ASPE 1992 Convention
Technical Proceedings

92CP008

LEGIONNAIRES' DISEASE

Steven E. Howe, PE, CIPE
Robson & Woese
Syracuse, NY

ABSTRACT

Legionellosis, also called Legionnaires' Disease, continues to be a serious cause of illness in health care facilities. Although the original outbreak in Philadelphia occurred in 1976, cases of Legionellosis continue to be reported today in hospitals throughout the world. For the organism infect people, several factors must be present; unfortunately, these conditions are all too often met in large facilities.

The source of the outbreak must be determined, in conjunction with local, state and/or federal authorities. Once the source has been identified, then a program of remedial action must be developed and implemented. The various methods of treating the plumbing system to prevent Legionellosis are discussed in detail.

Legionnaires' Disease Continues To Infect Health Care Facilities

Legionellosis, a bacterial form of pneumonia, continues to be a significant problem in health care facilities. Although the most common strain of this bacterium is Legionella pneumophila, there are at least 15 groups and 35 species and subspecies. Much clinical research as to the most efficient method of testing and detection of legionella has been done. The virulence or potency of the different strains varies from weak to those which can cause death. Virulence can also vary with an individual serogroup. Most people are normally resistant to the weaker strains of the bacteria. If sufficient quantities of the virulent strains are inhaled, an individual can receive a strong case of pneumonia. In some outbreaks, the death rate has been as high as 20 percent. Even from a non-medical perspective, the high level of publicity associated with an outbreak makes the public aware that we are dealing with a very serious disease, which can be deadly.

Although there was no knowledge of the disease before several major outbreaks of the disease occurred, Legionellosis disease has probably existed for centuries. The first major outbreak was recognized at the now famous Bellevue Stratford Hotel, the site of an American Legion convention in the year 1976. Of the people attending the convention, 186 contracted the disease and 29 deaths resulted. By 1978, Legionnaires' Disease has been identified in 38 states and on the European continent.

There have been three international symposiums on the subject and numerous articles written. In spite of the widespread literature and increased awareness of the problem, the disease continues to be reported across the country as well as in countries around the world.

Legionnaires' Disease is a form of pneumonia caused by legionellaceae bacteria. The incubation period has a range of two to ten days. The symptoms consist of chest pains and lung congestion, abdominal pains, diarrhea, and a temperature of 102F to 105F.

The early reported cases had to do with poorly maintained cooling towers and malfunctioning air condition systems. Legionella bacteria continued to be identified from cooling tower basins. The water in the cooling tower basins provide an ideal environment for bacteria growth. This is due to optional temperatures, along with interaction with protozoa. The cooling tower mist has been shown to carry the legionella bacteria and has infected people who have inhaled the mist or inhaled air from contaminated air conditioning systems.

Cultures of the bacteria have also been identified in the domestic hot water heating systems for large hospitals, hotels and mental institutions. A study in Germany found 70% of the hospitals and 18% of the hotels investigated were Legionella positive. Out of 84 hospitals in Quebec, 57 had at least one sample test positive for Legionellaceae in a one year period. In 22 hospitals out of the 84, 30% of the samples were positive, and in nine hospitals, the distilled water system was found to be contaminated. Although the organism is widespread in most aquatic environments, few people actually develop symptoms.

The energy conservation crisis of the 1970's and concerns about scalding people, along with ensuing regulations, codes and guidelines, led to the lowering of water temperatures in the water heater storage tanks from 140F to 110F-120F in health care facilities. The organism has been isolated from water heater sediments, along with scrapings from shower heads. Additional cultures have been grown, from water samples taken from water heaters, and the hot water side of faucets and bathtubs.

The problem in large buildings if further compounded by long runs of circulating water piping and lower water temperatures in unused parts of the system. "Legionella pneumophila locates and concentrates in areas within the water distribution system laden with silt and sediment." Even if hot water is generated, at temperatures greater than 140F, in many areas, health regulations require that the water temperatures at the tap in hospitals be a maximum of 110F. Standard design practice has been to limit the temperature leaving the water heater to 120F and to use a 20F temperature drop to size the circulating system. The lower water temperature in the return loop may lead to propagation of the bacteria.

