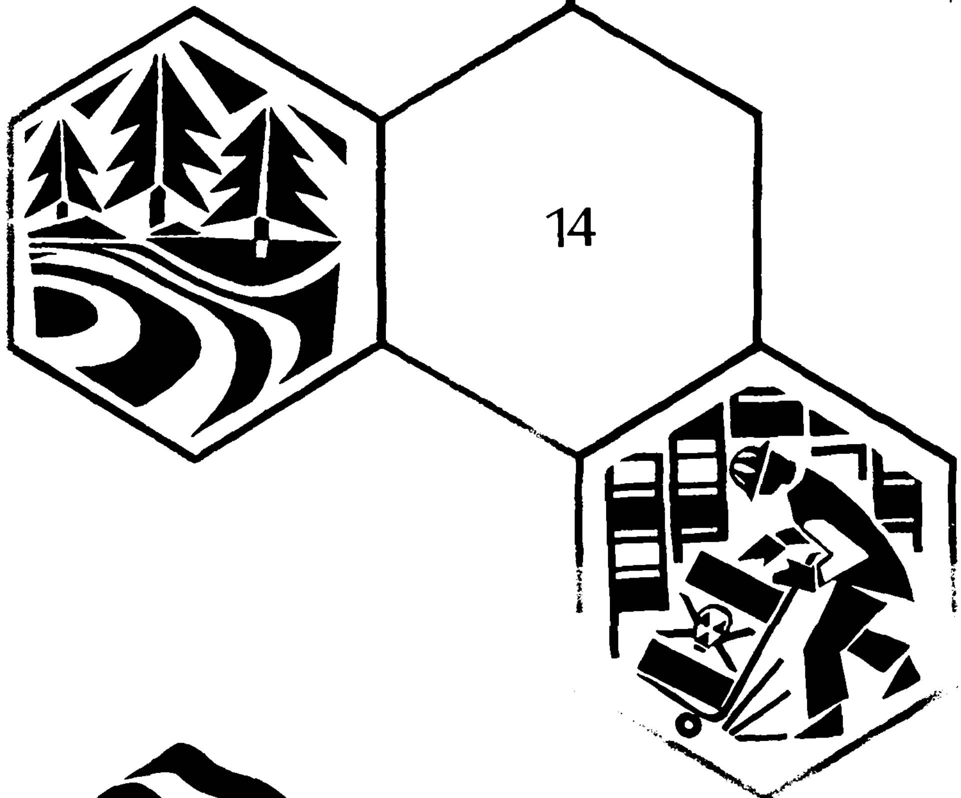
ENVIRONMENTAL HEALTH



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Environmental Aspects of the Control of Legionellosis

WORLD HEALTH ORGANIZATION
Regional Office for Europe
Copenhagen

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ENVIRONMENTAL ASPECTS OF THE CONTROL OF LEGIONELLOSIS

Report on a WHO meeting

Copenhagen
30 September – 4 October 1985

WORLD HEALTH ORGANIZATION
Regional Office for Europe
COPENHAGEN
1986

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FOREWORD

In the framework of the WHO European health strategy, a set of 38 targets has been endorsed by the Member States of the Region. Target 24 relates to the indoor environment and states that "By the year 2000, all people of the Region should have a better opportunity of living in houses and settlements which provide a healthy and safe environment".

There is a concern about health hazards from indoor air pollutants emanating from building materials, furnishings and fittings, which have become of greater significance during the last decade because of the "tightening" of buildings in the interests of energy saving and the introduction of new materials containing potentially harmful chemicals. These problems are being addressed by the ongoing activities of the WHO Regional Office for Europe in indoor air climate and quality.

This volume deals with the transmission of diseases, particularly legionellosis, through mechanical ventilation, air conditioning and heating systems.

The bacteriological, chemical and epidemiological aspects of this disease were reviewed by a WHO meeting in 1981. The meeting described here focused on the practical aspects of legionellosis control, linked to the proper design, operation and maintenance of technical facilities such as air conditioners and domestic hot water supply.

