SUBJECT: Cooling Tower Inventory BOH07021 (City Wide)

RECOMMENDATION:

(a) That the Board of Health write to the Ministers of Health and Long Term Care (MOHLTC) and Environment (MOE) to urge them to prescribe standards for Legionella control programs in cooling towers.

(b) That the Board of Health endorse the communication plan outlined in this report and distribute two guidelines for best practices regarding Legionella control in cooling towers:

(i) The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) Standard – Minimizing the Risk of Legionellosis Associated with Building Water Systems, 2000 (Appendix A)

EXECUTIVE SUMMARY:

In the late summer of 2006 an increase in the number of Legionella infections in Hamilton residents was detected and investigated by Public Health Services. Many possible local sources for the Legionella infections were followed up and checked and none were found to contain Legionella bacteria that matched the bacteria causing human cases.

The limited evidence suggests that the increase in cases of Legionella infections was most likely caused by dissemination of Legionella bacteria likely located in a reservoir associated with air conditioning equipment and located or situated so that the general public was exposed to Legionella contaminated exhaust, vapours, or discharges. Cooling towers and evaporative condensate units are known to be reservoirs for Legionella bacteria and are known to create conditions favourable for the growth, discharge, and transmission of Legionella bacteria in sufficient concentrations to cause illness in humans.

The Health Protection Division of Public Health Services has been conducting an inventory of cooling towers in Hamilton in order ascertain their location and general degree of maintenance regarding Legionella control methods. Knowing the locations of as many cooling towers as possible in the City of Hamilton will significantly assist with future public health risk assessments, investigations, and interventions regarding community acquired Legionella infections.

There is currently no regulatory scheme governing the maintenance of cooling towers. This report recommends the implementation of a communication strategy to increase awareness of the standards of practice for cooling tower maintenance, and advocacy to the province to consider setting standards for Legionella control programs in cooling towers. As a separate matter, a policy framework for public communication for legionella investigations was approved by the Board of Health in October of 2006.

BACKGROUND:

In the late summer of 2006 an increase in the number of Legionella infections in City of Hamilton residents was detected and investigated by Public Health Services. Many possible local sources for the Legionella infections were followed up and checked and none were found to contain Legionella bacteria that matched the bacteria causing human cases. The investigation included the homes of the Legionella cases, public outdoor pools and splash pads nearby their homes, consultation with Public Works Water/Waste Water Division regarding construction/repair activity being conducted on the municipal water distribution system and hydrant maintenance near their homes, their place of work, places they visited during the incubation period of their illness, four public ornamental water fountains, and two dental practices.

In addition, cooling towers in the downtown area were tested for Legionella bacteria. Water samples from twenty six cooling towers were tested and eight cooling towers were found to contain Legionella or Legionella-like bacteria. However, none of these Legionella bacteria were the same as the Legionella bacteria that caused the Legionella
As of April 10, 2007, 212 cooling towers have been identified in Hamilton. The owners, operators, or chemical supply companies for 207 of these cooling towers have been consulted and have provided general information regarding Legionella control programs. For the purposes of this report and the inventory being done by Public Health Services, the term cooling tower refers to cooling equipment that has a reservoir and circulates water as a coolant and operates in a manner that could exhaust or discharge water mists and/or vapours into the environment. These systems are typically (but not always) located on roof tops of tall or large buildings. Inhalation of Legionella contaminated water mists and/or vapours is the most common route of exposure of humans to Legionella bacteria causing illness.

Public Health Services collected the aforementioned information regarding cooling towers in the City of Hamilton in order to:

- Inform and advise the owners/operators/management companies of the activities they should initiate and maintain to control the growth of Legionella bacteria in cooling towers and evaporative condensate units under their control.
- Create a map and database of cooling tower locations for future reference should the incidence of Legionella infections in the City of Hamilton warrant an investigation.

Unfortunately there is no formal list or registry of cooling towers in Ontario. During our inventory activities, it has come to our attention that a Certificate of Approval from the Ministry of Environment is necessary in order to construct and operate a cooling tower in Ontario under certain conditions, but these conditions are related to noise concerns and not environmental discharges or emissions. The actual number of cooling towers in Hamilton is likely higher than the 175 found to date. Public Health Services will continue to look for cooling towers on an ongoing basis.

According to responses from representatives of the cooling tower maintenance and chemical supply companies and cooling tower operators PHS consulted, there is variation in what is perceived to be a Legionella control program. There are published and recommended guidelines for Legionella control procedures for cooling towers, but there are no prescribed minimum cooling tower maintenance standards in Ontario. ASHRAE Guideline 12-2000; Minimizing the Risk of Legionellosis Associated with Building Water Systems and CTI – Legionellosis Guideline: Best Practices for Control of Legionella, July 2006 appear to be the most comprehensive guide for Legionella control in cooling towers.

Legionella control programs are fairly complex, and include cleaning the system of nutrients, regular inspections, mechanical filtration, keeping operation and maintenance records, and water treatment. The main focus of PHS activities was to obtain location and contact information for future reference if ever needed. Additionally, PHS collected
s some general information regarding water treatment for Legionella control in cooling towers.

It was found that:

- 98.5% (204 of 207) of the cooling towers assessed use chemicals in the water to minimize microbial growth. According to literature, not all chemical treatments are effective and ideally, chemicals should be alternated to minimize microbial resistance. The fact that all cooling towers are using chemicals to minimize microbial growth is a positive indication that there is a perceived need to control microbial growth.

- 75% (156 of 207) of cooling towers use an oxidizing biocide chemical in the water (chlorine or bromine, or derivatives thereof). Literature suggests that oxidizing biocides are more effective disinfectants than non-oxidizing biocides.

- 23% (48 of 207) of cooling towers use a non-oxidizing biocide chemical.

- 19% (39 of 207) of the cooling towers continuously inject biocide into the cooling tower water. This is considered a best case scenario for ensuring that the concentration of chemicals to inhibit or minimize microbial growth is present as much as possible. Again, the use of chemicals (biocides) alone is not a complete Legionella control program, but it is a key component.

- 69% (142 of 207) of the cooling towers intermittently added biocides into the cooling tower water. Personnel or equipment typically add a set volume of biocide according to a routine schedule (i.e. every other day, once a week, etc) based on a calculation. The intermittent addition of biocides does not provide continuous inhibition of microbial growth. Therefore, this may increase the risk of these cooling towers being colonized by Legionella bacteria.

- 11% (23 of 207) of the cooling towers using a biocide added it according to a process referred to as “hyper-halogenation”. This process involves adding a volume of chemicals to achieve a relatively high concentration of biocide. The time between the addition of chemicals to the cooling tower water is longer than the intermittent addition of biocide (e.g. twice a year VS bi-weekly). Hyper-halogenation is practiced mainly for infrastructure preservation. These cooling towers should also be considered to be at increased risk of colonization by Legionella bacteria.

These findings indicate that the water treatment processes (and public health safety) at approximately 81% of the cooling towers in Hamilton could be significantly improved by implementing continuous feed of an oxidizing biocide.

Public Health Services is proposing an educational initiative in May 2007 to inform and urge the Hamilton owners/operators/management companies of cooling towers to initiate Legionella control measures in cooling towers under their control. This educational initiative will involve mailing a copy of the American Society of Heating, Refrigeration,
and Air Conditioning Engineers (ASHRAE) Standard – Minimizing the Risk of Legionellosis Associated with Building Water Systems (Appendix A) and the Cooling Technology Institute (CTI) – Legionellosis Guideline: Best Practices for Control of Legionella, July 2006 (Appendix B) to all known parties responsible for the operation and maintenance of cooling towers in Hamilton.

Additionally, there are cooling tower microbial control methods that do not involve the use of chemicals. These are relatively new technologies that appear to have merit. It is reported that some of these new technologies also offer significant energy savings. Public Health Services will also consider including a recommendation to cooling tower owners/operators that they may want to investigate these new Legionella/microbial control technologies when considering their Legionella control program.

**ALTERNATIVES FOR CONSIDERATION:**

1. In the absence of provincial standards for Legionella control in cooling towers, await development of such provincial standards. In the opinion of PHS staff, this alternative is insufficient given the potential risks associated with sub-optimal cooling tower operation and maintenance.

2. Enact a municipal bylaw mandating minimum standards for cooling tower operation and maintenance. In the opinion of PHS staff, this represents significant operational and enforcement challenges. If enforcement were to be managed by PHS under the Health Protection and Promotion Act, Section 13 (health hazard) authority, it may fail to meet the requirements under the health hazard powers that the threat to health be imminent, until such time as additional human cases occur.

**FINANCIAL/STAFFING/LEGAL IMPLICATIONS:**

**Financial:**

Will be managed within existing resources.

**Staffing:**

None

**Legal:**

PHS has used Health Protection and Promotion Act, Section 13 (health hazard) powers to assist in gathering relevant information about cooling towers in Hamilton. As in 2006, should remediation be warranted, due to human cases of Legionella, this same legislative authority will suffice to order cooling tower remediation.

**POLICIES AFFECTING PROPOSAL:**

None known at this time
RELEVANT CONSULTATION:

Public Health Services has consulted with:

- City of Hamilton Building and Licensing Division of the Planning and Economic Department
- City of Hamilton Legal Services
- City of Toronto Public Health Department
- Ontario Ministry of Environment
- Ontario Ministry of Health and Long Term Care,
- Plant Engineering and Maintenance Association of Canada
- Technical Standards and Safety Association
- Heating, Refrigeration, and Air Conditioning Institute

These consultations have verified that there is no registry or list of cooling towers or prescribed standards for Legionella control in cooling towers. Public Health Services has also consulted with many cooling tower maintenance and chemical supply companies regarding Legionella control programs. Consultation with these companies has been very beneficial in terms of locating cooling tower owners/management companies, and has assisted Public Health Services to gain a better understanding of Legionella control programs. During the consultations, the extent of inadequate Legionella control was also evident.

