open recirculating cooling systems.

Monitoring. Evaluate system cleanliness and the effectiveness of microbial control by visual inspection as well as regular monitoring of bulk water and surface microbial populations. Check the cooling tower deck and tower fill for gross evidence of biofouling, and when operations permit, inspect the mist eliminator section for biological deposits. Suspect deposits should be collected and examined under a microscope to confirm biological content.

Continuous application of halogens. For relatively clean systems, or where clean potable makeup water is used, feed a source of halogen (chlorine or bromine) continuously, according to label instructions, to maintain a free residual of 0.5 to 1.0 ppm in the hot return water. A biodispersant/biodetergent may aid in the penetration, removal and dispersion of biofilm, and often increases the efficacy of the biocide. Periodic use of nonoxidizing biocides may also be required to control biofilm and planktonic organisms in systems that use makeup water from other than potable water sources and those with process leaks or contamination; the choice of nonoxidizing biocide should be based on the results of toxicant evaluations.

Intermittent use of halogens. Continuous halogenation is always preferred for *Legionella* risk management, but if this is not possible, intermittent use of a halogen is necessary. As a minimum control program, a free halogen residual of at least 1.0 ppm should be established and held for no less than one hour each day. Free residual must be monitored throughout the distribution system. Bulk water and surface counts, along with microscopic examination of deposit samples, are needed to ensure that the concentration and duration of halogen residuals are adequate. A biodispersant may increase the efficacy of the biocide. Nonoxidizing biocides are critical for systems treated intermittently with halogens.

Hyperhalogenation. Periodic online disinfection may be necessary for systems that have process leaks, that have heavy biofouling, that use reclaimed wastewater as makeup, that have been stagnant for a long time, that regularly have total aerobic bacteria counts exceeding 100,000 CFU/mL, or that have *Legionella* concentrations exceeding 100 CFU/mL. Such systems require hyperhalogenation — *i.e.,* the maintenance of a minimum of 5 ppm of free halogen residual for at least 6 h. This will discourage the development of large populations of *Legionella* and their host organisms, and may eliminate the need for conducting more-complicated and higher-risk off-line emergency disinfection procedures.

Emergency disinfection. When very high (*i.e.,* >1,000 CFU/mL) *Legionella* counts exist, where cases of Legionnaires' disease are known or suspected and may be associated with the cooling tower, or when very high total microbial counts (>100,000 CFU/mL) reappear within 24 h of a routine hyperhalogenation disinfection, an extensive 15-step disinfection procedure should be carried out.

Tower design. New and retrofit towers should be designed with state-of-the-art, high-efficiency nesting-type drift eliminators to prevent the escape of entrained water droplets that might contain *Legionella*. Based on expected water quality and treatment, select a tower fill to minimize fouling and poor distribution of water that might encourage *Legionella* propagation, and for proper air and water management to control drift rate and splash-out. Distribution components should be designed to minimize the creation of very small droplets, which are more likely to escape through the drift eliminators, and to minimize masses of water at locations that might bypass air seals and allow circulating water to enter the exiting airstream. Towers, as well as discharge piping and equalizers, should be designed to provide good continuous water flow through and out of the tower to move water effectively, with no dead flow locations.

Finally, locate cooling towers away from building air intakes, so that tower drift and splash-out are not fed into building air supply systems.

Inspection and maintenance. Visually inspect cooling towers frequently, focusing on general cleanliness, leaks and evidence of biomass. Maintain the tower and its components in good working order, remove any organic fouling, dirt or debris, and correct any defects in the components or their installation that could lead to the emission of excessive drift or spray.

failed. Most displayed close-to-average performance, although some clearly were statistically better and others worse than average, both in terms of overall *Legionella* prevalence and the occurrence of high levels (>1,000 CFU/mL) of *Legionella*.

"One particular biocide that seemed to stand out was THPS. While it was not perfect, THPS alone or in any combination had generally very low *Legionella* colonization rates and very few high levels of *Legionella*," he notes.

In general, Miller found that the halogenated biocides (mostly bromine because of the pH at which most cooling towers operate) were no better than the nonoxidizing, organic biocides. The key "is to alternate two different biocides in order to broaden the kill and to prevent development of resistance," he says. "Which two biocides are chosen is sometimes a matter of cost as well as effectiveness," he adds.

A comprehensive approach to risk management

Rather than recommend specific best practices, the U.K. Health and Safety Executive has taken a risk-assessment and -management approach. Its Approved Code of Practice and Guidance, "Legionnaires' Disease, L8, The Control of *Legionella* Bacteria in Water Systems," requires employers to: identify and assess sources of risk; prepare a scheme for preventing or controlling the risk; implement, manage and monitor precautions; keep records of the precautions; and appoint a person to be managerially responsible.