The organism naturally occurs in low concentrations in public drinking water taken from surface waters or subsurface aquifers, and can be found in filtered and unfiltered public water systems. It has also occurred in homes supplied by private wells. Low levels of chlorine residual from zero to 1 part per million are not adequate to inhibit the growth of Legionella bacteria. By the time the water in our larger municipal systems reaches the customer, there is generally only small amounts of residual chlorine available. There also appears to be a relationship that when large cold water mains are subject to pressure fluctuations or physical shock and corroded iron modules are released to the cold water supply. These disruptions often occur during construction projects or water main repairs.

For infection to occur, the organism must be present in significant numbers, be one of the virulent strains and be transmitted to the person's lower lung in the form of an aerosol. It may multiply in water in the temperature range of 68-113F. A study in Chicago identified the culture in 19 out of 52 apartments. In all cases, it was found that there was zero free chlorine residual, and the mean temperature for positive samples was 119F and at 137F for negative samples. No positive samples were found in apartments with hot water temperatures greater than 13 1F. It should be noted that in that particular study, none of the residents were found to have any symptoms of Legionellosis.

The question of why the disease outbreaks occur sporadically, although cultures have been shown positive in so many apartments as well as numerous facilities in Germany, Canada, and Britain, may be answered in a conceptual chain linking the environmental sources with the infection of people. This chain was first postulated by David Fraser at the 2nd International Symposium. These include the following:

1. Environmental reservoir – the organism is present in cold water but is practically undetectable.
2. Amplifying factors which consist of warm water, sediments, etc., promote the rapid growth of the organism from low to higher concentrations.
3. A mechanism must be available to spread the organism to people from the reservoir. This would consist of something which would produce aerosols.
4. The strain or serogroup of Legionella that is atomized must be virulent to humans.
5. The organism must be introduced at an appropriate site. In the case of Legionella, this entrance would occur by breathing into the lungs.
6. The human must be susceptible to the infection.

This theory appears to be valid, as water is the natural reservoir and heating it between 104-120F allows the bacteria to multiply. The aerosol form is spread to humans by inhalation of the organism. Research is still continuing as to which strains are virulent to humans. At first there was some confusion whether drinking the water would cause infection, but this has not been proven.

The primary mechanism of infection is the inhalation of the organism in aerosol form. This appears to occur from showers, lavatory taps, bathtubs, spa baths, respiratory equipment washed with tap water, and humidification equipment. Mist from cooling towers and evaporating condensers has caused infection up to two miles away.

There also appears to be a relationship that patients who have received organ transplants and major operations are particularly susceptible to the disease. These patients may bc immuno-compromised as part of their treatment. The disease also stems more prevalent in people with other significant underlying diseases: smokers, and males over 50 years old.

There have also been outbreaks among healthy individuals staying in hotels. An outbreak of Legionella occurred from the use of a whirlpool spa at an inn in Vermont. People who used the spa were more likely to exhibit scrologic evidence of infection.

It would appear that elevating the domestic hot water temperature would alleviate the problem of Legionella. The American Society of Plumbing Engineers Research Foundation published a report examining the issue of burns caused by hot water temperatures versus providing minimum temperatures to prevent the outbreak of Legionella. Their conclusions recommend outlet temperatures for water heaters to be a minimum of 140F, due to the fact that the bacteria have not survived at temperatures greater than 131F They also recommend the deletion of 1l0F maximum temperatures at outlets. It is important to consider that water will cause full thickness epidermal (third degree) burns in 60 seconds. 140F water will cause third degree burns in five seconds. Hospital patients, children and people with lack of feeling in their bodies are particularly at risk for scalding type injuries. With these serious implications in mind, one compromise would be the usage of temperature mixing valves on all showers and outlets to prevent temperatures from exceeding 110F. Thermal mixing balancing valves also incorporate high temperature limit stops, which are set to reduce the possibility of scalding.