The report is primarily intended for those involved with the design and management of such facilities in buildings, together with their surveillance and control in relation to public health. I hope that it will provide useful guidance in this important field.

J.I. Waddington
Director, Environmental
Health Service

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INTRODUCTION

Twelve participants from six countries, including epidemiologists, bacteriologists and building services engineers, and representatives of the American Society of Heating, Refrigerating and Air Conditioning Systems, International Building Council for Research, Study and Documentation, and the European Heating and Ventilating Associations (Annex 1) attended the meeting which reviewed the epidemiological evidence for the transmission of legionellosis by air-conditioning systems, cooling towers and domestic hot water systems. The meeting focused on the engineering aspects of the control of legionellosis in relation to the design, operation, maintenance and monitoring of cooling towers, domestic hot water systems, cold water systems, hot/cold taps and showers, rubber fittings, air-conditioning systems and home humidifiers. Biocides and disinfection, as well as epidemiological needs, were also extensively discussed. The need to monitor these systems in such buildings as hospitals, hotels and offices was also considered. The Working Group started by referring to the WHO publication Legionnaires' disease [1], which reviews the medical aspects of the disease, and concluded by recommending measures that could be taken to reduce the risk of infection.

Dr B. Velimirovic was elected Chairman and Dr R. Good Vice-Chairman. Professor J. Stolwijk acted as Rapporteur.

Legionellosis, caused by *Legionella* spp., comprises two distinct but related illnesses: Legionnaires' disease, an infection of the lower lung, and Pontiac fever, an influenza-like disease without pulmonary involvement.

Legionnaires' disease accounts for only a small proportion of all reported cases of pneumonia, though the rate of infection is higher in men over 50 years of age. Numerous outbreaks have appeared in recent years all over Europe, North America and North Africa, mainly in hospitals and hotels but also less often in other buildings. The milder Pontiac fever has not been directly responsible for deaths.

EPIDEMIOLOGY

Microorganisms are ubiquitous in indoor air but very little is known about the adverse effects of human exposure to them. In 1979, a WHO Working Group on Health Aspects related to Indoor Air Quality recommended that studies on the effects of ventilation rates on transmission of infectious diseases should be encouraged [2].

Since the spread of climatization installations with air-handling systems in public buildings, schools, offices, shipping centres, hotels and hospitals, there have been numerous reports of disease outbreaks in which air-handling systems were implicated. These diseases have been published under various headings: humidifier fever, air conditioner disease, allergic hypersensitivity pneumonitis in atopic individuals, bronchospasms caused by spores of thermophilic Actinomycetales [3-5], tracheitis, common cold and pneumonias associated with forced-air heating, humidification and ventilation in offices [6] or cooling with a car air conditioner [7].

Air supply and exhaust ducts, grills, diffusers [8], humidifiers [9-12], heating coils [13], cooling water apparatus [8,14], room air conditioners [5,15-17], inhalation therapy equipment [16-18], nebulizers [19-21], cold steam vaporizers [22,23], and paediatric mist tents [24] have all proven to be capable of supporting the growth and dissemination of bacterial and fungal pathogens. The various pathogens have included *Bacillus subtilis* [25], *Pseudonomas* spp. [26-28], *Staphylococcus* spp. [23,28,29], *Mycoplasma* spp. [30], Adenovirus type 4 [31], *Rhinovirus* spp. [32] and measles [33].

Mechanisms of various respiratory illnesses and their environmental variables were comprehensively reviewed by Zeterberg in 1973 [30]. An outbreak of measles pointed to the need to pay more attention to this problem. In 1979, measles were spread throughout a school near Rochester, New York, by a ventilation system that used recirculated air from the same room as the index case [33].

Increased attention has focused on environmental conditioning devices since the identification of *Legionella pneumophila*. In 1976, an explosive epidemic of pneumonia occurred among people attending the annual American Legion meeting in Philadelphia, Pennsylvania. Epidemiological investigation of this outbreak implicated an indoor environmental exposure. Opinion has been expressed that human manipulation of the environment and new technology have facilitated the transmission of legionellosis [34].