Public Works has indicated that they will implement the appropriate standards for all City-owned facilities.

CITY STRATEGIC COMMITMENT:

Community Well-Being is enhanced. ☑ Yes ☐ No

Participation in community life is accessible to all Hamiltonians. There are many cooling towers located and operated throughout the urban area of the City of Hamilton. Cooling towers have historically been implicated as the source of Legionella infections in people. Cooling towers that are operated and maintained according to industry best practices and guidelines will diminish the likelihood of the occurrence of future Legionella infections and enhance community well being.

Environmental Well-Being is enhanced. ☑ Yes ☐ No

Human health and safety are protected. There are many cooling towers located and operated throughout the urban area of the City of Hamilton. Cooling towers have been historically implicated as the source of Legionella infections in people. Human health and safety would be better protected if cooling towers were operated and protected according to industry best practices and guidelines.
Economic Well-Being is enhanced. ☑ Yes ☐ No
Economic well-being would be enhanced if the likelihood of future Legionella infections associated with cooling towers were diminished, as the likelihood of public concern and interruptions to the day-to-day business and social activities would be reduced.

Does the option you are recommending create value across all three bottom lines? ☑ Yes ☐ No

Diminishing the risk of public exposure to Legionella bacteria from cooling towers (known reservoirs and sources of infection) should reduce the likelihood of future community acquired Legionella infections, thus reducing the likelihood and negative impact on the broader community.

Do the options you are recommending make Hamilton a City of choice for high performance public servants? ☐ Yes ☑ No
SPECIAL NOTE

This American National Standard (ANS) is a national voluntary consensus standard developed under the auspices of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). Consensus is defined by the American National Standards Institute (ANSI), of which ASHRAE is a member and which has approved this standard as an ANS, as “substantial agreement reached by directly and materially affected interest categories. This signifies the concurrence of more than a simple majority, but not necessarily unanimity. Consensus requires that all views and objections be considered, and that an effort be made toward their resolution.”

Compliance with this standard is voluntary until and unless a legal jurisdiction makes compliance mandatory through legislation.

ASHRAE obtains consensus through participation of its national and international members, associated societies, and public review.

ASHRAE Standards are prepared by a Project Committee appointed specifically for the purpose of writing the Standard. The Project Committee Chair and Vice-Chair must be members of ASHRAE, while other committee members may or may not be ASHRAE members, all must be technically qualified in the subject area of the Standard. Every effort is made to balance the concerned interests on all Project Committees.

The Manager of Standards of ASHRAE should be contacted for:

a. interpretation of the contents of this Standard,
b. participation in the next review of the Standard,
c. offering constructive criticism for improving the Standard,
d. permission to reprint portions of the Standard.

DISCLAIMER

ASHRAE uses its best efforts to promulgate Standards and Guidelines for the benefit of the public in light of available information and accepted industry practices. However, ASHRAE does not guarantee, certify, or assure the safety or performance of any products, components, or systems tested, installed, or operated in accordance with ASHRAE’s Standards or Guidelines or that any tests conducted under its Standards or Guidelines will be nonhazardous or free from risk.

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**ASHRAE Guideline 12-2000**  
Minimizing the Risk of Legionellosis Associated with Building Water Systems

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1. PURPOSE

The purpose of this guideline is to provide information and guidance in order to minimize Legionella contamination in building water systems.

2. SCOPE

2.1 This guideline provides specific environmental and operational guidelines that will contribute to the safe operation of building water systems to minimize the risk of occurrence of Legionellosis.

2.2 This guideline is intended for use with nonresidential building systems (including but not limited to hotels, office buildings, hospitals and other health care facilities, assisted living facilities, schools and universities, commercial buildings, industrial buildings, etc.) and centralized systems in multifamily residential buildings (including but not limited to central heating/cooling systems, central domestic water systems, common area fountains, etc.). While not specifically intended for noncentralized or single-family residential building systems, some of the information may be useful for these systems.

2.3 This guideline is intended for the use of designers, installers, owners, operators, users, maintenance personnel, and equipment manufacturers.

3. ECOLOGY OF LEGIONELLA

3.1 Infection and Disease

The majority of Legionnaires’ disease cases diagnosed and reported to the public health officials are sporadic (i.e., not occurring as part of a recognized outbreak). Compared with outbreak-associated infection, much less is known about transmission of sporadic Legionellosis, although it is likely that transmission occurs by similar mechanisms. Exposure to legionellae in sporadic cases may occur in a variety of settings, including the home, the workplace, and public places visited during routine daily activities or during travel. The proportion of sporadic disease attributable to exposure in each of these settings and to various environmental sources is unknown.

Legionellae are bacteria. When legionellae are present in aquatic environments, the risk of transmission of infection to humans depends on the presence of several factors: conditions favorable for amplification of the organism, a mechanism of dissemination (e.g., aerosolization of colonized water), inoculation of the organism at a site where it is capable of causing infection, bacterial strain-specific virulence factors, and the susceptibility of the host. Over 40 species of Legionella have been identified; L. pneumophila appears to be the most virulent and is associated with approximately 90% of cases of Legionellosis. Most L. pneumophila infections are caused by serogroup 1; however, certain serogroup 1 strains may be more virulent. The risk of acquiring Legionnaires’ disease is greater for older persons and for those who smoke tobacco or have chronic lung disease. Persons whose immune system is suppressed by certain drugs or by underlying medical conditions appear to be at particularly high risk.

3.2 Habitats

Legionellae bacteria are commonly present in natural and man-made aquatic environments. The organism is occasionally found in other sources, such as mud from streams and potting soils; however, the overall importance of nonaquatic environmental sources in human disease is not yet known. In natural water sources and municipal water systems, legionellae are generally present in very low or undetectable concentrations. However, under certain circumstances within man-made water systems, the concentration of organisms may increase markedly, a process termed “amplification.” Conditions that are favorable for the amplification of legionellae growth include water temperatures of 25-42°C (77-108°F), stagnation, scale and sediment, biofilms, and the presence of amoebae. Legionellae infect and multiply within several species of free-living amoebae, as well as ciliated protozoa. The initial site of infection in humans with Legionnaires’ disease is the pulmonary macrophage. These cells engulf legionellae, provide an intracellular environment that is remarkably similar to that within host protozoa, and allow for multiplication of the bacterium. Hence, legionellae may be considered protozoanotic; i.e., they naturally infect free-living amoebae and incidentally infect the phagocytic cells within human lungs under certain circumstances. Although legionellae may be cultivated on special agar media in laboratory settings, growth in nature in the absence of protozoa and/or in the absence of complex microbial biofilms has not been demonstrated. Intracellular growth of legionellae within protozoa and/or within diverse microbial biofilms may be the primary means of proliferation.

There is an indication that growth of Legionella is influenced by certain materials. Natural rubbers, wood, and some plastics have been shown to support the amplification of Legionella, while other materials such as copper inhibit their growth.

Generally, Legionella thrive in diverse, complex microbial communities because they require nutrients and protection from the environment. Controlling the populations of protozoa and other microorganisms may be the best means of minimizing Legionella.

3.3 Transmission of Legionnaires’ Disease

Most data on the transmission of Legionnaires’ disease are derived from investigations of disease outbreaks. These data suggest that, in most instances, transmission to humans occurs when water containing the organism is aerosolized in respirable droplets (1-5 micrometers in diameter) and inhaled by a susceptible host.

Prior to actual disease a number of events occur, some of which can be influenced by good engineering and maintenance practices. These events and prevention opportunities are outlined in Figure 1. The first event, survival in nature, is generally outside the scope of building engineering and management practices. The next three events—amplification, dissemination, and transmission—can be influenced by engineering design and maintenance practices. Subsequent events are influenced by the individual’s health.

The most effective control for most diseases, including Legionellosis, is prevention of transmission at as many points
as possible in the disease’s chain of transmission. The rationale for this is if one preventive measure fails, others will be in place and act as fail-safe mechanisms. With this philosophy in mind, it may be desirable to design interventions to prevent transmission of Legionellosis at as many points as possible in the disease’s chain of transmission. General concepts are presented so that readers may develop an understanding of the types of conditions that may allow amplification and transmission of Legionella.

A variety of aerosol-producing devices have been associated with outbreaks of Legionnaires’ disease, including cooling towers, evaporative condensers, showers, whirlpool spas, humidifiers, decorative fountains, and a grocery store produce mister. Aspiration of colonized drinking water into the lungs has been suggested as the mode of transmission in some cases of hospital-acquired Legionnaires’ disease.

Numerous investigations have demonstrated that cooling towers and evaporative condensers have served as the sources of Legionella-contaminated aerosols causing outbreaks of community- and hospital-acquired infection. Outbreak-associated transmission via cooling towers and evaporative condensers has been most commonly documented when those infected have been in close proximity to the contaminated devices; however, data from a few Legionnaires’ disease outbreak investigations suggest that legionella may be carried in cooling tower aerosols for distances of up to 3 kilometers (2 miles) (this is regarded as requiring an unusual combination of climatic conditions). A number of outbreaks of Legionellosis associated with cooling towers and evaporative condensers have occurred after these devices have been restarted following a period of inactivity.