New construction design should consider several factors. For air conditioning system design. the cooling tower should be located downwind of air intakes and open windows, as the mist can carry the organism a great distance. A continuing cooling tower treatment program should be instituted. Condensate drip pans for air conditioning equipment should be designed for ease of cleaning by maintenance staff, and should not have direct connection to the building sewer piping.

Storage water heaters should be designed horizontally for less temperature stratification. Care should be given not to oversize the tanks. Convenient blowdown valves should be provided at the bottom of the tank. Duplex water heaters should be hydraulically balanced to prevent either tank from being stagnant. Instantaneous or semi-instantaneous heaters can eliminate stratification. However, they still can become contaminated if operated at temperatures that are favorable to growth of the organism.

It is possible in some steam storage water heaters, to have the aquastat set at 140F, with the temperature at the bottom of the tank being below 130F. It is, therefore, recommended that the tank be set at 165F to insure disinfection temperatures throughout the tank. The usage of solar, heat pumps, refrigerant, or other heat reclamation devices. which would preheat and store water at less than 131F, should be eliminated. Cold water piping should be insulated to prevent warming from adjacent hot water piping to greater than 65F. The British Technical Manual recommends the distribution temperature to be high enough to create a minimum of 122F on the return legs to the unit. The layout of the hot water piping system should eliminate, as much as possible, any "dead legs" or portions of the system where the water will stand and the temperatures will drop. This can be accomplished by the recirculation of the hot water piping to within feet of all fixtures. Further scientific investigation is required to substantiate the proper length of unrecirculated pipe to fixtures. Temperature mixing valves should be located within six feet of the fixtures served.

Central mixing valves will mix the hot water from the water heaters with cold water to obtain the blended circulating water temperature. Consideration should also be given to the usage of larger circulation pumps and recirculation piping sized on a 5F to 9F temperature differential. This will keep the temperature in the hot water piping at a higher level.

The usage of a single pipe system with heat tracing has also been shown to be effective. Testing of heat traced systems has shown that the water temperature is the only significant factor in determining bacteria growth.

Plumbing fixtures and valves should be utilized without faucet aerators or rubber washers, both of which have been shown to harbor Legionella bacteria. Rubber should also be eliminated from shock absorbers or any other component of the hot water system. One manufacturer is marketing a low aerosol type shower head, which may decrease the inhalation of the bacteria.

If cases of Legionellosis are confirmed, the first requirement would be to meet with the medical staff for infection control and with an experienced state or county public health epidemiologist. A team approach to the investigation is always necessary, involving the epidemiologist, the infection control department, and the engineering staff. If a confirmed problem exists, employee notification is required by OSHA to allow proper treatment if it is needed. Healthy employees will not generally be affected by the presence of the bacteria in the water.

Sampling for Legionella in the hot water supply has shown that the organism will exist in small quantities in most buildings. Simply finding the organism in the water without human illness is not a significant or reportable event for facilities that do not have a transplant ward. In this case, increasing the temperature of the water heater and heat flushing would appear to be the most advisable course of action.

Next, the team should ascertain the location and time of the onset of the cases and the serotype of the Legionellae. The investigation should proceed to determine the sources of the outbreak. Prior approval of the State Health Department is required before undertaking corrective measures to the air cooling equipment or the domestic water system.

If the investigation and sampling points toward association with the cooling tower, the following is suggested. The treatment of cooling towers normally consists of shock treatment, with chlorination at 50 parts per million, draining and cleaning of the tower. Workers cleaning the tower should be protected with breathing equipment to guard against exposure to aerosols in the cleaning process. This would be followed by continuous treatment with appropriate chemicals proven to kill the organisms and host organisms. One effective chemical is diecyl-dimethyl ammonium chloride. Several other chlorine-based chemicals have proven effective. The engineer should work with the facility's cooling tower chemical treatment supplier for effective treatment.