LEGIONELLOSIS

In the course of investigation of the well-known 1976 Philadelphia outbreak of respiratory disease, *L. pneumophila* was isolated originally from specimens from patients. *L. pneumophila* also has been retrospectively identified as the cause of illnesses associated with a 1965 epidemic at St. Elizabeth's Hospital in Washington, DC [35], a 1968 epidemic in Pontiac, Michigan [36] and a

1974 epidemic at the Bellevue Stratford Hotel in Philadelphia [37], the same place where another outbreak occurred 2 years later. Based on serological studies, the disease can be traced as far back as 1943 [38].

L. pneumophila is widely distributed in nature and has been isolated from a range of aquatic sources including drinking water, water taps and shower heads, water in cooling towers and evaporative condensers, rivers and riparian soil. The development of a suitable culture medium and serological techniques (serogrouping and subtyping with monoclonal antibodies) has improved the knowledge of its epidemiological features, and several hundred reports on disease outbreaks have been obtained from different parts of the world. There are now 22 reported species with a total of 36 serogroups. Among these are at least 10 serogroups of *L. pneumophila*, two serogroups of *L. bozemanii* and *L. longbeachae* type 1 and 2. The epidemiological importance of new species is not completely known, and new strains or groups will likely be added in the future.

A summary of *Legionella*[1] outbreaks and the implicated environmental source is given in Table 1. The early outbreaks have relied on epidemiological information to determine the source of the organisms. However, culturing and serological techniques developed for *Legionella* have improved the ability to determine the environmental source. The use of monoclonal antibodies, as in the case of the outbreaks in Providence, Rhode Island [57], and in Paris, France [54], has confirmed one specific environmental source when multiple environmental sites were culture positive for *Legionella*.

Many sporadic cases as well as two major outbreaks have been associated with soil disturbances or excavation. The 1965 outbreak in Washington, DC [35] and the 1984 Connecticut outbreak [58] subsided when the excavation was stopped. However, *Legionella* is rarely isolated from terrestrial habitats. It may be that *Legionella* cannot be cultured from this habitat, and hence soil should be considered a potential reservoir.

Air-conditioning systems and cooling towers have been found to harbor *Legionella* and have been suspected of transmitting it through the indoor environment. Numerous publications on the association of legionellosis and *Legionella*-positive air-conditioning systems are on record. *L. pneumophila* appears to be well adapted for survival in water in evaporative condensers and cooling towers. The water in these units is commonly at 31-36°C, an ideal temperature for *Legionella* growth, and their operation

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[1] Throughout this report, *Legionella* either refers to the genus or indicates that the species was not specifically identified.

Table 1. *Legionella outbreaks and the implicated source by year*

Year	Site	Reference	Source	Confirmation*
1965	Washington, DC	[35]	Excavation	U
1968	Pontiac, MI	[36]	Evaporative condenser	U
1973	James River, VA	[39]	Steam turbine coolant	U
1976	Philadelphia, PA	[40]	Cooling system	U
1978	Bloomington, IN	[41]	Cooling tower	U
1978	Memphis, TN	[42]	Auxiliary cooling tower	S
1979	Atlanta, GA	[43]	Evaporative condenser	S
1979	Corby, UK	[44]	Hot and cold water	S
1979	Eau Clair, WI	[45]	Cooling tower	S
1979	Oxford, UK	[46]	Shower	S
1980	Adriatic, Italy	[47]	Hot water	S
1980	Burlington, VT	[48]	Cooling tower	S
1980	Chicago, IL	[49]	Jet nebulizer/room humidifier	S
1980	London, UK	[50]	Hot water system	S
1980	Los Angeles, CA	[51]	Drinking water	S
1980	San Francisco, CA	[52]	Cooling tower	S
1981	Burlington, VT	[53]	Whirlpool	S
1981	Paris, France	[54]	Hot water system	M
1982	Rochester, MI	[55]	Whirlpool	S
1982	Windsor, ON	[56]	Industrial coolant	S
1983	Providence, RI	[57]	Cooling tower	M
1984	Stamford, CT	[58]	Excavation	S
1985	Stafford, UK	[59]	Cooling tower	S

* U = Unconfirmed environmental source
S = Serologically confirmed environmental source
M = Serologically confirmed environmental source with monoclonal antibody.

concentrates organics that would serve as nutrients for further amplification of the *Legionella*.

