Legionella LIVES

It's been almost a quarter century since a then-mysterious disease killed 34 convention attendees. Unfortunately, its legacy is still going strong. An understanding of its biology, history, and current prevention strategies is the best remedy you can employ.

BY JACK SPRINGSTON, CIH, CSP

In the summer of 1976, *Legionella* was thrust into the public spotlight following an outbreak at an American Legion Convention in Philadelphia's Bellevue Stratford Hotel. A total of 221 cases of pneumonia, and 34 deaths, occurred among the more than 4,000 convention attendees as a result of exposure to this previously unidentified bacteria. It wasn't until 1977 that the offending agent, *Legionella pneumophila*, was finally identified by the Centers for Disease Control (CDC).

However, this was not the first outbreak. Retrospective studies have shown a number of pneumonia outbreaks which we now know were caused by *Legionella*. The earliest documented outbreak of Legionnaires' disease occurred in 1957 in Austin, MN. A total of 78 persons, 46 of whom were employees at a local meat packing plant, were hospitalized with acute respiratory disease of unknown cause. Eventually two of the patients died.[1]

In July and August of 1964, at least 81 patients at the St. Elizabeth Medical Center, a large psychiatric hospital located in Washington DC, developed pneumonia after being exposed to *Legionella* bacteria. Seventeen of the patients died as a result of the disease. Evidence suggests that the bacteria may have originated from extensive soil excavations that were being carried out on the campus of the hospital during the summer months.[2]

THE ECOLOGY OF LEGIONELLA

Legionella are gram-negative rod-shaped bacteria that are ubiquitous in freshwater environments, occurring naturally in surface waters including lakes, rivers, streams, and mud. *Legionella* apparently survive in low numbers in routine water treatment used to produce potable water. They can be carried in the treated drinking water into buildings, where they colonize in the plumbing fixtures, especially in hot water systems. Cooling towers and other systems, therefore, may become contaminated through the makeup water.

Legionella is known to grow in water temperatures between 68°F and 122°F, with optimal growth occurring between 95°F and 115°F. It will not multiply at temperatures below 68°F, and cannot survive in water above 140°F. Other factors affecting growth include a pH range of 2.0 to 9.5, the presence of L-cysteine-HCL and iron salts, sediment in water which supports the growth of supporting microbiota, and free-living aquatic amoebae and other protozoa. Algal slime provides a stable habitat for the multiplication and survival of *Legionella*.

In addition, *Legionella* is an intracellular parasite on other bacteria and protozoa. Once it insinuates itself into a larger bacteria, it resists the host defenses and then multiplies.[3] *Legionella*, due to its susceptibility to desiccation and ultraviolet radiation, tends to be shortlived in the air.[4]

Currently, at least 35 species and 54 serogroups of *Legionella* have been identified, with more than 20 of these species linked to human diseases. Some serogroups are even further separated into subtypes. Over 80% of all legionellosis is caused by *L. pneumophila*, with serogroup 1 being the most frequently identified form of the bacterium isolated from patients with Legionnaires' disease.[5] However, other serogroups and subtypes of the bacterium are also frequently isolated from water sources and often are linked with disease.

Although many other species have not yet been associated with human diseases, this may be because of their extremely rare

Isolated from human sources*		Isolated from environmental sources only	
L. anisa	*L. jordanis*	*L. adelaidensis*	*L. quinlivanii*
L. bozemanii	*L. longbeachae*	*L. brunensis*	*L. rubrilucens*
L. birminghamensis	*L. maceachernii*	*L. fairfieldensis*	*L. santicrucis*
L. cherrii	*L. micdadei*	*L. erythra*	*L. spirtensis*
L. cincinnatiensis	*L. oakridgensis*	*L. gratiana*	*L. steigerwaltii*
L. dumoffii	*L. pneumophila*	*L. israelensis*	
L. feeleii	*L. sainthelensi*	*L. jamestowniensis*	
L. gormanii	*L. tucsonesis*	*L. moravica*	
L. hackeliae	*L. wadsworthii*	*L. parisiensis*	

*Species which have been isolated from either human disease or have been serologically implicated in human infections.

TABLE 1. *Legionella* species.

