COOLING TECHNOLOGY INSTITUTE

Legionellosis

Guideline: Best Practices for Control of Legionella

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This guideline document summarizes the best current state of knowledge regarding the specific subject. This document represents a consensus of those individual members who have reviewed this document, its scope and provisions. It is intended to aid all users or potential users of cooling towers.

Approved by the CTI Executive Board

This document has been reviewed and approved as part of CTI's Five Year Review Cycle. This document is again subject to review in 2002.

Guideline: Best Practices for Control of Legionella

I. WHAT IS LEGIONNAIRES' DISEASE?

Following the 1976 American Legion Convention at the Bellevue Stratford Hotel in Philadelphia, 34 attendees died and 221 people became ill from pneumonia caused by the bacterium *Legionella pneumophila*. Although not recognized at the time, *Legionella* is not a new microorganism. It has since been found in many archived tissue samples at the US Centers for Disease Control and Prevention (CDC). These specimens were taken from persons with previously undiagnosed pneumonia-like illnesses.

This disease, now commonly known as Legionnaires' Disease, is a respiratory infection that strikes susceptible individuals exposed to *Legionella pneumophila*. Infection results from inhaling airborne water droplets or mist containing viable *Legionella pneumophila*, which are small enough to pass deep into the lungs and be deposited in the alveoli, the small pockets in the lungs. The dose of *Legionella pneumophila* required to infect humans is not definitively known. Ingesting *Legionella pneumophila* has not been shown to cause illness. Legionnaires' Disease can have an incubation period of two to ten days. Most reported cases have occurred in the 40- to 70-year old age group. Although healthy individuals may develop Legionnaires' Disease, people thought to be at increased risk of infection include smokers, patients with cancer, chronic respiratory diseases, kidney disease, and any immuno-suppressed condition. The fatality rate is estimated at 10 to 20% of those who contract the disease; but in immuno-suppressed persons or those with other underlying diseases, this figure can be much higher.

Legionella pneumophila is a ubiquitous organism. It appears in almost every ground and surface water. The organism survives typical chlorine disinfection for potable water and consequently can appear in finished water distributed to homes and industry. It is important to keep the incidence of Legionellosis in perspective. For example, in the United States, the Technical Manual published by OSHA (Occupational Safety and Health Administration) estimates over 25,000 cases of the illness occur each year. More than 4,000 deaths are believed to occur, but only about 1,000 are reported. However, the CDC usually investigates less than ten community outbreaks per year (in 1995 there were three). An outbreak is considered to occur when two or more cases of the disease can be attributed to a work site.

II. SYMPTOMS OF LEGIONNAIRES DISEASE

Initial symptoms of Legionnaires' Disease include high fever, chills, headache and muscle pain. A dry cough soon develops and most patients suffer breathing difficulty. Some patients also develop diarrhea or vomiting and can become confused or delirious. Legionnaires' Disease may not always be severe; in community outbreaks, mild cases may be recognized that would probably have escaped detection except for the increased awareness of the disease.

A common but less serious infection caused by *Legionella pneumophila* is an illness known as "Pontiac Fever." The symptoms of Pontiac Fever are similar to those of moderate to severe influenza: headache, fatigue, fever, arthralgia (joint pain), myalgia (muscle pain) and, in a small proportion of cases, nausea, vomiting and coughing. The incubation period is one to two days and the illness passes in five to ten days. No deaths have been attributed to Pontiac Fever. Since this illness generally escapes detection, statistical information about its occurrence is sparse.

III. MICROBIOLOGY

Legionella is the name given to a genus of bacteria for which at least 37 different species have been identified. *Legionella pneumophila*, for which fourteen serogroups have been identified, is the species most commonly associated with disease outbreaks. Serogroups 1, 4, and 6 are most commonly associated with human illness. *Legionella pneumophila* are rod-shaped bacteria and are widespread in natural water sources. They have been found in rivers, lakes, and streams; mud and soil samples; water and sludge from cooling towers; and in other man-made water systems. They have been detected in many drinking water sources, including well water, resulting in the contamination of a variety of public and private systems using this water.

A cooling tower system can present an ideal environment for growth of *Legionella pneumophila*. Cooling tower drift in the form of aerosols can be easily inhaled. Showers, wash stands, sinks, air scrubbers and air washers / handlers can also provide a good growth environment and possible means of transmission of *Legionella pneumophila* bacteria.