Shower heads and tap faucets can produce aerosols containing legionella in droplets of respirable size. Epidemiologic studies and air sampling conducted during outbreak investigations have established the role of aerosols produced by showers and tap faucets in disease transmission. Aerosols produced by respiratory therapy equipment that have been filled or rinsed with contaminated potable water in hospitals have also caused disease transmission.

Heated spa pools operate at temperatures conducive to bacterial growth. The aeration of spa pools can result in formation of potentially contaminated aerosols. A range of pathogenic microorganisms, including *Pseudomonas aeruginosa* and *L. pneumophila*, have been found in spa pools. Outbreaks of Legionellosis have occurred among bathers as well as people near colonized spas.

A more complete and detailed description of the most common amplifiers associated with building water systems, including the treatment recommended to minimize the risk of Legionellosis, is found in Sections 4-10.

### 4. POTABLE AND EMERGENCY WATER SYSTEMS

#### 4.1 Potable Water Systems

**4.1.1 System Description.** Potable water systems in buildings for this discussion start at the point where the water enters the building and end where it exits the piping at a faucet, showerhead, etc. The systems include all piping, hot water heaters, storage tanks, faucets, nozzles, and other distribution outlets.

**4.1.2 System Operation.** Factors associated with the plumbing system that may influence the growth of legionellae are as follows:

- *Chlorine concentration.* Municipal potable water supplies are generally chlorinated to control the presence of microorganisms, historically to control microbes associated with sewage. The legionellae are more tolerant of chlorine than many other bacteria and may be present in small numbers in municipal water supplies.

- *Temperature.* Although legionellae have been recovered from cold water, the temperature range favorable for amplification is 25-42°C (77-108°F). The environment becomes more hostile as the temperature is moved from this range.

- **Design of plumbing system.** Growth of legionellae may occur in portions of the system with infrequent use, in stagnant water, and in portions of the system with tepid temperatures. Growth may also occur in dead-end lines, attached hoses, shower nozzles, tap faucets, hot water tanks, and reservoirs.

- **Plumbing materials.** Rubber washers and fittings, including water hammer arrestors and rubber hoses with spray attachments, have been shown to provide sites for growth of legionellae. Organic compounds leached from plumbing materials may contribute to growth of heterotrophic bacteria, including legionellae.

- **4.1.3 Water Droplet Size.** Contaminated potable water sources present the greatest risk when dispersed into the air in a very small droplet size (less than 5 micrometers) that can be inhaled deeply into the lungs. Actions that may generate small droplets are those that break up the water stream, i.e., shower nozzles, aerators, spray nozzles, water impacting on hard surfaces, and bubbles breaking up.

- **4.1.4 Nutrients.** Both dead and living microorganisms, biofilms, and debris may provide nutrient sources for legionellae growth. When legionellae are found in plumbing systems, it is common to detect the microbes in the sediment.
in hot water tanks and in peripheral plumbing fixtures that accumulate sediment. Legionellae growth appears to be heaviest at the solid-liquid interface with the development of slime deposits.

4.1.5 Associated Cases of Legionnaires’ Disease. Portable heated water systems are an important potential source of Legionellosis in all buildings and are of particular importance in hospitals, nursing homes, and other health care facilities. Many reports link legionella in hospital tap water to epidemics and clusters of nosocomial (hospital-acquired infection) Legionnaires’ disease, often involving immunosuppressed patients.

4.1.6 Recommended Treatment. Where practical in health care facilities, nursing homes, and other high-risk situations, cold water should be stored and distributed at temperatures below 20°C (68°F), while hot water should be stored above 60°C (140°F) and circulated with a minimum return temperature of 51°C (124°F). However, great care should be taken to avoid scalding problems. One method is to install preset thermostatic mixing valves. Where buildings cannot be retrofitted, periodically increasing the temperature to at least 66°C (150°F) or chlorination followed by flushing should be considered. Systems should be inspected annually to ensure that thermostats are functioning properly.

Where practical in other situations, hot water should be stored at temperatures of 49°C (120°F) or above.

Those hot or cold water systems that incorporate an elevated holding tank should be inspected and cleaned annually. Lids should fit closely to exclude foreign materials.

Detailed current plans for hot and cold water piping systems should be readily available. Hot water heaters and storage vessels for such systems should have a drainage facility at the lowest point, and the heating element should be located as close as possible to the bottom of the vessel to facilitate mixing and prevent water temperature stratification. In high-risk applications, insulated recirculation loops should be incorporated as a design feature. For all situations, the pipe runs should be as short as practical. Moreover, where recirculation is employed, the pipe runs should be insulated and long dead legs avoided. New shower systems in large buildings, hospitals, and nursing homes should be designed to permit mixing of hot and cold water near the showerhead. The warm water section of pipe between the control valve and showerhead should be self-draining.

Copper-silver ionization is a relatively new approach to controlling Legionella in hot water distribution systems and has been used successfully in a number of hospitals. Electrolytically generated copper and silver ions build up in the hot water recirculating system to levels effective in eradicating Legionella, typically in the range of 0.2-0.8 mg/L copper and 0.02-0.08 mg/L silver. The optimal concentration of copper-silver ions for controlling Legionella in hot water is not known. A particular concentration may not be universally effective because of variables in water quality and system design. It is also important to note that the efficacy of copper-silver ions, like chlorine, is adversely affected by elevated pH.

Where decontamination of hot water systems is necessary (typically due to implication of an outbreak of Legionellosis) the hot water temperature should be raised to 71-77°C (160-170°F) and maintained at that level while progressively flushing each outlet around the system. A minimum flush time of five minutes has been recommended by the Center for Disease Control Hospital Infection Control Practices Advisory Committee. However, the optimal flush time is not known and longer flush times may be necessary. In the original report describing this method, multiple 30-minute flushes were required to significantly reduce Legionella colonization. The number of outlets that can be flushed simultaneously will depend on the capacity of the water heater and the flow capability of the system. Local building and sanitary codes should be checked for any temperature limits of water discharged to the sewer. Appropriate safety procedures to prevent scalding are essential. When possible, flushing should be performed when the fewest building occupants are present (e.g., nights and weekends). For systems where thermal shock treatment is not possible, shock chlorination may provide an alternative. However, there is less experience with this method of decontamination. Also, users should realize that the required levels of free chlorine residual can cause corrosion of metals. Chlorine should be added to achieve a free chlorine residual of at least 2 mg/L throughout the system. This may require chlorination of the water heater or tank to levels of 20 to 50 mg/L. The pH of the water should be maintained between 7.0 and 8.0. Each outlet should be flushed until the odor of chlorine is detected. The chlorine should remain in the system for a minimum of 2 hours (not to exceed 24 hours), after which the system should be thoroughly flushed.

Once the decontamination is complete, recolonization is likely to occur unless the proper temperatures are maintained, continuous supplemental chlorination is continued, or alternative approaches, such as the use of a silver/copper ionization device, are employed.

In high-risk applications, monthly removal of shower heads and tap aerators to clean out sediment and scale and to clean them in a chlorine bleach solution is recommended.

For potable water systems that were opened for repair or other construction or systems that were subjected to water pressure changes associated with construction (which may cause water to become brown and the concentration of Legionella to dramatically increase), it is recommended that as a minimum the system be thoroughly flushed. High-temperature flushing or chlorination may be appropriate, and this judgement should be made on a job-specific basis. If only a portion of the system is involved, high-temperature flushing or chlorination may be used on only that portion of the system.

4.2 Emergency Water Systems—Safety Showers, Eye Wash Stations, and Fire Sprinkler Systems

4.2.1 System Description. All three of these systems are generally plumbed to the potable water system, have little or no flow with resulting stagnant conditions, and may reach temperatures warmer than ambient. Legionellae, heterotrophic bacteria, and amoebae have been cultured from these systems. When the devices are used, aerosolization is expected.
4.2.2 Associated Cases of Legionnaires’ Disease. Cases of Legionellosis resulting from exposure to these waters have not been documented.

4.2.3 Recommended Treatment. Safety shower and eye wash stations should be flushed at least monthly. In the case of fire sprinkler systems, it is recommended that fire-fighting personnel wear protective respiratory gear and that non-fire-fighting personnel exit the burning area. Appropriate precautions should be taken when checking the operation of fire sprinkler systems.

5. HEATED SPAS

5.1 System Description

Heated spas are small baths or pools used for relaxation (i.e., recreational), hygienic, or therapeutic purposes. Common features include warm water temperatures, (32-40°C/90-104°F) and the constant recirculation and agitation of the water through high-velocity jets and/or injection of air. While there is some confusion over the names used for each, the differences among the types of baths and pools are related mainly to size, purpose, material used, and equipment.

5.1.1 Whirlpool Spa (Spa, Hydrotherapy Pool). These are recreational baths or pools (public or private) holding more than one person and filled with warm turbulent water. The water is not replaced after each use but rather is filtered to remove particulates and chemically treated (typically with chlorine or bromine) to provide microbiological control. They may be located indoors or outdoors. Most smaller units are made from molded fiberglass, while larger in-ground varieties are generally made of gunite or concrete with a white plaster finish. They are generally circular in shape, always shallow (less than 1.3 m [52 in.]), and contain seats that allow occupants to submerge up to the chest or neck.