For hot water systems, boost the hot water heater temperature to 165F and clear the tank of any sediment buildup. A variety of disinfection systems have been tried. In laboratory tests, heat, zone reactors, ultraviolet sterilizers, chlorine, and a silver copper ionizer have shown to be successful in disinfection. Sodium Hypochlorite, in the 1.5 to 2 ppm dosage in conjunction with increased water temperatures, have shown to be successful in many hospitals in controlling this organism. Chlorine and/or heat treatment are the primary recognized means of control. The objections with chlorine is that the higher levels may produce more trihalomethsanes in the water supply. There are also increased taste and odor complaints from users of the facility. Increased chlorine levels can also cause increased corrosion of the piping system. At 5 ppm, one hospital experienced significant quantities of leaks. This can be combated with the addition of sodium silicates for corrosion suppression. The addition of chemicals, to the drinking water supply in any institution, will require prior approval of the governing health agency.

Heat shocking of the hot water system with 176F will kill the organism, if all the "dead-legs" of the system are concurrently flushed. Proper notification of all personnel and patients is required to minimize the risk of scalding. There has also shown to be a recurrence of the problem and the treatment must be repeated. Ozone and ultraviolet light systems are effective at killing organisms, but do not carry a residual into the piping system, and have not been proven conclusively at a facility site. Ozone treatment of water can cause problems with mineral deposits on the piping. This will depend on the mineral content of the water. Ultraviolet light has commonly been used for disinfection of pure water systems, but its effectiveness is greatly diminished with increased levels of turbidity in the water. The silver-copper ionizer provides both an initial kill and allows residual ions to be transported in the piping system for further disinfection. A silver copper unit has been used successfully at a hospital in Indianapolis, Indiana, and in Pittsburgh, Pennsylvania, and a similar type will soon be undergoing pilot testing in a hospital in New York State. Depending on further testing, this unit may hold some promise as a disinfection system. The potential toxic effects, due to long term drinking of water with silver and copper ions has not been investigated, although the levels are below EPA drinking water standards.

The hot water piping system should be checked for poor circulation and balanced. Whole sections of piping may be dead because the system was never balanced correctly. Temperature, pH, and chlorine residuals should be taken at the extremities of the system.

Install bag filtration equipment to filter the incoming cold water to 5 microns. This will filter out algae, amoeba, protozoan, rust particles, and sediment, which may harbor Legionella internally or act as a shield for disinfection.

Locating the source of the contamination and remediation measures must be followed by good monitoring and record keeping. This will insure maintenance of the equipment and prevent recurrence of the problem.

Any major facility has the potential for contamination by this organism, particularly large hospitals. Careful design practices, good cooling tower maintenance and vigilance, on the part of the maintenance staff of the hot water system, can prevent occurrences of this serious disease.

REFERENCES

1. Mayberry, W.R., *"Nonhydroxy, Monohydroxy and Dihydroxy Cellula-Fatty Acids Profiles of Legionella Species: An Update."* James.W. Quillen College of Medicine, Johnson City, TN. 1992 International Symposium on Legionella.

2. Struklens, M.J., et al., *"Genomic Analysis May Provide a More Reliable Epidemiological marker of Legionella Pneumophila Serogroup 1 Than Monoclonal Antibody Typing,"* Univ. Brussels, Belgium. Centre National de Reference des legionellages, Lyon, France, 1992 International Symposium on Legionella.

3. Barlett, C.L. Legionella Infections, London: Edward Arnold (1986).

4. Helms, C.M., et al *"Legionnaires' Disease Associated with a Hospital Water System."* JAMA, 259:2423-2427, (1988)

5. Fallon, R.J. and Rowbotham, T.J., *"Microbiological Investigations Into An Outbreak of Pontiac Fever Due to Legionella Micdadea Associated with the Use of a Whirlpool."* J. Clin Pathol, 43(6), 479-483, (June 1990).