Since the Second International Symposium on *Legionella* in Atlanta in 1983, emphasis had shifted from cooling tower exhaust to domestic water supplies as sources of infection. Most nosocomial cases in France were acquired in non-air-conditioned hospitals and often by patients too old or sick to take showers or even to enter the bathroom. High concentrations of legionellae have been demonstrated in tap water from hospitals with nosocomial cases, suggesting that drinking *Legionella*-contaminated water may be a hazard.

In spite of hundreds of published reports and an impressive body of knowledge which has accumulated over the last years, the whole epidemiological story of legionellosis is not yet complete. *Legionella* can grow and survive in a wide range of habitats and remain active at elevated temperatures, low oxygen tension and a wide range of pH values. Demonstration of *Legionella* as an ubiquitous group of organisms simultaneously present in different systems in a building makes the causal proof of transmission more complicated.

The epidemiological evidence for air-conditioning systems (via aerosol) is based on temporal and geographical associations, consistent and specific associations with a contaminated *Legionella* source and intervention (disinfection) that ends the outbreak. However, hospital investigations have showed in many of the nosocomial Legionnaires' disease outbreaks that the hot and cold water system was another important reservoir.

In these outbreaks, microbial density may have a role, since most nosocomial cases of Legionnaires' disease attributed to tap water have involved systems in which quantitative cultures of tapwater and hot water tank sediment have yielded 10^5-10^9 organics/1 [60]. Conditions which favour the colonization of cooling systems also favour the colonization of hot water systems. The hot water system has many potential reservoirs, such as hot water storage tanks, showerheads and other outlets, and these sites have stagnation temperatures between 20 and 45°C.

What all of these forms of apparatus have in common is the capability to generate aerosols. The infection capacity of aerosols depends on their size. Droplets smaller than 1 um are too small to contain *Legionella*. Small droplets of about 6 um will penetrate alveoli, and those larger than 6 um will cause tracheobronchial deposition within the respiratory system. The fall velocity of droplet nuclei is only a few centimeters per minute. Thus, even a small amount of air turbulence in the room can hold droplet nuclei in the air for a long time.

Under laboratory conditions, airborne transmission of *Legionella* has been shown to occur in mice and guinea pigs [61].

However, it has never been shown that airborne spread can occur directly from animal to animal [62].

How does *L. pneumophila* spread from natural waters and how does it enter the piped water system? With the exception of a few outbreaks where hotels used additional water from a well, all the implicated water generally came from a municipal water system. It has been proposed that the bacterium is protected in transit within other organisms such as free-living amoebae [63] and ciliated protozoa [64]. Cysts of amoebae are not killed by chlorine and would survive water treatment procedures. Freshwater amoebae and *Legionella* are frequently found in similar aquatic habitats. Infected amoebae could perhaps provide a reservoir for the *Legionella*.

The biology of *Legionella* at this point does not yet lead to a specific, biologically-based prescription for its control. Control measures are still based on experiences in outbreaks. Engineering results and experiences are discussed in the next section.

ENGINEERING FINDINGS

Legionella has been responsible for a number of pneumonia outbreaks and explosive acute upper respiratory episodes. It is likely that within health care institutions, individual cases of Legionnaires' disease would be investigated and the active agent for such a disease would be identified by the clinical laboratories in such institutions. This process would likely cause a bias, with an exaggerated implication of health care institutions and an under-representation of residential environments in which individual cases could escape identification as legionellosis.

Investigations of legionellosis outbreaks report findings quite specific to the particular case studied, and there is not yet a standardized approach recognizable for such investigations or for the reports which issue from such investigations. Although patterns are beginning to be discernable, they are by no means well established.