Legionella/ml	Cooling Towers	Hot Water Systems	Humidifiers/Fogger
< 1	Low	Low	Low but increasing
1-9	Low	Low but increasing	Moderate
10-99	Low but increasing	Moderate	High
100-999	Moderate	High	High
>1,000	High	High	High

TABLE 2. Suggested *Legionella* risk assessment levels.

occurrence in nature. As such, until proven otherwise, all strains of *Legionella* should be considered potentially pathogenic.[6]

HEALTH RISKS AND *LEGIONELLA* BACTERIA

Legionella is rather unusual in that exposure to it can cause two different types of disease: Legionnaires' disease, a severe form of pneumonia, and Pontiac fever, a nonfatal flu-like illness. The major mechanism or route of infection is inhalation of aerosolized water droplets or particles containing *Legionella* bacteria. No person-to-person spread of the disease has ever been documented, and ingestion of contaminated water does not appear to cause disease, either.[7]

Pontiac fever is a self-limiting, influenza-like illness which does not cause pneumonia. It has a very high attack rate, affecting over 95% of exposed individuals, and usually appears 36 to 48 hrs after exposure. Symptoms typically disappear within 2 to 5 days of onset.[8,9]

This variant first appeared in 1968 in Pontiac, MI, hence the disease's name. Ironically, 95 out of 100 employees in the Oakland County (MI) Health Department became sick. The CDC sent three investigators into the building who subsequently became sick. They were replaced by three other investigators who also became sick. The problem was eventually traced to an evaporative condenser in the basement, which was vented within 6 ft of the hvac fresh air intake.[10]

Symptoms of Legionnaires' disease can vary from a mild cough and low fever, to a rapidly progressive pneumonia and coma. Early symptoms, which commonly appear three to nine days after exposure, often include malaise, muscle aches, and a slight headache. Subsequent symptoms can include a high fever of up to 105°F, a dry cough, and shortness of breath.

Legionnaires' disease has a low attack rate (around 5%), but it boasts a fairly high fatality rate (10% to 15%).[11] Among elderly or immunosuppressed patients, the fatality rate is even higher — up to 80% if left untreated.[12] Approximately 1,000 cases of Legionnaires' disease are reported each year to the CDC. However, it is estimated that upwards of 25,000 cases of Legionnaires' disease (range 10,000 to >100,000), and 3,000 to 7,000 subsequent deaths occur in the U.S. annually.[13,14]

In order to cause disease, the bacteria must be virulent, present in sufficient quantities to cause disease, aerosolized from its water source, and inhaled deeply into the lungs. Once there, it can evade the host defenses by parasitizing phagocytes, in much the same way as salmonella and tuberculosis bacteria infect people. *Legionella* is characterized as an opportunistic disease which most frequently attacks elderly or immunocompromised/immunosuppressed individuals.

Additional host-specific risk factors include being a male over 50 years of age, cigarette smoking, diabetes, kidney failure requiring dialysis, organ transplants, corticosteroid therapy, AIDS, or other underlying diseases such as cancer. However, even healthy individuals can acquire the disease if they are exposed to a high enough airborne concentration of the bacteria.[15]

The mere presence of *Legionella* either in heat rejection systems or water services will not in itself cause disease. High numbers of *Legionella* have been noted in cooling towers and other sources with no associated disease. Most outbreaks from cooling towers and evaporative condensers have been associated with high numbers of *Legionella*, 1,000 colony forming units per ml (cfu/ml) or more, in the implicated water source. In a potable water system associated with an outbreak, the reported numbers of *Legionella* averaged 160 cfu/ml (range <1 to 1,500 cfu/ml), while as few as 10 cfu/ml in a fogger reservoir may have caused disease.[16] Using the various available data regarding outbreaks, a quantitative *Legionella* risk assessment criteria was subsequently developed by one laboratory and subsequently referenced by OSHA.[17,18]

Legionnaires' disease can occur as either epidemic clusters (11% of all reported cases) or sporadic (89%), and can be hospital-acquired (23%) or community-acquired (77%).[19] The disease has been documented nearly worldwide, including in England, Australia, and New Zealand. Interestingly enough, to date all reported outbreaks/epidemic clusters have been caused by *L. pneumophila*, while sporadic cases have been caused by a variety of species including *L. pneumophia, L. micdadei, L. bozemanii, L. dumoffii, L. longbeachae, L. anisa*, and other *Legionella* spp.[20]

Hospitalization with appropriate antibiotic therapy is essential in order to reduce the chance of fatality. The most commonly used antibiotic for Legionnaires' disease, erythromycin, does not actually kill *Legionella* but prevents it from multiplying intracellularly, thereby giving the immune system a chance to work. A second antibiotic, rifampin, may be prescribed for more severe cases. Even with treatment, though, 7% to 9% of previously healthy individuals, and 24% of individuals with seriously impaired immune systems, will still die.[21]