5.1.2 Hot Tub. These are traditionally deeper hot water baths or pools made of wood. Redwood is common, but they may also be made of cedar, mahogany, white oak, pine, or teak. Otherwise, the features and uses are similar to spas.

5.1.3 Whirlpool. This terminology has been traditionally used for the small therapeutic pools (often used in athletics) filled with warm, vigorously moving water, which may be small enough for treatment of a specific joint, such as a knee, ankle, or elbow. These pools are generally made of stainless steel and are emptied between uses.

5.1.4 Whirlpool Bath. These are small baths often found in bathrooms of hotel rooms or private residences. As such, they are used for both recreational and hygienic purposes. The baths are fitted with high-velocity water jets and/or air injection, but unlike whirlpool spas and hot tubs, the water is emptied after each use.

5.2 System Operation

Temperature. The water temperature in these spas, baths, and pools is generally in the range of 32-40°C (90-104°F), with the maximum temperature based on bather comfort. These warm temperatures are close to the optimum for the multiplication of Legionella and many other microorganisms. The warmer temperatures also accelerate the loss of the biocide.

Aerosol Production. Due to the operational features of the high-velocity water recirculation and air injection, a large number of bubbles of varying sizes rise to the water surface and burst. Microorganisms (e.g., Legionella) in the water can be released into the air via either bubbles or aerosol mist.

5.3 Water Droplet Size

This aerosol mist has water droplets of varying sizes (many less than 5 micrometers) and extends into the air to a height of at least 0.5 meters (1 1/2 ft) above the water surface (well within the breathing zone of the bathers). Under conditions of high relative humidity and air currents, the aerosol may also expose individuals outside the spa.

5.4 Nutrients

Due to the small volume of water per occupant (approximately 300 liters, compared to 10,000 liters in a typical swimming pool), the bathing load quickly contributes a variety of contaminants into the water, such as body oils, skin flakes, bacteria and fungi, suntan lotion, and other organic materials. In addition to serving as nutrients, these organic materials can also cause an increase in chlorine (or bromine) demand, resulting in a reduction in free available halogen.

5.5 Associated Cases of Legionnaires’ Disease

In surveys of whirlpool spas, legionellae have been isolated from as many as 33% of the spas sampled, but only in those spas where the disinfectant (chlorine or bromine) levels were not adequately maintained. Thus, it is generally presumed that outbreaks of Legionellosis from whirlpool spas are likely to be associated with spas that have similar deficiencies in their disinfectant levels.

It is universally recognized that water treatment criteria for spas (and swimming pools) should include disinfection against coliforms and other fecal pathogens (bacteria, viruses, and protozoa). In recent years, these types of recreational and therapeutic spas have been recognized as important sources of infection by other waterborne pathogens, including Pseudomonas aeruginosa and Legionella species. Several multiple-case outbreaks of Legionellosis (Legionnaires’ disease and Pontiac fever) have been traced to spas and hot tubs, and fatalities have occurred.10,36 No cases of Legionellosis have been traced to whirlpool baths.10,11

5.6 Recommended Treatment

5.6.1 Whirlpool Spas. Whirlpool spas are currently subject to state and local regulations related to public swimming and bathing facilities. These regulations may cover all areas of operation, including mechanical specifications, operational parameters (i.e., flow rate, temperature), water chemistry, and bacteriology. To minimize the occurrence of whirlpool-related infectious diseases (including Legionellosis), the following guidelines are relevant.

5.6.1.1 Bather Load. Clearly post and enforce the maximum number of occupants (0.93 m² [10 ft²] of surface area per bather). Using this formula, a 2.5 meter (8 ft) diameter circular spa would have a maximum bather load of five at one time.

5.6.1.2 Bather Health Restrictions. Clearly post warnings on the increased health risk related to use by individuals who are immunocompromised or who have chronic lung disease.
5.6.1.3 Filter Operation. Hygienic maintenance of spa filters is more difficult than that of swimming pool filters because of the higher ratio of number of bathers to pool volume. Health codes consistently accept filter flow rates as follows:

- High rate sand filters — 3.4-6.7 L/s per m² (5-10 gal/min per ft²) of filter media
- Diatomaceous earth filters — 1 L/s per m² (1.5 gal/min per ft²) of filter media
- Cartridge filters — 0.25 L/s per m² (0.375 gal/min per ft²) of filter media

Maintenance of filters includes back flushing regularly to remove the buildup of organic debris. Determining the frequency of back flushing is currently based on manufacturer recommendations (flow-rate requirements) rather than microbiological criteria. As a general rule, daily back flushing may be required during periods of heavy usage. Filter cartridges should also be cleaned or replaced on a regular basis (once or twice weekly).

5.6.1.4 Water Chemistry. The American National Standards Institute and National Spa and Pool Institute (ANSI/NSPI) have established chemical standards related to pool disinfection. The standards are generally used as a basis for most state and local regulations and have been modified slightly by the Centers for Disease Control in their “Interim Recommendations to Minimize Transmission of Legionnaires Disease from Whirlpool Spas on Cruise Ships (1995).”

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Ideal Values</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free chlorine (mg/L)</td>
<td>3.0</td>
<td>4.0-5.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Combined chlorine (chloroamines) (mg/L)</td>
<td>None</td>
<td>None</td>
<td>0.2</td>
</tr>
<tr>
<td>Bromine (mg/L)</td>
<td>4.0</td>
<td>4.0-6.0</td>
<td>10.0</td>
</tr>
<tr>
<td>pH</td>
<td>7.2</td>
<td>7.4-7.6</td>
<td>7.8</td>
</tr>
</tbody>
</table>

The upper value of 10 mg/L (free chlorine or bromine) should not be considered a routine target maintenance level; however, this level is acceptable for relatively short durations.

The ideal values should be considered minimum values for control of Legionella because of the relative resistance of Legionella to halogens (compared to other bacteria and enteric viruses). Maintaining the required free available halogen level is absolutely critical for controlling the growth of bacteria (including Legionella) in the spa water. Thus, these parameters should be measured frequently, as often as hourly during periods of heavy use. Automatic systems that continuously monitor the free halogen and adjust as needed would offer the best control of the water chemistry. In addition, it would be desirable to install halogen level-dependent injector devices on both sides of the filter to ensure that adequate levels of biocide are maintained within the filter and within the water exiting the filter.

Several alternative or adjunctive nonhalogen water treatment procedures are currently being marketed, including copper/silver ion water treatment, iodination treatment, ultraviolet light treatment, and ozonation. While any or all of these approaches may successfully control Legionella and other bacteria in pools and spas, there are insufficient data at the present time to recommend any major variation from current water treatment practices. This situation may change as additional data from laboratory and real-world studies become available.

5.6.1.5 Bacteriological Parameters. Regular testing of all spas can provide an important record of safe operating conditions and may alert operators of unsafe conditions when they occur. However, since bacteriological results require as much as 24 hours (or longer for Legionella) for results, they should be used only to spot-check or confirm the effectiveness of the disinfection system, not as a replacement for frequent testing of the water chemistry or routine maintenance. Where culturing for legionellae is to be done, see section 11 for input on proper sampling, handling, and shipping.

- Standard agar plate count (35°C)—200 cfu per ml. (maximum)
- Total coliforms—2 organisms per 100 ml. (maximum)
- Fecal coliforms—None allowable
- Pseudomonas aeruginosa (41°C)—None allowable
- Legionella species—None allowable

5.6.1.6 Routine Maintenance. Current ANSI/NSPI recommendations include taking the spa out of service at the end of each day in order to carry out a superhalogenation (i.e., shock disinfection) using 10 mg/L or 10 times the combined chlorine level, whichever is greater, for one to four hours. Due to the buildup of total dissolved solids and organic matter in the water, the spa water should also be replaced at least once a week (depending on the frequency of use). Daily water changes may be necessary under continuous conditions of high use. At the same time, the spa should be thoroughly cleaned, including a vigorous scrubbing of the spa surface, weirs, and skimming devices, in order to remove buildup of microbial biofilm. Conditions of high bacterial counts also require shock disinfection in order to achieve safe operating conditions, often coupled with changing the water, cleaning the spa, and maintenance of filters.

5.6.1.7 Training and Record Keeping. Training of maintenance personnel on all aspects of the safe operation of whirlpool spas should be mandatory. As part of this training, it should be emphasized that spas are not the same as swimming pools; thus, maintenance required for safe operation is very different. Maintenance personnel should also be trained to maintain good records of all water chemistry measurements, back flushing of filters, water changes, and spa cleaning. Results of samples sent to outside labs for bacteriological analysis should also be maintained. All records should be kept for a period of at least two years.

5.6.2 Whirlpool Baths. Since whirlpool baths are always filled with fresh potable tap water and drained at the end of each use, the recommendations for control of Legionellosis would fall initially under those guidelines developed for potable water systems.
6. ARCHITECTURAL FOUNTAINS AND WATERFALL SYSTEMS

6.1 System Description

In these systems, water is either sprayed in the air or cascades over a steep media such as rocks, and then it returns to the man-made pool. This guide is not intended to cover fountains in natural bodies of water or natural waterfalls.

6.2 System Operation

These systems are sometimes operated intermittently with on-time often scheduled only during certain time periods. Applications can include elaborate displays specifically intended to periodically attract large crowds in entertainment centers. Systems that are operated intermittently may encourage greater biocontamination.

6.2.0.1 Temperature. Because of the high temperature ranges needed for proliferation of legionellae bacteria, outdoor fountains and pools in hotter climates and indoor fountains and pools subject to sources of heat may be susceptible to becoming amplifiers. Temperature increases may be facilitated by heat from the pump/ filter systems themselves. Intermittent operation may also create situations where temperature increases occur in limited parts of the system.