IV. ECOLOGY

The ecology of *Legionella pneumophila* in water systems is not fully understood; however, the following conditions have been found to affect its growth rate:

- Sediment, sludge, scale and organic materials can harbor the bacterium and promote growth. The formation of a biofilm within a water system is thought to play an important role in harboring and providing favorable conditions in which *Legionella pneumophila* can grow. A biofilm is a layer of microorganisms contained in a matrix that may form a thin layer of slime on surfaces in contact with water. *Legionella pneumophila* grows within biofilms and within protozoa acting to shield *Legionella pneumophila* from concentrations of biocides that would otherwise kill or inhibit *Legionella pneumophila* when freely suspended in water.
- Water temperatures in the range of 68°F (20°C) to 113°F (45°C) favor growth. It is uncommon to find proliferation below 68°F (20°C), and it does not survive above 140°F (60°C). The optimum laboratory temperature for the growth of the bacterium is 99°F (37°C). Organisms may, however, remain viable and dormant in cool water, multiplying only when the temperature reaches a suitable level and when growth and reproduction are not inhibited by adequate bio-control.
- *Legionella pneumophila* have been shown to colonize certain types of water systems that may have stagnant areas, e.g., water heaters, tanks, reservoirs, and basins. Fittings, piping, and various gasket materials used in these systems can also be colonized. Stagnant conditions promote growth of *Legionella pneumophila* and make eradication difficult.
- Commonly encountered microorganisms (such as algae, amoebae and other bacteria) in untreated or ineffectively treated water may promote *Legionella pneumophila* growth. Some protozoa serve as hosts for *Legionella pneumophila*, which can enable rapid proliferation of *Legionella*.

V. BEST PRACTICES AND RECOMMENDATIONS FOR MINIMIZATION OF RISKS ASSOCIATED WITH LEGIONELLA

The following best practices for microbiological control are recommended to promote and maintain clean heat transfer surfaces and a healthy work environment around open recirculating cooling systems. The practices outlined in this document are a description of the consensus of existing best practices as recommended by various authoritative bodies worldwide. Evidence exists that other compounds, such as ozone and peroxides, and some treatment techniques such as ultraviolet light can kill *Legionella* bacteria in limited circumstances. However, a substantial body of support for such measures as "best practices" (for control of *Legionella* in cooling tower systems) has not been presented.

The CTI reviewed publications and interviewed representatives from authorities such as OSHA, CDC, ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers), the UK HSE (United Kingdom Health and Safety Executive), the UK BACS (British Association of Chemical Specialties), and the health & safety agencies of Japan, Australia, Singapore, and Taiwan, among others. *In no way, however, should these recommendations be interpreted to guarantee the absence of Legionella bacteria or any other particular pathogen, and consequently that these measures will prevent illness (e.g. Legionellosis).*

Nevertheless, we believe these measures can be effective in fostering the safety of cooling systems. This is accomplished directly by destruction of planktonic (free-swimming) bacteria including *Legionella*, and indirectly by eliminating conditions that favor *Legionella* amplification (multiplication), i.e. the elimination of biofilms and amoebae and other protozoa that feed on biofilms and which serve as *Legionella* hosts. Research continues on effective means for control of protozoan cysts, which can also harbor and protect *Legionella* for extended periods.

These best practice recommendations focus on chemical control parameters. Halogens serve as the primary disinfectants in these recommendations. Sources of halogens include chlorine gas, liquid bleach, chlorine dioxide and stabilized donors such as isocyanurates, hydantoins, etc. It must be recognized, however, that chemical treatment is only one aspect of risk minimization. Design, operation, and maintenance practices are also crucial to reducing health risks associated with cooling systems.

Monitoring *Legionella* in Cooling Water Systems

Evaluate system cleanliness and the effectiveness of microbial control by visual inspection as well as through regular monitoring of bulk water (planktonic) and surface (sessile) microbial populations.

Check the cooling tower deck and tower fill for gross evidence of biofouling. When operations permit, the mist eliminator section of the cooling tower should also be inspected for biological deposits. Collect suspected biological deposits for microscopic examination to confirm biological content and the presence or absence of amoebae and ciliated protozoa. When performed by a trained microscopist, this approach can provide valuable, same-day information on system cleanliness and associated health risk since some protozoans can serve as host organisms for *Legionella* allowing amplification of *Legionella* to dangerous levels. High numbers of protozoa therefore represent an increased risk for multiplication of *Legionella* and consequent increase in the risk of Legionnaires' disease for susceptible individuals.

Use dipslides, PetriFilm™, or other culturing techniques to quantify total aerobic heterotrophic bacteria populations in bulk water and on surfaces. Alternatively, ATP-based biomonitoring can be used. This technique has the advantage of eliminating the 2-day delay in results imposed by incubation requirements of culture-based methods.