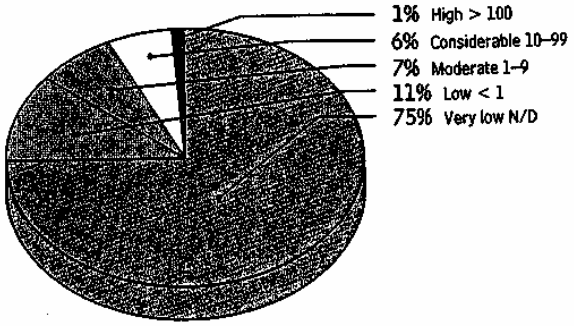

FIGURE 1. *Legionella* concentrations in New York City hot water systems surveyed from January 1995 to August 1999.

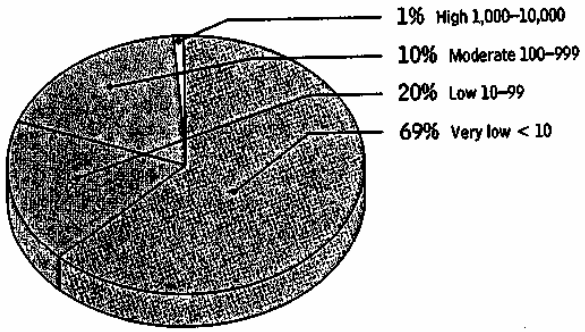

FIGURE 2. *Legionella* concentrations in New York City cooling towers surveyed from January 1995 to August 1999.

AMPLIFIERS AND DISSEMINATORS

A variety of building systems have been linked to Legionellosis, including cooling towers, evaporative condensers, domestic hot water systems, spas, whirlpools, humidifiers, decorative fountains, faucets, showerheads, and even vegetable misters in supermarkets.[22] Plumbing systems have been implicated in numerous outbreaks, including cases in nursing homes, workplaces, and private residences.

Hot water systems tend to be ideal breeding habitats for *Legionella* bacteria. *Legionella* can flourish in a hot water system, particularly if the temperatures are maintained below 140°F. Scale and biofilm buildup within the hot water tank and the piping not only furnish the bacteria with food, but also provide protection from high temperatures and any chemical disinfectants. *Legionella* are also often found in dead legs, or unused sections of piping, where the stagnant water can provide an ideal environment for amplification.

Sampling data from 107 New York City commercial buildings, collected between January 1995 and October 1998 by our laboratory, indicated that 18.4% of the hot water system samples contained *Legionella* bacteria at detectable levels. Studies in residential hot water systems have shown *Legionella* contamination in 30% and 32% of the heaters tested.[23,24] Another separate study, conducted at a Canadian hospital over a four-year period, showed 24.7% of the

Update: The latest on Legionnaire's disease

BY MATTHEW R. FREIJE

Here is the most recent news on Legionnaires' disease and *Legionella* control:

Public awareness. On November 21, CNN & TIME, a TV newsmagazine, aired a segment on Legionnaires' disease in hospitals. CNN reported that "every year thousands of patients contract [Legionnaires'] disease from contaminated hospital water systems." The show included an interview with Dr. Victor Yu, a Legionnaires' expert from the VA Medical Center in Pittsburgh: "These outbreaks, they're actually occurring all through the country every week," said Yu. "It's an explosive problem to realize that people are dying, to realize that the means are there for preventing all this from happening, and that those means are not being exercised." Indeed, awareness of Legionnaires' disease is growing, and more people are realizing that preventive measures are not implemented in most buildings.

Outbreaks. Most cases of Legionnaires' disease still go undetected, and the public hears about very few cases that are detected. However, some of the multicase outbreaks make the news. For example, an outbreak in the Netherlands, which occurred in late February-early March 1999, involved 242 cases of illness and 28 deaths. The outbreak was blamed on a whirlpool spa displayed at a trade show. Briefs on recent outbreaks are posted at www.hcinfo.com/outbreaks-news.htm.

Patient testing. Special laboratory tests are required to detect Legionnaires' disease. Most hospitals still do not make these tests available. But a new 15-min test (by Binax Inc., www.binax.com) for a common strain of *Legionella* makes patient testing easier and cheaper, which should result in more testing and more diagnosed cases.

Lawsuits. Legionnaires' disease is conducive to lawsuits. A case of Legionnaires' disease can be linked to an environmental source (e.g., a cooling tower) by comparing the *Legionella* strain found in the victim to the strain found in a water sample. This may allow a plaintiff to rule out some water supplies (in the victim's house) and implicate others (in the defendant's building) as the source of the Legionellae that caused the illness — similar to the way DNA tests are used to link criminal defendants to a murder scene. Legionnaires' lawsuits are not rare. Several are in process at the time of this writing.