6.3 Water Droplet Size

These systems can produce droplets of various sizes and certainly have the potential to produce droplets less than 5 micrometers. Generally speaking, the legionellae risk increases as the rate of aerosol production increases.

6.4 Nutrients

Fountains are subject to contamination from a wide variety of sources, including materials scrubbed from the air and returned to the pool with the falling water droplets as well as organic and inorganic materials dropped, thrown, or blown into the pool.

Algae and bacteria are recognized as a particular problem in pools less than 1 meter (3 ft) deep. When used, filter systems are similar to the types used for swimming pools.

6.5 Associated Cases of Legionnaires' Disease

Several multiple-case outbreaks of Legionellosis have been associated with decorative fountains in public buildings, particularly hotels. However, the true incidence of disease from these sources may be much higher due to the occurrence of isolated cases where no association with the building or the fountain was suspected.

6.6 Recommended Treatment

6.6.1 Design Considerations

- Drains or sumps should be situated at the lowest level of the pool, with no other local low points that are not served by drains or sumps.
- Provision for maintenance should be considered in the design stage. Access to pump(s) and filter(s) should be provided. Stagnant areas or areas that are difficult to clean should be avoided.

6.6.2 Maintenance

- Regular cleaning is recommended.
- Use of filters should be considered; however, systems with a small water volume may be drained and refilled with fresh water every few weeks in lieu of filtering.

6.6.3 Water Treatment

Microbial fouling control is important, especially where the conditions are such that there are significant periods of time when the temperature of the fountain water is in the range that is favorable for the amplification of legionellae growth (see 3.2). When biocidal treatment is employed for microbial fouling control, the biocide must be registered with the Environmental Protection Agency for use in decorative fountains. For further information on water treatment, see 7.6.2 of this guideline and the “Water Treatment” chapter in the Applications volume of the ASHRAE Handbook.

7. COOLING TOWERS INCLUDING FLUID COOLERS (CLOSED-CIRCUIT COOLING TOWERS) AND EVAPORATIVE CONDENSERS

7.1 Cooling Towers

7.1.1 System Description. A cooling tower is an evaporative heat transfer device in which atmospheric air cools warm water, with direct contact between the water and the air, by evaporating part of the water (see Figure 2). Air movement through such a tower is typically achieved by fans, although some large cooling towers rely on natural draft circulation of air. Cooling towers typically use some media, referred to as “fill,” to achieve improved contact between the water and the cooling air.

7.1.2 System Operation. Cooling towers associated with building water systems are typically used for rejection of waste heat from the condenser of chillers providing air conditioning for a building. Water from the cooling tower is piped to the condenser where it is heated and then back to the cooling tower to be cooled.

7.1.2.1 Temperature. The typical temperature of the water in cooling towers ranges from 29°C (85°F) to 35°C (95°F) although temperatures can be above 49°C (120°F) and below 21°C (70°F) depending on system heat load, ambient temperature, and system operating strategy.

![Figure 2 Typical cooling tower/chiller system.](image-url)
7.1.2.2 Circulating Water System. Cold water piping from the cooling tower runs to one or more pump(s), then to the chiller condenser, where it is heated, and then back to the hot water distribution system in the cooling tower. Considerable variation in the piping arrangement occurs. Stagnant areas or dead legs may be difficult to clean or penetrate with biocides.

A significant volume of water may be contained in the piping system.

7.2 Closed-Circuit Cooling Towers and Evaporative Condensers

7.2.1 System Description. Closed-circuit cooling towers and evaporative condensers are also evaporative heat transfer devices. Both are similar to conventional cooling towers, but there is one very significant difference. The process fluid (either a liquid such as water, an ethylene glycol/water mixture, oil, etc., or a condensing refrigerant) does not directly contact the cooling air. Rather, the process fluid is contained inside a coil assembly (see Figure 3).

7.2.2 System Operation. Water is drawn from the basin and pumped to a spray distribution system over the coil assembly while the cooling air is blown or drawn over the coil by fans. Removal of heat is achieved by evaporating part of the water.

7.2.2.1 Temperature. Water temperature in closed-circuit cooling towers and evaporative condensers is similar to that in cooling towers.

7.2.2.2 Circulating Water System. Most commonly, there is no external piping in these systems. Because the water is totally contained within the unit, the volume of water is generally significantly less than with conventional cooling tower systems.

7.3 Water Droplet Size

Cooling towers and evaporative condensers incorporate inertial stripping devices called drift eliminators to remove water droplets generated within the unit. While the effectiveness of these eliminators can vary significantly with the design (new state-of-the-art eliminators are significantly more efficient than older designs) and the condition of the eliminators, it should be assumed that some water droplets in the size range of less than 5 micrometers leave the unit. In addition, some larger droplets leaving the unit may be reduced to 5 micrometers or less by evaporation.

7.4 Nutrients

Because cooling towers and evaporative condensers are highly effective air scrubbers and because they move large volumes of air, organic material and other debris can be accumulated. This material may serve as a nutrient source for legionellae growth. Diverse biofilms, which can support the growth of legionellae, may be present on heat exchanger surfaces, structural surfaces, sump surfaces, and other miscellaneous surfaces.

7.5 Associated Cases of Legionnaires’ Disease

Evaporative heat rejection equipment such as cooling towers and evaporative condensers have been implicated in numerous outbreaks of Legionnaires’ disease, and studies have shown that detectable levels of legionellae are present in many, if not most, such devices.

7.6 Recommended Treatment

The key recommendations are that the system be maintained clean and that a biocidal treatment program be used. It is also recommended that the services of a qualified water treatment specialist be used to define and oversee the treatment.

7.6.1 System Maintenance. Keeping the system clean reduces the nutrients available for Legionella growth. Regular visual inspections should be made for general cleanliness. The cold water basin of the unit should be cleaned when any buildup of dirt, organic matter, or other debris is visible or found through sampling. Mechanical filtration may be used to help reduce these solids. Strainers, cartridge filters, sand filters, centrifugal-gravity-type separators and bag-type filters can be used to assist in removal of debris.

The drift eliminators should also be inspected regularly and cleaned if required or replaced if deteriorated or damaged.

Operation and maintenance records should include the following information:

- system schematic
- system water volume, with date and method of determination
- manufacturers’ instructions for equipment operation
- regular water treatment procedures
- material safety data sheets for chemicals used (MSDS)
- names of persons responsible for system operation and shutdown
- dates of inspections and written results of inspections
- dates and nature of routine maintenance
- dates of equipment repairs or modifications with description of work done
7.6.2 Water Treatment. Water treatment provides a heat transfer fluid that allows equipment to function optimally. Objectives of water treatment for cooling water systems is to use water efficiently as well as to

- minimize microbial growth,
- minimize scale,
- minimize corrosion,
- minimize sediment/deposition of solids (organic or inorganic) on heat transfer surfaces.

An effective water treatment program should allow more efficient operation due to lower fouling, a longer system life due to decreased corrosion, and safer operation of the system due to reduced chances of microbial exposure to the public.

Control of scaling and corrosion is necessary in many water treatment programs. Scale such as calcium carbonate and/or other minerals containing silica, magnesium, and phosphate may precipitate onto heat exchanger and piping surfaces. Scaling can be minimized by use of inhibitors containing phosphonates, phosphates, and polymers to keep calcium and carbonate and other minerals in solution. Corrosion can be minimized by the use of inhibitors such as phosphate, azoles, molybdenum, and zinc. Scale and corrosion inhibitors are effective if microbial fouling and biofilm development are properly controlled. Microbial fouling can influence scaling and corrosion processes and can affect the performance of inhibitors. Microbial biofilms on surfaces can consume certain inhibitors (such as phosphates, phosphonates, and azoles), prevent access of inhibitors to surfaces, create localized oxygen-depleted zones, change the pH near surfaces, and accumulate or trap deposits onto surfaces.

Surfactants have also been used to minimize deposition on surfaces (particularly heat transfer surfaces). When used, the surfactant must be compatible with the scale and corrosion inhibitors as well as appropriate for the type of dirt, oil, or other material that is present.

Equally important to controlling scale and corrosion is keeping the system clean and free of sediment. Common sources of sediment include materials scrubbed from the air (dirt, leaves, paper, kitchen or other organic exhaust), precipitated solids (calcium, magnesium, carbonate silica), and corrosion products (rust). Microbes including bacteria, protozoa, algae, and (infrequently) fungi can grow in cooling systems and use the above materials as nutrients. Consequently, it is desirable to either prevent the entry of the material into the system or to remove it from the system.

Strategies to accomplish this include siting of the tower (relative to kitchen exhausts, etc.), scale and corrosion control, and filtration and/or separation.

Microbial fouling is controlled by the use of biocides, which are compounds selected for their ability to kill microbes while having relatively low toxicity for plants and animals. In the USA, the Environmental Protection Agency has regulatory authority for biocides and requires registration of all biocides. In addition, registration is required in each state where the biocide will be distributed. The data package submitted to the EPA includes efficacy data against a variety of microbes and toxicity data for animals. Much of the laboratory data are provided by the manufacturers of the individual biocides. Biocides must be used in accordance with the directions on the label.

There are two main groups of chemical biocides: oxidizers and nonoxidizers.