6. Habicht, W., and Muller, H.E., *"Occurence and Parameters of Frequency of Legionella in Warm Water Systems of Hospitals and Hotels in Lower Saxony."* Zentralbl Baktreriol Mikrobiol Hyg [B], 186(1), 79-88, (March 1988).

7. Joly, J.R., and Alary, M., *"Legionellaceae in Water Distribution Systems of 84 Acute Care Hospitals in Quebec."* Faculté dé Medécine Université Laral, Qubec, Qc, 1992 International Symposium on Legionella.

8. Farrell, I.D., et al., *"A Field Study of the Survival of Legionella Pneumophila in a Hospital Hot-Water System."* Epidemiol Infection, l04(3), 38 1-7, (June 1990).

9. Vickers, R.M., et. al., *"Determinations of Legionella Pneumophila Contamination of Water Distribution Systems: 15-Hospital Prospect Study."* Infection Control, Vol. 8, No. 9, 362 (1987).

10. Stout, J.E., et al., *"Legionnaires' Disease Acquired Within the Homes of Two Patients."* JAMA,Vol.257(9), 1215-1217 (1987).

111. Wireman, J.W., et al., *"Methods of Preventing Legionnaires'."* 1992 International Symposium on Legionella.

12. Arnon, P, and Weil, D., *"Legionella Pneumophila Contimination of Residential Tap Water"* 2nd International Symposium, Washington, D.C. (1983).

13. Fraser, D.W., *"Sources of Legionellosis In Legionella."* Thorsberry, C. (Ed.), Proceedings of the 2nd International Symposium, Washington, D.C., 277-280 (1983).

14. Bollin, G.E., et al., *"Aerosols Containing Legionella Pneumophila Generated by Showerheads and Hot Water Faucets."* Appl Environ Microbiol, 50: 1128-131 (1985).

15. Klaucke, D.N. et al., *"Legionnaires 'Disease: The Epidemiology of Two Outbreaks in Burlington, Vermont."* Am J. Epidemiol, 119: 382-91 (1984).

16. Arnow, P. Chou, and T. Weil Detal, *"Noscomia Legionnaires' Disease Caused By Aerosolized Tap Water From Respiratory Devices."* J. Infect Dis., 146: 460-467 (1982).

17. Zuraveleff, J., et al., *"Legionella Pneumophila Contimination From a Hospital Humidifier: Demonstration of Aerosol Transmission and Subsequent Subclinical Infection in Exposed Guinea Pigs."* Am. Rev. Respir. Dis., 128: 657-661 (1983).

18. Bock, B., et al., *"Legionnaires'Disease in Renal Transplant Recipients."* Lancet, 1: 410-413 (1978).

19. Korvick, J.A., et al., *"Legionella Species as Hospital-Acquired Respiratory Pathogens."* Seminars in Respiratory Infections, Vol. 2, No. 1, 34-37, (March 1987).

20. Steelle, A., *"Temperature Limits in Service Hot Water Systems."* ASPE Convention Technical Proceedings, 15-20 (1988).

21. Katcher, M.L., *"Scald Burns from Hot Tap Water,"* JAMA, 246(11), 1219-1222 (1981).

22. Wagstaff, T., *"Annex Interim Guidance on the Prevention and Control of Legionellae and "Safe" Hot Water Temperatures."* Estates Directorate, London, I-7 (1990).

23. Sellick, J., and Mylotte, J., *"Nosocenial Legionella Ptteumophila Pneumonia in a Hospital With an Instantaneous Hot Water Heater".* SUNY Buffalo and Buffalo General Hospitals, Buffalo, NY, International Symposium on Legionella (1992).

24. The Chartered Institute of Building Services Engineers, *"Technical Memoranda 13 Minimizing the Risk of Legionnaires'Disease."* 222 Balham High Road, London.

25. Helms, C.M., et al., *"Legionnaires 'Disease Associated With a Hospital Water System A Five-Year Progress Report on Continuous Hyperchlorination."* JAMA, 259(16), 2423-2427, (April 22-29, 1988).