Most professional and government agencies that have issued *Legionella* position statements and guidelines do not recommend testing for *Legionella* bacteria on a routine basis. These reasons derive from difficulties in interpreting *Legionella* test results and in using test results as a basis for control. Note the following aspects:

- An infectious dose level for *Legionella* has not been established and in any case, (given variations in strain virulence and wide differences in individual susceptibility) the concept of a fixed infectious dose level may be misleading. Since no fixed "danger" level can be assigned, it also follows that no specific level of the organism can be assigned as "safe."
- *Legionella* may be "non-detectable" in bulk water samples collected on one day but can repopulate and be found within a few days. *Legionella* can be released from biofilms or from host life forms associated with these films. *Legionella* are reported to be capable of rapid recolonization of previously cleaned systems, especially if conducive conditions are present.
- Simple detection of the organism in a cooling system does not necessarily mean there is a risk of disease, in part because not all *Legionella* serogroups are associated with Legionellosis.
- Culture-based techniques used by testing labs to quantify *Legionella* have a 10 to 14 day turnaround for results. This period is too long for *Legionella* monitoring to serve as an effective tool for treatment control.

Various studies have shown that some 40 to 60% of cooling towers tested contained *Legionella*. Therefore, it is best to assume that any given system can harbor the organism, and that routine, continuous microbiological control practices should be implemented to minimize the risk of *Legionella* amplification and associated disease.

Testing for *Legionella* is recommended in the event of an outbreak (to identify potential sources of the organism) and to evaluate the effectiveness of disinfection procedures. If testing is required, contact a laboratory experienced in performing *Legionella* analyses on environmental samples. Also, concurrent sampling should be performed on the bulk water and surface deposits for microscopic detection of higher life forms, along with total aerobic heterotrophic counts. Collect bulk water samples from several locations within the system (e.g., makeup water, hot return water, basin water, and from sample taps on heat exchangers remote from the cooling tower if available). Where evident, collect deposit samples from the basin walls, tower fill, and distribution decks. The following three scenarios are possible:

- A low *Legionella* count with an undetectable or small population of amoebae/protozoa (higher life forms) and low biofilm counts (low sessile bacteria numbers) is a good indication of a clean, well-maintained system with low risk to health.
- A low bulk water *Legionella* count along with low numbers of higher life forms in deposits, but with high biofilm counts may indicate a low present health risk but suggests the potential for future problems if steps are not taken to reduce biofilm levels. Since protozoa that promote *Legionella* amplification graze on bacteria in biofilms, the presence of significant biofilm can promote the development of higher, and thus potentially more dangerous, levels of *Legionella*.
- A low bulk water *Legionella* count associated with a large number of higher life forms indicates a strong potential for amplification, and the low *Legionella* count cannot therefore be interpreted to indicate a system with a low health risk.

Recommended Target Values
Routine Treatment of Cooling Water Systems

Parameter	Dipslides	Agar Pour Plate or Petrifilm	Microscopic Exam
Planktonic Counts (Bulk Water)	<10,000 CFU/mL	<10,000 CFU/mL	No higher life forms
Sessile Counts (Surfaces)	<100,000 CFU/cm^2	<100,000 CFU/cm^2	No higher life forms
Deposits	NA	NA	No higher life forms

Note: Results from dipslides, agar pour plates, or Petrifilm are colony forming units (CFU per milliliter or per square centimeter) of total aerobic heterotrophic bacteria. Legionella bacteria are not detected by these conventional plate count media. Microscopic examination for the presence of higher life forms requires a trained microscopist and specialized microscopy equipment.

Routine Treatment
Continuous Application of Halogens

- For relatively clean systems or where clean potable water makeup is used, feed a source of halogen (chlorine or bromine) continuously and maintain a free residual. Continuous free residuals of 0.5 to 1.0 ppm in the cooling tower hot return water have been recommended by many agencies. Periodic monitoring of the residual at sample points throughout the cooling water system is needed to insure adequate distribution. The effectiveness of either halogen decreases with increasing pH; bromine is relatively more effective at a higher pH (8.5 to 9.0).
- Stabilized halogen products should be added according to the label instructions, and sufficient to maintain a measurable halogen residual.
- Discharge of system water directly to surface water may require dehalogenation.
- A biodispersant/biodetergent may aid in the penetration, removal, and dispersion of biofilm and often increases the efficacy of the biocide.
- Continuous halogen programs may require periodic use of nonoxidizing biocides. These may 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 biocides should be based on the results of toxicant evaluations. Reapply as dictated by results of biomonitoring.

Routine Treatment
Intermittent Use of Halogens

Continuous halogenation is always preferred for *Legionella* risk minimization; however, if this is not possible, intermittent use of halogen is necessary.