Oxidizing biocides include bromine, bromo-chlorohydrantoin, chlorine, chlorine dioxide, iodine, isocyanurates, ozone, or other compounds with the ability to accept electrons from other compounds that serve as reducing agents. Oxidizing biocides can accelerate corrosion of metals if they are dosed at excessive concentrations. Halogen biocides (chlorine, bromine, and iodine) react with the protein in cell membranes to cause the protein to become dysfunctional, thus killing/controlling the organism. Ozone and chlorine dioxide are believed to oxidize other components of the microbial cell.

Nonoxidizing biocides include many organic compounds registered with the EPA for cooling water applications, such as bromonitropropanediol, bromonitrostyrene, carbamates, dectylthiotheneamine, dibromonitrolpropionamide, dodecylguanidine hydrochloride, glutaraldehyde, isothiazolones, methylene bisthiocyanate, quaternary phosphonium salts, and trihydroxymethylnitromethane. Quaternary ammonium compounds are sometimes used but were found to be ineffective against legionellae in a recent study. These biocides function in a number of ways, including reacting with intracellular enzymes, solubilizing cell membranes, and precipitating essential proteins in microbial cell walls. Properly used, nonoxidizing biocides are effective for control of the microbial fouling process in cooling water systems.

Both oxidizers and nonoxidizers can undergo chemical reactions with materials in the water that decrease their effectiveness. Some biocides react with components of some scale and corrosion inhibitors to render both compounds less effective for their intended purpose. Selection of corrosion/scale inhibitors as well as the biocide requires a knowledge of water chemistry, a basic understanding of water microbiology, and specific information about the system (what the system is cooling, sources of contamination, etc.).

It is generally sound practice to regularly alternate the biocides used for a cooling water system to avoid the selection and growth of resistant strains of microbes. The alternating biocide approach has been emphasized with the rationale that the population that survives the biocide treatment one week is susceptible to the alternate biocide a week or two later. Alternating the dose and frequency of the same biocide is also used to achieve this goal.

Because *Legionella* are known to enter cooling water systems in the makeup water, it should be assumed that they are present in the water along with other bacteria, protozoans, and algae. Protozoa are highly resistant to both oxidizing and nonoxidizing biocides; hence they must be controlled by limiting the microbial biofilms that serve to provide them nutrients.

For further information on the subject of water treatment, see the “Water Treatment” chapter in the Applications volume of the ASHRAE Handbook.
7.6.3 Cooling Tower System Shutdown and Start-Up Procedure

Shutdown

When the system is to be shut down for a period of more than three days, it is recommended that the entire system (cooling tower, system piping, heat exchangers, etc.) be drained to waste. When draining the system is not practical during shutdowns of short duration, the stagnant cooling water must be pretreated with an appropriate biocide regimen before tower start-up.

Start-Up for Drained Systems

- Clean all debris, such as leaves and dirt, from the cooling tower.
- Fill the system with water. While operating the condensing water pump(s) and prior to operating the cooling tower fans, execute one of the two alternative biocidal treatment programs described below.
  1. Treat with the biocide that had been used prior to shutdown. Utilize the services of the water treatment supplier. Maintain the maximum recommended biocide residual (for the specific biocide) for a sufficient period of time (residual and time will vary with the biocide) to bring the system under good biological control.
  2. Treat the system with sodium hypochlorite to a level of 4 to 5 mg/L (ppm) free chlorine residual at a pH of 7.0 to 7.6. The chlorine residual must be held at 4 to 5 mg/L (ppm) for six hours, measurable with standard commercial water test kits.
- Once one of these two biocidal treatments has been successfully completed, the fan can be turned on and the system returned to service. Resume the standard water treatment program (including biocidal treatment).

Start-Up for Undrained (Stagnant) Systems

Remove accessible solid debris from the cooling tower sump and from any remote storage tank(s) that may be used.
- Perform one of the two biocide pretreatment procedures (described in “Start-Up for Drained Systems”) directly to the cooling tower sump or remote storage tank. Do not circulate stagnant bulk cooling water over cooling tower fill or operate cooling tower fans during pretreatment.
- Stagnant cooling water may be circulated with the main cooling system pump(s) if tower fill is bypassed. Otherwise, add approved biocide directly to the bulk water source and mix with either manual or by sidestream flow methods. Take care to prevent the creation of aerosol spray from the stagnant cooling water from any point in the cooling water system.
- After biocidal pretreatment has been successfully completed, the cooling water should be circulated over the tower fill with fans off. When biocide residual is maintained at a satisfactory level for at least six hours, the cooling tower fans may be operated.

7.6.4 Emergency Decontamination of Wet-Type Heat Rejection Systems for Legionella. The Cooling Tower Institute has formulated an “Emergency Protocol” for decontaminating cooling towers and evaporative condensers using chlorine and dispersants. However, this procedure must not be used routinely because it can be very corrosive and produce toxic fumes. This procedure has been adapted to include additional safety precautions and a 10 mg/L free residual chlorine level for 24 hours.

7.6.5 Siting. In locating cooling towers and evaporative condensers, attention should be given to the following considerations.

- Locate as far as possible from fresh air intakes, including windows that can be opened.
- Do not locate in the immediate area of kitchen exhaust fans, plants, truck bays, or other sources of organic matter.
- Consider the direction of prevailing winds and do not locate upstream of outdoor public areas.
- Consider future construction, including nearby sites.

8. DIRECT EVAPORATIVE AIR COOLERS, MISTERS (ATOMIZERS), AIR WASHERS, AND HUMIDIFIERS

8.1 System Description

Direct evaporative air-cooling equipment and humidifiers cool and humidify air by direct contact with the water, either by wetted-surface materials (as in wetted media air coolers) or with a series of sprays (as in air washers and misters). These devices (see Figures 4 and 5) are used to control the temperature and humidity levels for commercial, industrial, and agricultural applications.

They utilize either once-through or recirculating water. Wetted media systems may include a pump, water distribution piping, and a sump to collect or hold water. A fan may be utilized to move air across the system and distribute evaporatively cooled and humidified air to the location being served. Concentration of contaminants in the water is limited by bleed off and quality of fresh water makeup.

8.1.1 Wetted Media. Wetted media devices utilize a porous substrate to provide an extended surface area for evaporation of water. Water is either circulated over the media or the media are rotated through a water bath. Since evaporation occurs from the surface of the media, no water droplets are produced. Mist eliminators are generally not necessary. These

Figure 4 Direct evaporative air cooler/humidifier.
devices utilize either once-through potable building water or are equipped with a recirculating system including a pump, automatic makeup water valve, a bleed-off/purge, and a positive draining reservoir.

8.1.2 Air Washers. Air washers utilize high-pressure nozzles to reduce water to small droplets for efficient evaporation. These systems have a chamber or casing containing one or more banks of spray nozzles and drift eliminators. Air washers contain a sump for collecting and holding excess spray water. The eliminator section removes entrained droplets of water from the air. Air washers also utilize either once-through potable building water or are equipped with a recirculating system including a pump, automatic makeup water valve, a bleed-off/purge, and a positive draining reservoir. The water may be chilled for additional cooling and/or dehumidification.

8.1.3 Misters. Misters produce an aerosol by use of ultrasonic devices, spinning disks, or spray nozzles. Normally these devices are supplied with fresh potable water directly from the building water systems; however, some systems contain a reservoir.

8.1.3.1 Heated Element and Steam-Type Humidifiers. Heated element and vapor-type humidifiers convert water to vapor that is discharged into the space being conditioned. Due to the elevated temperature and the fact that water droplets are not generated, these humidifiers are not considered a risk for the growth of Legionella during normal operation. However, if the humidifier is improperly installed, moisture may accumulate in the duct and lead to bacterial growth. During periods of time when equipment is not in use, all water should be drained from the system to avoid the possibility of bacterial growth.

8.2 System Operation

See 8.1.

It should be noted that due to process conditions, there may be periods of time when equipment is shut down. It is common practice to drain sumps when the units are not in use. In addition, a continuous bleed or purge cycle is usually employed to limit the buildup of solids and contaminants in the basin. High dilution rates remove bacteria, nutrients, and other contaminants before they are a problem. It is rare for growth of Legionella to occur under these conditions.

8.2.1 Water Temperature—Wetted Media Evaporative Air Coolers/Humidifiers and Air Washers. For wetted media evaporative air coolers/humidifiers and air washers, the recirculating water temperature approximates the wet-bulb temperature of the airstream to which it is exposed. Since the wet-bulb temperature in most regions where these devices are used is well below 25°C (77°F), the water tends to be maintained at temperatures below the Legionella growth temperature range of 25-42°C (77-108°F).

8.2.2 Water Temperature—Misters. For misters supplied directly from the building potable water system, the temperature would tend to be at the supply cold water temperature. If fed from a stagnant reservoir, or pipes exposed to heat, the temperature could increase. The temperature could exceed 25°C (77°F), which is favorable for amplification of legionellae.

8.2.3 Water Temperature—Air Washers. Air washer operating conditions are based on the requirements of the process; however, a standard operating temperature range for circulating water is 4-10°C (40-50°F). The normal operating portions of air washer systems tend to be maintained at temperatures below the Legionella growth temperature range of 25-42°C (77-108°F).

8.3 Water Droplet Size

8.3.1 Wetted Media. Wetted media equipment generally produces few droplets during operation. However, large droplets may form as a result of improper maintenance and uneven water or air distribution. The exact size of the droplets will vary with the condition of the wetted media and mist eliminators (where used), air velocity through the unit, and irrigation rate. It should be assumed that under extreme conditions droplets of less than 5 micrometers could be created.