Water sampling. The debate continues about whether or not to test water routinely for *Legionella*. Guidelines by the [U.S.] Centers for Disease Control and Prevention (CDC, Atlanta) do not include a recommendation for routine sampling unless cases of disease have been identified, but CDC officials have suggested recently that routine testing may be appropriate in hospitals that treat high-risk patients. Some building owners voluntarily test plumbing systems and cooling towers for *Legionella* in order to check preventive measures and establish a defense against lawsuits.

New technology. In plumbing systems, copper-silver ionization has outperformed chlorine, partly because of its apparent ability to disinfect systems laden with biofilm. Studies indicate chlorine dioxide is also more effective than chlorine, plus lower in cost and less harmful to ingest. Suppliers claim it even removes biofilm over time. Chlorine dioxide has been used for drinking water in the United Kingdom, but it is still uncommon in the United States, partly because of concerns about the safety of onsite generation of chlorine dioxide. However, new technology (by Halox, www.halox.com) claims to make the generation process much safer than before.

Chlorine dioxide may be effective against *Legionella* in cooling towers also. Look for reports of studies on actual cooling towers (rather than laboratory models). Another biocide, by Sterilex (www.sterilex.com), was recently accepted by the U.S. EPA and also claims to remove biofilm from cooling tower piping. The Sterilex product is added to cooling towers periodically as a supplemental biocide.

Information. A free *Legionella* newsletter, sent by e-mail about once a month, covers new technology for *Legionella* control, outbreaks briefs, and new findings on Legionnaires' disease. To register for "Legionella E-news", go to www.hcinfo.com (the web site of HC Information Resources). Also, Denis Green of Australia has formed a *Legionella* discussion group. To join, go to www.egroups.com/group/legionnaires_disease/.

Regulations. The New York State Department of Health was to send a letter of Legionnaires' recommendations to 250 hospitals and 650 nursing homes in December. A NYDOH official said it is deviating from CDC's no-routine-sampling guidance by recommending routine sampling in hospitals that treat high-risk patients (e.g., hospitals that perform transplants). The State of Maryland is also beginning the process of drafting Legionnaires' guidance.

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samples were positive for *L. pneumophila*.[25]

Both cooling towers and evaporative condensers have been verified as potential disease transmitters,[26,27] although evaporative coolers have not.[28] Cooling towers provide all of the elements needed for *Legionella* to grow — warm water, algae, fungi, protozoa, dirt, and biofilm. Contrary to what some water treatment companies may claim, studies indicate that there is no significant correlation between total bacteria counts and *Legionella* concentrations in cooling towers.[29] The only way to determine if *Legionella* is present, is to sample and analyze for it specifically.

Sampling data from 51 New York City commercial buildings, collected between January 1995 and October 1998 by our laboratory, indicated that 31% of the cooling tower system samples contained *Legionella* bacteria at detectable levels. In a comparable study, where 304 samples were collected from commercial building cooling towers in an urban area, 16.4% of those were found to have *Legionella* present.[30]

CONTROL OF *LEGIONELLA*

In order to reduce or eliminate the risk of Legionellosis, it is necessary to minimize the concentrations of *Legionella* in the affected system, and/or prevent the transmission of *Legionella* bacteria from the affected system to susceptible individuals.

Decontamination of contaminated hot water systems usually consists of thermal pasteurization, or "superheating" as it is commonly referred to. Superheating simply consists of raising the water heater temperature to at least 158°F (70°C) for 24 hrs, and flushing each outlet for 20 min. The temperature at the outlet should reach at least 140°F (60°C). Prior to performing superheating, all dead legs should be removed because these stagnant areas can "re-seed" the system following treatment.

For older buildings, where there may be significant scale buildup inside the piping, additional flushing time may be necessary.

Scale Thickness In Inches	Loss of Heat Transfer Efficiency
0.0625	15%
0.125	20%
0.250	39%
0.500	70%
0.750	90%

TABLE 3. Scale thickness vs. loss of heat.

This is because the scale acts as an insulator and helps protect the *Legionella* bacteria buried within it from temperatures necessary to kill them. The insulating properties of scale can be quite significant, as shown in Table 3. One possible treatment method in older buildings is to leave each outlet open just a fraction, enough to allow a slow stream of water flow passing through the piping over a period of 8 hrs or so. This should allow enough time so that the entire scale layer becomes heated to over 140°F.