Several cases show indications that more than one source of *Legionella* is possible in a given building [48,54,57]. Therefore, unless the investigation includes serotyping or monoclonal antibody typing of isolates from patients, as well as isolates from all possible environmental sources, it is difficult to be absolutely certain of the actual source of the infection. Under other circumstances a reservoir may be identified in the building system, but the mode of dissemination to the patients is either not documented or cannot be determined [59].

The velocity and the direction of air flow in a building can vary substantially, depending on thermal gradients, pressure differences created by wind pressure or stack effects. As a result, the dissemination of airborne *Legionella* may occur only under special circumstances which escape consideration in an evaluation of "normal" operating conditions.

Often the *Legionella* in the reservoir exists in an environment in which many other species occur at much higher concentrations. Current environmental detection methods are not adequate for isolating *Legionella* in samples with such high background bacterial densities. This has made the assessment of *Legionella* in such environmental sources qualitative at best.

This problem in detection and association can be further amplified by the fact that the host susceptibility to infection is highly variable from person to person, which may then lead to different outcomes, even though there are no differences in the characteristics of the building and its systems.

Cooling towers

In a larger air-conditioning system or refrigeration system utilizing one or more compressor systems, heat is removed from the air-conditioned or refrigerated space, or other refrigerating equipment. This heat must be rejected to the ambient environment. Through various steps, this heat will appear at the condenser side of the compressor system. In small systems this heat is then carried off by cooling the condenser with ambient air.

In larger systems the heat is usually carried off by water flowing through a heat exchanger. If a large water supply at suitable temperatures is available, such as in groundwater, a river or a lake, the heated water can be returned to the source. More commonly, the heated water is cooled in a cooling tower before being returned to the condenser.

In most cooling towers the heated water is sprayed into a large chamber and through suitable fan systems mixed with a large supply of outdoor air. The water spray droplets lose heat through evaporation and through convective and conductive heat exchange with the cooling air. The cooled water spray is collected at the bottom of the cooling tower and pumped back to the condenser. The air is discharged to the environment at an elevated temperature and at a higher dew point because of the partial evaporation of the spray. This description is for a wet-type heat rejection unit (WTHRU). It is possible to accomplish the same heat rejection in a closed system in which the water passes through a water-to-air heat exchanger, referred to as a dry-type heat rejection unit (DTHRU). Such systems are more costly to construct and operate for the same level of heat rejection than are WTHRUs, and are therefore not in wide use. DTHRUs have not been reported to be associated with the multiplication and spread of *Legionella*, probably because dry environments would be extremely unlikely to ever have a role in the dissemination of *Legionella*.

A cooling tower, because of its operation, is characterized by a number of attributes which are favourable for the initiation and support of microbial growth. The elevated temperature of the water spray and the air flowing through it and the high dew point create a favourable environment for growth. The high volume of air which is taken in for cooling purposes is scavenged by the water spray. A high proportion of the viable particles and organic debris carried in the air stream will end up in the water and on the interior structures of the cooling tower, thus supplying a continuous inoculum and a source of nutrients. If no effective control is instituted, a cooling tower can harbor very large reservoirs of microorganisms. Although the design of a cooling tower attempts to limit to a minimum the number of water droplets which leave the tower with the exhaust air stream, a certain amount of this "drift" will leave the cooling tower as small water droplets, which will carry with them some of the microbial life present in the tower.

Water aerosols from cooling towers have been implicated in a number of legionellosis outbreaks [36,40,42,43,45,48,52,56], and *Legionella* spp. can often be identified as multiplying in cooling towers. In some or many locations cooling towers may be the most important amplifiers and distributors of airborne *Legionella*. In many of these outbreaks, the placement of cooling towers and air intakes for building ventilation systems was arranged such that the likelihood of introducing cooling tower drift into the building ventilation system was not minimized.

The control of microbial growth in cooling towers with WTHRUs is not only important in preventing the culture and spread of pathogenic organisms into the community but is also necessary to assure the continued effective operation of the cooling tower.