That's essentially the approach ASHRAE is taking as well. Its standard — SPC-188, "Prevention of Legionellosis Associated with Building Water Systems" — is expected to be a risk-management standard modeled after the food industry's Hazard Analysis and Critical Control Points (HACCP) methodology. HACCP is similar to the Hazard and Operability Analysis (HAZOP) approach to risk assessment that is used widely throughout the chemical process industries.

"The HACCP risk-management plan requires the establishment of a team to evaluate the facility's systems for *Legionella* risk, develop flow diagrams of those systems, and then determine critical control points for *Legionella* hazard control," explains Miller, who serves on the ASHRAE standard-writing committee. "For cooling towers, the two main control points are typically the biocides added to control *Legionella* proliferation, and efficient drift eliminators to prevent airborne spread of potentially infectious aerosols," he continues.

Some petrochemical plants have already started to take a proactive approach to managing their *Legionella* risk. "Major corporations in America are confronting the legionellosis issue more seriously now because of (a) more awareness that there is a problem, (b) recent high-dollar lawsuits, and (c) OSHA has been very clear that *Legionella* is a known biological hazard for which protection from harm is required by the General Duty Clause of the Occupational Safety and Health Act," reports William F. McCoy, vice-chair of ASHRAE's SPC-188 committee and co-founder of Phigenics LLC (Chicago, IL), a company that pro-

Suggested remedial actions if *Legionella* is detected in cooling towers and evaporative condensers.

Legionella Count, CFU/mL	Hazard Level	Recommended Actions
Detectable, but <1	1	Review routine maintenance program recommended by the manufacturer of the equipment to ensure that it is being followed. The presence of barely detectable numbers of *Legionella* represents a low level of concern.
1–9	2	Implement Action 1. Conduct the follow-up analysis after a few weeks for evidence of further *Legionella* amplification. This level of *Legionella* represents little concern, but the number of organisms detected indicates that the system is a potential amplifier for *Legionella*.
10–99	3	Implement Action 2. Conduct review of premises for direct and indirect bioaerosol contact with occupants and health risk status of people who may come in contact with the bioaerosols. Depending on the results of this review, action related to cleaning and/or biocide treatment of the equipment may be indicated. This level of *Legionella* represents a low but increased level of concern.
100–999	4	Implement Action 3. Cleaning and/or biocide treatment of the equipment is indicated. This level of *Legionella* represents a moderately high level of concern, since it is approaching levels that may cause outbreaks. It is uncommon for samples to contain numbers of *Legionella* that fall in this category.
≥ 1,000	5	Immediate cleaning and/or biocide treatment of the equipment is definitely indicated. Conduct post-treatment analysis to ensure the effectiveness of the corrective action. This level of *Legionella* represents a high level of concern, since it poses the potential for causing an outbreak. It is very uncommon for samples to contain numbers of *Legionella* that fall in this category.

Source: GE Water and Process Technologies (www.gewater.com).

vides risk-management services and new products to solve problems in building water systems. Also, the World Health Organization's (WHO) recent publication of "*Legionella* and the Prevention of Legionellosis" has gotten the attention of corporate safety officers, he adds.

McCoy says that several large multinational corporations are establishing corporate water-management plans (WMP) for their facilities. Based on the principles of hazard-analysis-and-control risk management, these plans are set up to answer three questions:

1. What are the hazards? Plant audits are conducted to determine if biological hazards exist in the facility.

2. What is being done to control the hazards? Water treatment standard operating procedures (SOPs) are established to improve operational efficiency and improve safety.

3. How do we know that the hazards have been controlled? This involves obtaining evidence under operating conditions that the SOPs have, in fact, controlled or eliminated the hazards (validation), and regular reporting to confirm that the WMP is being implemented properly (verification).

The good news for facilities with cooling towers, Miller points out, is that "they are already using biocides for biofouling, whether they have addressed *Legionella* or not. The only difference is that *Legionella* will be referred to as a 'hazard' by the new HACCP standard, and must be addressed. While there are some new things that need to be done in terms of risk management, in practice, it just means validating that the existing biocides are controlling the *Legionella* levels. If they are not, then there would be a change to something else."

Huchler, though, issues a stronger warning: "Although the CTI released its guideline in 2000, eight years later we're still seeing infections that trace back to industrial cooling towers … Plant managers must understand the risks of ignoring the issue and the consequences they'll face if their cooling towers cause legionellosis."

Even in the absence of specific regulations, the publication of the ASHRAE and CTI standards will set the level of care that prudent companies will use in the design and operation of their towers. So if an incident were to occur, "all eyes will be on what you've done and whether it meets the accepted standard level of care," she says.

She concludes: "When you tabulate the potential costs in terms of loss of human life, lost production and the loss of goodwill — there will be no doubt about the right thing to do." CEP