Periodic chlorination is another method of controlling *Legionella* in hot water systems. Scale and sediment are first removed from the tank. Sodium hypochlorite is then added until approximately 10 ppm of free residual chlorine is produced. Since the biocidal activity of chlorine is very sensitive to pH levels, the pH of the water should be maintained between 7.0 and 7.6. All taps are then flushed until the distinct odor of chlorine is evident, and the water should be allowed to stand for 1 hr. The tank is then drained and refilled, and each outlet flushed to remove the chlorine from the system.[31]

There are two disadvantages to chlorine shock treatment vs. superheating in hot water systems. The first is fairly obvious: Chlorine is very corrosive and will shorten the service life of metal plumbing. The second is that chlorine will not penetrate any scale layers, and therefore, any *Legionella* buried within these layers can recontaminate the system after a short period of time following treatment.

Continuous chlorination of water distribution systems with 2 ppm free chlorine following superheating, has been shown to be effective in controlling *Legionella*.[32] However, a silicate-based solution also needs to be added in order to help control the corrosion of the piping.

Alternative methods to control *Legionella* growth include the use of metal ions (see sidebar above) such as copper or silver in solution. Findings have shown that when these ions are absorbed by bacteria, they affect the organism's enzyme balance which then inhibits its reproduction and respiration capabilities.[33] Commercial, in-line ultraviolet (UV) systems have proven effective in controlling *Legionella* and can be installed on incoming water lines or on recirculating systems. However, stagnant zones, such as dead legs, can diminish the effectiveness of this treatment, as can scale buildup on the UV lamp surface. Ozone injected into the water is yet another method to control *Legionella*.[34]

Biological treatment of cooling towers usually consists of the addition of algaecides and bactericides, such as gluteraldehyde. These chemicals help to control multiplication of bacteria, protozoa, and algae. This, in turn, reduces the amount of microbiota available to *Legionella* as a nutrient source. However, the control of other microorganisms does not necessarily indicate the control of *Legionella*, so any testing performed to determine the effectiveness of treatment must include sampling for viable *Legionella* bacteria. Biocides should be administered via a continuous feed rather than slug dos-

ing, in order to maintain consistent concentrations in the system.

Cleaning of the system is very important in the overall control of *Legionella*. Without any cleaning, a buildup of algae, fungi, protozoa, dirt, and/or biofilm can occur in the system. Such buildup can place a greater demand on a biocide, and may prevent it from making contact with microorganisms. Studies have indicated that bacteria sequestered in amoebae are afforded a 30- to 120-fold increase in protection from water treatment regimens.[35] At a minimum, cooling tower systems should be bled (blowdown) and flushed twice a year. All surfaces should be thoroughly cleaned and allowed to air dry.

For cooling towers that have been implicated in outbreak or cluster of Legionnaires' disease, or where high levels have been found, emergency treatment is necessary. One such procedure calls for the slug chlorination of the system with 50 ppm of free residual chlorine, along with a dispersant. Then maintain 10 ppm of free residual chlorine for 24 hrs. As noted earlier, the pH must be within a range of 7.5 to 8.0 for the chlorine to be effective. The entire system is then drained and the chlorination process repeated.[36] Bromine, which is less affected by pH levels, can be used in place of chlorine.

At a minimum, cooling tower systems should be bled (blowdown) and flushed twice a year. All surfaces should be thoroughly cleaned and allowed to air dry.

Since even well-maintained towers can still be colonized by *Legionella*, it is important to eliminate any possible transmission of drift from the tower to people. The first step, obviously, is the use of high-efficiency drift eliminators. Such eliminators, however, may actually aid in *Legionella* growth by increasing the system temperature.[37]

Next, if possible, locate the cooling towers as far away as possible from operable windows, outdoor air intakes, and outdoor areas frequented by people. At a minimum, outdoor air intakes should be located at least 25 ft from any cooling towers. In addition, prevailing wind directions must be taken into account with regards to air intakes and cooling towers.

CONCLUSION

Legionella bacteria tend to be an unwanted occupant of the building environment. Their ability to contaminate domestic water systems, coupled with their potential to cause severe health complications, presents a very real concern to building owners and managers. Fortunately, there are methods readily available for both the detection of *Legionella* and its control. Establishing a proactive approach of periodic testing, along with proper water treatment in both cooling towers and hot water systems, is the best way

to avoid disease outbreaks and potential lawsuits. **ES**

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