A number of methods are in use to control, reduce or eliminate microbial growth in cooling towers with WTHRUs. Perhaps the most common is the chlorination of the circulating water. Continuous chlorination to a level of 2-4 ppm of dissolved chlorine appears to be effective in eliminating microbial growth. However, that level of chlorination could be highly corrosive to many cooling tower components and is therefore not likely to be maintained on a continuous basis. Hyperchlorination at intervals adequate to control both microbial growth and formation of slime, which can support such growth and protect it from subsequent chlorination, is a common intermediate strategy. Recommended maintenance procedures for cooling towers should include hyperchlorination treatments (to a level of 15 ppm, pH should be kept below 7, with circulation for 2 h followed by draining and refilling), and thorough cleaning of surfaces and components to remove all scale and sludge.

The temperature of the cooling water in towers has important consequences for the growth rate of microbial organisms; optimum growth is around 36°C. Although system and load characteristics may not permit a change in the operating temperature of cooling tower water, it could be considered as one of the possible strategies for reducing microbial growth. At temperatures above 55°C, microbial growth in cooling towers can be expected to be substantially curtailed.

It is of considerable importance that all cooling tower components are easily accessible for regular surveillance and cleaning if required. If the preventive biocidal treatment of the environment should be ineffective at any time, the ability to recover the system by thorough inspection and maintenance is crucially dependent on easy access.

The spread of any *Legionella* species cultured in a cooling tower would also be diminished if the amount of water aerosol drift from the cooling tower could be reduced or eliminated. In systems serving health care institutions with susceptible populations, it is especially important to design the relative location of cooling towers and air-conditioning, air-intake systems so that the drift from the cooling tower would have a low likelihood of being drawn into the outdoor air intake. As a guideline it could be suggested that to avoid horizontal spread, no air intakes be located closer than 20 times the square root of the total exit area of a cooling tower. To avoid intake of drift from a tower on the roof of a building with air intakes, the exit from the tower should be above the roof at a height at least equal to the square root of the roof area. Once aerosolized, the viability of *Legionella* depends on the relative humidity, with maximum survival at 65% relative humidity. At that humidity a 10% survival has been reported after 2 h [65].

Domestic or institutional hot water systems

As our experience with and understanding of *Legionella* increases, it is becoming more and more obvious that hot water distribution systems, especially in Western Europe, are more often implicated in outbreaks of legionellosis than cooling towers. This could be due to the relatively lower prevalence of air-conditioning and WTHRUs in Western Europe as compared with the United States where the original major outbreaks of legionellosis were encountered and diagnosed.

It is not surprising that a majority of sites where *Legionella* has been detected in water distribution systems involve health care institutions. Such institutions have among their occupants people with diminished ability to fight off infections, and they tend to contain personnel and laboratories able to detect and identify pathogens in patients and in the environment.

Much less is known about the prevalence of *Legionella* in domestic hot water supplies in the residential or commercial environment, but there is little reason to expect it to be lower than in the hospital environment. When samples of the water distribution systems in such buildings are evaluated, *Legionella* spp. have been reported in a substantial fraction of the samples, especially in samples taken from hot water distribution systems [66]. *Legionella* can be found in domestic hot and cold water supplies [60]. Its presence is not always associated with sporadic, endemic or epidemic legionellosis.

As *Legionella* also can simultaneously be found in thermally altered water associated with air-conditioning and humidification systems, causation of legionellosis by *Legionella* in drinking water is often difficult to show. Evidence for legionellosis from drinking-water sources consists of cases found where the drinking water is the only source [44,46,67,68], and of cases in which the outbreak occurs after repairs, pressure changes, changes in water colour, etc [51]. Legionellosis often has been reported to cease to occur after contaminated systems were hyperchlorinated or after the water temperature in a hot water system was elevated [50,69]. In many cases, monoclonal antibody typing [50,70], plasmid analysis or matching of antigenic profiles in immunoelectrophoresis [71,72] have allowed definite connections to be established. *Legionella* spp. are more frequently isolated from hot water systems than from other parts of the distribution system.

Water taps, shower heads and especially hot water tanks have yielded cultures [46,50,54].