8.3.2 Air Washers. The major causes of droplets being entrained into the airstream are fouled spray nozzles and damaged or dirty mist eliminators. Air washers can produce droplets of various sizes and certainly have the potential to produce droplets less than 5 micrometers in diameter.

8.3.3 Misters. These systems can produce droplets of varying size and certainly have the potential to produce droplets less than 5 micrometers in diameter.

8.4 Nutrients

Because direct evaporative air coolers/humidifiers are efficient air scrubbers and move large volumes of air, organic matter and other debris can be accumulated. This may serve as a nutrient source for Legionella growth.

8.4.0.1 Wetted Media Evaporative Air Coolers/ Humidifiers and Air Washers. Wetted media evaporative coolers/humidifiers and air washers have potential for growth where dirt, scale, or biological matter can accumulate. Most
likely areas of such accumulation are collection troughs, mist eliminators, or water storage tanks.

8.4.1 **Misters.** Nutrient availability would be minimal when fed potable water directly from the building potable water system. If distribution piping and/or a holding reservoir is used, nutrients in the form of sediment and other debris may exist.

8.5 **Recommended Treatment**

8.5.1 **All Systems.** Regular inspection and maintenance of evaporative air coolers/humidifiers, air washers, misters, and ancillary equipment are recommended. Avoid dead-end piping, low spots, and other areas in the water distribution system where water may stagnate during shutdown.

Consider the use of photochemical ozone generators to control microbial concentrations in water in sumps and distribution piping. Water filters and air filters should be cleaned as required. The entire cooling water loop should be cleaned and flushed monthly.

8.5.2 **Recirculating Systems.** Proper sump water level or spray pressure must be maintained. Bleeding off or purging some of the water is the most practical means to minimize scale and nutrient accumulation. The bleed rate or purge depend on water quality (including hardness) and airborne contaminant level. Regular inspections should be made to ensure that the bleed rate or purge is adequate and is maintained. As an added precaution, sumps could be automatically drained during shutdown of the fan. When it is impractical to shut a system down for cleaning, it should be provided with a positive draining sump and easily accessible flush-out of the water distribution header so it can be flushed during operation. After flushing, dose the recirculating cooling water with a biocide approved by the EPA for such applications.

8.5.3 **Air Washers.** Use corrosion inhibitors to prevent corrosion of metals in the systems and formation of corrosion products. Control the level of suspended solids that can supply nutrients and growth areas for legionella. Finally, the microbiological activity should be controlled through the utilization of biocides approved by the EPA for such applications.

8.5.4 **Wetted Media Evaporative Air Coolers/Humidifiers.** Media located inside a large built-up air house may not dry completely during period of shutdown (i.e., weekends), resulting in stagnation. In order to dry out the media, pumps should be shut down prior to scheduled fan shutdowns. Smaller systems and those having the media located adjacent to inlet louvers normally dry sufficiently without assistance. For systems experiencing high contaminant loading, a flush-out cycle may be used that runs fresh water through the pad every 24 hours during a period of time when the system is not in operation. Media should be cleaned or replaced when necessary.

8.5.5 **Misters.** Never recirculate atomized water. Drain pipes and reservoir when equipment is not in use. For portable misters, drain and disinfect piping and reservoir regularly. Only sterile water should be added to the reservoir of portable humidifiers used in health care environments or in other areas where immunocompromised persons are likely to be exposed to the generated aerosols.

8.6 **Siting**

Evaporative air coolers/humidifiers should not be located near the outlet of a cooling tower, fluid cooler, evaporative condenser, kitchen exhaust, or any other source of organic contamination. Filtration upstream of the evaporative air cooler/humidifier is recommended when particulate contamination is expected. Filtration downstream of the equipment must be a sufficient distance to allow absorption of moisture into the air stream.

8.7 **Associated Cases of Legionnaires’ Disease**

There have been no known cases of Legionnaire’s disease with air washers, wetted media evaporative air coolers/humidifiers, or steam humidifiers. A supermarket vegetable misting device using water from a holding tank was implicated in one outbreak of Legionnaires’ Disease. There is a documented case of Legionnaires’ Disease that occurred in a hospital setting and resulted from aerosolized tap water from a humidifier.

9. **INDIRECT EVAPORATIVE AIR COOLERS**

Indirect evaporative air coolers cool air in a heat exchanger, which transfers heat to a secondary airstream as shown in Figure 6. Although the primary air is cooled by the evaporatively cooled secondary air, no moisture is added to the primary air.

9.1 **System Description**

The heat exchanger is cooled by evaporation of water utilizing one of several methods:

1. direct wetting of the heat exchanger surface
2. cooling of secondary air utilizing evaporative cooling media
3. atomizing spray into secondary airstream or onto heat exchanger surface
4. cooling tower and coil.

![Figure 6](https://example.com/figure6.png)  
*Figure 6  Indirect evaporative cooler.*
9.2 System Operation

9.2.1 Temperature. The recirculated water temperature approximates the wet-bulb temperature of the secondary airstream. As is the case with direct evaporative air coolers, it is unlikely that the water temperature will exceed 25°C (77°F).

9.3 Water Droplet Size

Water droplet size will vary with exchanger type, condition of the media and mist eliminators (where used), air velocity through the unit, and other factors. Refer to the section of this guideline regarding specific exchanger type, i.e., cooling towers, misters, etc.

9.4 Nutrients

See 7.4 for equipment using a cooling tower to cool the secondary airstream and 8.4 for equipment using evaporative coolers or misters to cool the secondary airstream.

9.5 Recommended Treatment

See 7.6 for equipment using a cooling tower to cool the secondary airstream and 8.5 for equipment using evaporative coolers or misters to cool the secondary airstream.

9.6 Siting

Indirect evaporative air coolers should not be located near the outlet of a cooling tower, fluid cooler, evaporative condenser, kitchen exhaust, paint booth, incinerator, or any other source of organic matter.

9.7 Associated Cases

There has been no positive association of Legionnaires’ disease with indirect evaporative air coolers.

10. METALWORKING SYSTEMS

10.1 System Description

In these systems, metalworking fluids are applied to cutting surfaces for lubrication and to prevent overheating of both the machine tool and the machined part.

10.2 System Operation

Both oil-based and water-based fluids are used. A variety of such fluids are commercially available from many companies.

As a rule, microbial growth does not occur in oil-based products. However, water-based fluids do become contaminated by microorganisms.

10.2.1 Temperature. As the fluids cool the machine tool and machined part, they become heated and the ambient temperature of the fluid sumps ranges between 24° and 32°C (75°F and 90°F), permitting the growth of many pathogens including Legionella species.

10.3 Water Droplet Size

These systems can produce droplets of varying size depending on the specific machining operation and have the potential to produce droplets less than 5 micrometers in size.

10.4 Nutrients

These systems are typically open and subject to contamination from the air and surfaces that are being machined.

10.5 Associated Cases of Legionnaires’ Disease

Metalworking systems have been implicated in the outbreak of Pontiac fever as well as acute respiratory syndrome and hypersensitivity pneumonitis. 45

10.6 Recommended Treatment

Exposures from metalworking operations can be a serious potential health concern, the magnitude of which is not fully understood. Biocides are supplied with fluid concentrates, which are diluted when used and/or added to the fluid reservoir. However, the variety of fluids, microbial types, turnover rate, and metal operations makes successful dosing not always predictable. Selections of biocides should be based on fluids and microbes being treated.

It is recommended that care be taken to minimize contamination and to reduce exposure to machine operators until further information is available.

11. MONITORING FOR LEGIONELLA

Culturing for Legionella may be appropriate if carried out for a specific purpose, such as verifying the effectiveness of a water treatment protocol, tracing the source of an outbreak, evaluating the potential amplifier/transmission sources at a facility, verifying that the decontamination procedures have been effective, or in health care facilities caring for patients with exceedingly high risk of developing Legionnaires’ disease (e.g., organ transplant recipients). 46-48 Where culturing is performed, proper sampling, handling, and shipping methods should be used. 49

However, except as discussed in 5.6.1.5, routine culturing of samples from building water systems may not be predictive of the risk of transmission for the following reasons.

1. Presence of the organism cannot be directly equated to the risk of infection. The bacterium is frequently present in water systems without being associated with known cases of disease.

2. Interpretation of the results of culturing of water is confounded by use of different bacteriologic methods in various laboratories, by variable culture results among sites sampled within a water system, and by fluctuations in the concentration of Legionella isolated from a single site.

3. The risk of illness following exposure to a given source is influenced by a number of factors other than the concentration of organisms in a sample. These factors include, but are not limited to, strain virulence, host susceptibility, and how efficiently the organisms are aerosolized to the small particle size required to reach the deep portion of the human lung and remain viable.

4. Test results only represent the counts at the time the sample was collected. A negative result from such a sample is likely to lead to a false sense of security because any amplifier can quickly become heavily colonized if it suffers neglect. Testing is not a substitute for sound maintenance practices and water treatment.
12. REFERENCES


43Letter From ASHRAE TC 3.6 to the Centers for Disease Control and Prevention.


(This informative annex is not a part of this guideline and is for information purposes only.)

ANNEX A

BIBLIOGRAPHY


ASHRAE is concerned with the impact of its members' activities on both the indoor and outdoor environment. ASHRAE’s members will strive to minimize any possible deleterious effect on the indoor and outdoor environment of the systems and components in their responsibility while maximizing the beneficial effects these systems provide, consistent with accepted standards and the practical state of the art.