- As a minimum control program for relatively clean systems or where clean, potable water is used for makeup, establish a free halogen residual of at least 1.0 ppm and hold this residual for no less than one hour each day. Free residual must be monitored throughout the distribution system.
- Stabilized halogen products should be added according to the label instructions and to achieve a measurable halogen residual. This residual should be held for no less than one hour each day.
- Bulk water and sessile counts, along with microscopic examination of deposit samples, will be necessary to ensure that the concentration and duration of halogen residuals are adequate.
- A biodispersant may aid in penetrating the biofilm and may increase the efficacy of the biocide.
- Discharge of system water directly to surface water may require dehalogenation.
- Nonoxidizing biocides are critical to the cleanliness of systems treated intermittently with halogens and are recommended. The choice of nonoxidizing biocide should be based on the results of toxicant evaluations. Reapply as dictated by the results of biomonitoring.

Routine On-Line Disinfection
Hyperhalogenation

Hyperhalogenation as practiced is the maintenance of a minimum of 5 ppm free halogen residual for at least 6 hours. Periodic on-line 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
- When the total aerobic bacteria counts regularly exceed 100,000 CFU/ml
- When *Legionella* test results show greater than 100 CFU/ml

Periodic hyperhalogenation will discourage development of large populations of *Legionella* and their host organisms. Consequently, periodic hyperhalogenation may eliminate the need for conducting more complicated and higher risk off-line emergency disinfection procedures.

Emergency Disinfection

The following emergency disinfection procedure is based on OSHA and other governmental recommendations. This procedure may require modification based on system volume, water availability and wastewater treatment capabilities.
Conduct emergency disinfection:

- When very high *Legionella* counts exist (i.e., >1000 CFU/ml).

- In cases where Legionnaires disease are known or suspected and may be associated with the cooling tower.
- When very high total microbial counts (>100,000 CFU/mL) reappear within 24 hours of a routine disinfection (hyperhalogenation).

Emergency Disinfection Procedure

1. Remove heat load from the cooling system, if possible.
2. Shut off fans associated with the cooling equipment.
3. Shut off the system blowdown. Keep makeup water valves open and operating.
4. Close building air intake vents in the vicinity of the cooling tower (especially those downwind) until after the cleaning procedure is complete.
5. Continue to operate the recirculating water pumps.
6. Add a biocide sufficient to achieve 25 to 50 ppm of free residual halogen.
7. Add an appropriate biodispersant (and antifoam if needed).
8. Maintain 10 ppm free residual halogen for 24 hours. Add more biocide as needed to maintain the 10 ppm residual.
9. Monitor the system pH. Since the rate of halogen disinfection slows at higher pH values, acid may be added, and/or cycles reduced in order to achieve and maintain a pH of less than 8.0 (for chlorine-based biocides) or 8.5 (for bromine-based biocides).
10. Drain the system to a sanitary sewer. If the unit discharges to a surface water under a permit, dehalogenation will be needed.
11. Refill the system and repeat steps #1 through 10.
12. Inspect after the second drain-off. If a biofilm is evident, repeat the procedure.
13. When no biofilm is obvious, mechanically clean the tower fill, tower supports, cell partitions, and sump. Workers engaged in tower cleaning should wear (as a minimum) eye protection and a ½ face respirator with High Efficiency Particulate (HEPA) filters, or other filter capable of removing >1 micron particles.
14. Refill and recharge the system to achieve a 10 ppm free halogen residual. Hold this residual for one hour and then drain the system until free of turbidity.
15. Refill the system and charge with appropriate corrosion and deposit control chemicals, re-establish normal biocontrol residuals and put the cooling tower back into service.

VI. RECORDKEEPING

To ensure that adequate information is available to describe tower operations, records should be kept of precautionary measures and treatments, monitoring results and remedial work. Some government agencies specify the type and level of detail for these records. In any case, sufficient information should be recorded to show the particular measures taken, including but not limited to: instances of mechanical cooling tower cleaning, the frequency and amount of biocide addition, halogen residual levels, results of biomonitoring, and other significant aspects of the tower operation.

VII. SUMMARY

To minimize the proliferation of *Legionella pneumophila* and the associated risk of Legionnaires' disease, the consensus recommendations are:

- Minimize water stagnation
- Minimize process leaks into the cooling system that provide nutrients for bacteria
- Maintain overall system cleanliness. This will minimize the buildup of sediments that can harbor or provide nutrients for bacteria and other organisms.
- Apply scale and corrosion inhibitors as appropriate.
- Use high-efficiency mist eliminators on cooling towers.
- Control the overall microbiological population.

VIII. ADDITIONAL INFORMATION SOURCES

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