Humidifiers and nebulizers are another category of reservoirs of *Legionella* which are effective disseminators [49]. Similarly, swimming pools and whirlpools have been found to be contaminated with *Legionella* [53,55] and involved in the causation of legionellosis.

The source of *Legionella* in potable water supplies is not clearly identified. Tison & Seidler [73] found large numbers of non-viable *Legionella* in potable water, which were reduced by chlorination.

After thermal alteration or under conditions of stagnation, such bacteria might become viable. *Legionella* spp. are apparently more resistant to chlorine than *E. coli* [74,75], so that drinking water which is considered bacteriologically potable may contain *Legionella* that can multiply in thermally altered sites. *Legionella* species have been isolated from water at a range of temperatures, but optimal growth is limited to 30-50°C [76,78]. Lethal temperatures have been reported at above 55°C [79,80]. Electric water heaters appear to become contaminated more often than gas-fueled hot water heaters in which contaminated sediments are in direct contact with the hottest surfaces, thus assuring higher temperatures in the sediments which are the most likely medium.

ENVIRONMENTAL ASPECTS OF CONTROL OF LEGIONELLOSIS

Although the biology and ecology of *Legionella* are not adequately known to suggest firmly based control measures, a number of recommendations follow from the accumulated experience with *Legionella* in potable water systems. The principal control measures involve chlorination to 2 mg/l at all times, hyperchlorination to as high as 15 mg/l to regain control of a contaminated system and avoidance of system water temperatures which promote *Legionella* growth.

Water should preferably be heated to temperatures above 55°C, and no part of the hot water system should be allowed to be at 35–45°C for long periods. Cold water distribution systems or parts thereof should not be allowed to rise above 20°C in order to discourage *Legionella* development or growth.

In the design of new installations or the modification of existing systems, the following design guidelines should prevent the occurrence of *Legionella* contamination of the water distribution system:

1. The controls of heating tanks should be set at 50°C or higher to assure that no part of the system right up to the exit point of use falls below 50°C.

2. Rubber parts and other materials which support microbiological activity should be avoided.

3. All runs should be straight-through, without loops or stagnant volumes.

4. If chlorination is used in the hot water system, 1.5–2 mg/l of chlorine should be present at all times.

If a single case of legionellosis occurs in association with an existing building and installation, no monitoring for *Legionella* should be instituted but the design and operating practices, especially with respect to chlorination and water temperature, should be checked carefully.

If more than one case of legionellosis occurs, attempts must be made to identify possible sources by appropriate monitoring and control measures must be taken. Contamination has been successfully controlled with the following sequence of steps, all designed to eliminate the existing contamination and to prevent its recurrence. To prevent recurrence, these practices should be made permanent:

1. All cold water and all cold water storage should be kept chlorinated so that all water delivered at any outlet contains 1-2 ppm of free residual chlorine at all times.

2. Any cold water storage tanks should be inspected and cleaned at least on an annual basis. They should be kept at a temperature below 20°C and, if necessary, water temperature near the top of the tank should be monitored. Pressurized vessels can be sterilized by hyperchlorinating at 20 ppm or above for at least 2 h, draining and refilling.

3. Hot water supplies and hot water storage tanks should have all the water at temperature limits between 55 and 60°C. If scalding is a risk, warning signs need to be placed near hot water outlets.

4. Once a year, all hot and cold water outlets in a system, including thermostatic mixing valves, should be tested and a log maintained. Cold water outlets should be tested for chlorination and demonstrate 1-2 ppm of free chlorine within 2 min of running. Hot water supplies should demonstrate temperatures of 55-60°C within 2 min. All mixing valves, shower heads and aerating taps should be run hot for 1 min, followed by cold for 1 min, after which the water should contain between 1 and 2 ppm of chlorine.

5. A system should be adopted in which each shower in the building is to be run at least once each week, 2 min with hot water, followed by 3 min of cold chlorinated water. Unused or seldom-used taps and showers should be considered for removal.

6. If a room, part of a building or a whole building has been unoccupied for a period of time, re-occupancy should be allowed until a full test of the hot and cold water system has been carried out with satisfactory results.