ASHRAE’s short-range goal is to ensure that the systems and components within its scope do not impact the indoor and outdoor environment to a greater extent than specified by the standards and guidelines as established by itself and other responsible bodies.

As an ongoing goal, ASHRAE will, through its Standards Committee and extensive technical committee structure, continue to generate up-to-date standards and guidelines where appropriate and adopt, recommend, and promote those new and revised standards developed by other responsible organizations.

Through its Handbook, appropriate chapters will contain up-to-date standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with respect to dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations that is pertinent, as guides to updating standards and guidelines.

The effects of the design and selection of equipment and systems will be considered within the scope of the system's intended use and expected misuse. The disposal of hazardous materials, if any, will also be considered.

ASHRAE’s primary concern for environmental impact will be at the site where equipment within ASHRAE’s scope operates. However, energy source selection and the possible environmental impact due to the energy source and energy transportation will be considered where possible. Recommendations concerning energy source selection should be made by its members.
COOLING TECHNOLOGY INSTITUTE

Legionellosis
Guideline: Best Practices for Control of Legionella

July 2006

CTI Guidelines WTP-148 (06)
Foreword

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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 2011.
Guideline: Best Practices for Control of Legionella

I. PURPOSE

The purpose of this guideline is to provide information and guidance in order to minimize Legionella in evaporative cooling water systems, specifically evaporative condensers, closed-circuit fluid coolers, and cooling towers.

II. SCOPE

This guideline provided specific environmental and operational guidelines that will contribute to the safe operation of cooling water systems to minimize the risk of occurrence of Legionellosis.

III. 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.

IV. 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.

V. 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.

VI. 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.

VII. 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**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Dipslides</th>
<th>Agar Pour Plate or Petrifilm</th>
<th>Microscopic Exam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planktonic Counts (Bulk Water)</td>
<td>&lt;10,000 CFU/mL</td>
<td>&lt;10,000 CFU/mL</td>
<td>No higher life forms</td>
</tr>
<tr>
<td>Sessile Counts (Surfaces)</td>
<td>&lt;100,000 CFU/cm²</td>
<td>&lt;100,000 CFU/cm²</td>
<td>No higher life forms</td>
</tr>
<tr>
<td>Deposits</td>
<td>NA</td>
<td>NA</td>
<td>No higher life forms</td>
</tr>
</tbody>
</table>

**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 bi dispersant/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.

**Other Treatment Approaches:**
Because of the interest in controlling Legionella, a number of products have been promoted as a control of Legionellosis in Cooling Systems. Some of them are electronic water treatment devices, material coatings and
bio-static components. At the date of this publication, there is little application data to support these approaches. While these technologies may have some benefit, they should not distract your attention from the key issues of:

- Eliminating stagnant water areas
- Eliminating controllable sources of nutrient to the Cooling Water system.
- Maintain overall system cleanliness and provide good biological control.
- Use the best technology in Drift Elimination (lowest drift rate).

**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.

**VIII. 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.

**IX. MECHANICAL DESIGN CONSIDERATIONS FOR MINIMIZING LEGIONNAIRE’S DISEASE**

Any new or retrofit tower or component design should include consideration of the issues discussed below.

**Drift Eliminators (DE)**

- State-of-the-art high-efficiency nesting type eliminators, if not already present to minimize drift mass flow, are suggested [reference CTI CTI-140].
- Tower designers should use these eliminators within their design air velocity requirements as set and tested by the manufacturer. Drift eliminators are intended to prevent escape of entrained water droplets that might contain LD bacteria from the tower.
Plenum
- Tower designers should avoid locally elevated exit air velocities at the eliminators, designing the plenum to maintain airflow within the tolerances of design throughout, particularly at the center of the eliminator bank in counterflow towers and at the upper portions of the eliminator bank in crossflow towers.
- Tower designers should supply effective eliminator air seals, covering all open area beyond the eliminators themselves. Small gaps allow elevated local velocities and can lead to substantial water droplet formation and leakage.
- Proper installation of the eliminators and air seals is critical to minimize the drift rate.

Water Distribution, Falling Water, and Fill
- Tower designers should provide distribution components to minimize the creation of very small droplets which are more likely to escape through the drift eliminators.
- Tower designers should provide distribution components to minimize masses of water at louver or eliminator locations that might by-pass air-seals allowing circulating water to enter the exit airstream.
- Tower designers should provide tower air inlet and rain zones that minimize splash-out and aerosol droplet creation.
- Tower designers should select the fill for proper air and water management to control the drift rate and splash-out.
- Fill selection should be based on expected water quality and treatment, to minimize fouling and poor water distribution of water that might encourage Legionella propagation.

Fan and Fan Cylinder
- Tower designers should provide fan cylinder seal integrity such that no extraneous water can make its way to the fan even if the hot water basin (HWB) overflows (crossflow towers).

Siting and Flow
- System design engineers should place cooling towers away from building air intakes in such a manner that cooling tower drift or splash-out is not fed into the building air supply system.
- The tower should be designed to provide good continuous water flow through and out of the tower to move water effectively. There should be no dead flow locations in the basins.
- System design engineers should provide discharge piping and equalizers to move water effectively with no dead flow locations. Special attention should be paid to equalizer piping to ensure these areas are not stagnant.

X. COOLING TOWER INSPECTIONS AND PHYSICAL MAINTENANCE

It is important to visually inspect the cooling tower frequently to maintain the tower and its components in good working order. During maintenance and inspection operations, plant safety procedures must always be followed. Organic fouling, dirt or debris must be removed. Defects in the components or their installation, which may lead to emission of excessive drift or spray, should be corrected.

Inspection should also be performed on the outside of the unit for general cleanliness, leaks, or any evidence of biomass. Pools of water or small droplets emanating from the tower may be a sign of excessive drift. The appearance of heavy deposits on the outside of the unit may be an indication of excessive water loss due to windage or other factors. During maintenance and inspection operations appropriate plant safety procedures should always be followed.

Water Treatment System
Inspect the water treatment system for proper operation of all components.

Louvers
Inspect louvers and surrounding area for biomass and scale. Louvers should be undamaged and positioned as designed to prevent spray from splashing or blowing out of the tower. Missing or damaged louvers should be replaced. Out of position louvers should be properly placed back in position, making sure retaining hardware is also correctly placed.

Piping dead legs
Inspect circulating water piping system for deadlegs. Any deadlegs which cannot be removed or replaced with a circulating line should be bled frequently. Bleed equalizer piping between adjacent cooling tower cells frequently.

Cold water basins
Inspect the cold water basin for build-up of organic matter, dirt, and debris. If any significant accumulation of debris or sludge is found, the accumulation should be removed.
If the tower is taken out of service, the basin should be cleaned.

Crossflow hot water basin
Leaks from the hot water basin that might lead to droplets becoming entrained in the air-stream should be
repaired. Missing or broken nozzles should be replaced. Basin covers that may be missing or broken should be replaced or repaired. Water overflowing the basin should be corrected.

**Counterflow spray system**
The spray system should be properly positioned and free of fouling. Missing nozzles should be replaced. Misaligned nozzles may spray water up into the eliminators and should be correctly re-positioned. Leaks at piping joints or nozzles that spray water into the eliminators should be repaired.

**Eliminators**
The eliminator system is critical for controlling the water droplets leaving the cooling tower. Drift eliminators should be inspected for build-up of organic and inorganic material and for deterioration or damage. Eliminators should be cleaned as needed. Missing or damaged eliminators should be replaced. Any gaps in or between eliminators or between eliminators and casing, structural elements, air seals, or plenum framework should be corrected.

**Fill**
Fill air entrance and exit surfaces should be thoroughly inspected. Evidence of fouling should lead to a more extensive inspection and review of water treatment and maintenance procedures. Damaged or deteriorated fill should be replaced.

**XI. 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.

**XII. ADDITIONAL INFORMATION SOURCES**
3. American Society of Heating Refrigerating and Air Conditioning Engineers, Inc. (ASHRAE); Atlanta, Georgia; Guidelines on Legionnaires’ Disease; 404-636-8400.
4. Control of Legionella in Cooling Towers - Summary Guidelines; Wisconsin Division of Health, August 1987; A copy of this document may be obtained from the Wisconsin Division of Health, Madison, WS 53701; 608-267-9003.
5. The Control of Legionellae by the Safe and Effective Operation of Cooling Systems; British Association of Chemical Specialties; Code of Practice Update; May 1995.
9. The Health and Safety Executive Guidance Notes on the Control of Legionellosis, HS(G) 70 Second Edition, October 1994. HMSO London UK. General inquiries regarding this publication should be addressed to the Health and Safety Executive at Library and Information Services, Broad Lane, Sheffield S3 7HQ; Telephone 0742752539.
10. Legionnaires’ Disease: The Control of *Legionella* Bacteria in Water Systems; Approved Code of Practice and Guidance; UK Health and Safety Commission and Executive; Nov 1999; HMSO books, London, UK. General inquiries should be addressed to the Library and Information Services, Broad Lane, Sheffield S3 7HQ; telephone (0742) 752539.
11. *Legionella* - Current Status and Emerging Perspectives. James M. Barbaree, Robert F.
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16. Prevention and Control of Legionnaires’ Disease; Worksafe Western Australia; Oct 1995.

17. Australian/ New Zealand Standard; Waters-Examination for Legionella Including Legionella pneumophila; Revised AS 3896; Draft 15 Jan 1997.