7. Hot water heaters and storage tanks should be sterilized by pasteurization (raising temperatures to above 70°C and letting cool before draining) or hyperchlorination (at 20-30 ppm of free chlorine for 24 h before draining).

Humidifiers

Few reports of legionellosis are associated with the use of humidifiers. Nevertheless, humidifiers in ventilation systems which are based on air washing, or humidifiers which are based on spinning discs or ultrasonic nebulizers are capable of being very efficient disseminators of any *Legionella sp.* which might be present in the humidifier or in the feed water. On the other hand, humidifiers which are based on the release of steam into the air stream are thought to offer no such risk. Biocides should be used only during cleaning.

Evaporative coolers which are used in dry, hot climates to reduce dry bulb temperatures of the circulating air can also be a source of aerosolized *Legionella*, especially if air velocities are high enough to induce aerosolization.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. Legionellae are ubiquitous bacteria found in both natural and treated waters. Currently, 22 species and 36 serogroups are recognized. Each species (and serogroup) is potentially a cause of legionellosis.

2. The bacteria will not grow below 20°C. From 25 to 45°C, they will grow on culture media. The optimum temperature is 37°C under laboratory conditions, and the presence of algae, sludge and slight acidity appear to favour their growth in natural water. Above 60°C, legionellae are not viable.

3. The bacteria are known to be inhaled from aerosols containing droplets 1-5 um in diameter.

4. *Legionella* spp. cause legionellosis, which may be expressed as pneumonia (Legionnaires' disease) or as a milder influenza-like disease (Pontiac fever).

5. There is epidemiological evidence that *L. pneumophila* may be transmitted through the aerosol formed by taps, shower heads and the mist formed by cooling towers.

6. In some cases *L. pneumophila* contamination occurs through the make-up water added to cooling towers. However, it may be possible that the bacterium is passively collected from the air. The fact that the bacterium is found in an air-conditioning system, cooling tower or evaporative condenser does not indicate per se that the air-conditioning system is responsible for transmitting the disease. No association has been found between legionellosis and air-conditioning systems that have no cooling towers or evaporative condensers. It is not yet possible to take effective action to eliminate totally all risks of an outbreak of legionellosis.

ENVIRONMENTAL ASPECTS OF CONTROL OF LEGIONELLOSIS

Recommendations

1. Evidence of epidemiological connections between acute respiratory disease and environmental conditions should be kept up to date. A bibliography of reports on the subject should be distributed annually.

2. Regular testing of water systems for legionellae should not be done, since present methods do not indicate the significance of finding these ubiquitous bacteria.

3. Cooling towers, evaporative condensers, and hot and cold water systems should be kept as free as possible from slime, sludge, scale and other deposits. They should be regularly inspected and serviced on a fixed schedule.

4. Water-operated humidifiers in air-handling plants have not yet been associated with outbreaks of legionellosis, presumably because the operating temperature is too low. For better economy and safety, they should be used only where essential and kept scrupulously clean.

5. Room humidifiers have been associated with legionellosis, and their use should be limited as far as possible. When needed, only equipment that does not produce aerosols and that allows easy cleaning should be used.

6. Steam humidifiers should always be used to serve high-risk areas in hospitals and similar institutions.

7. Air washers have not yet been associated with outbreaks of legionellosis. Nevertheless, they should be regularly maintained and kept in good condition to avoid any risk.

8. Unused or infrequently used air-handling equipment should be removed or modified to avoid stagnant water which bacteria could inhabit.

9. Adequate space should be provided to ensure that good maintenance and easy cleaning of plant and equipment are possible.

10. All connections from air-handling units and cooler batteries to drainage systems should be individual traps and air breaks.

11. Water should be stored at not less than 60°C and distributed at not less than 50°C. However, for special types of user, it may be necessary to reduce hot water tap temperatures to about

40–45°C. This should be done by local thermostatic mixer valves to avoid water being held for any time at temperatures that will encourage the growth of *L. pneumophila*.

12. Showers should be developed that do not hold any residual water at temperatures of less than 50°C after use.

13. Detailed operating and maintenance instructions should be provided by the manufacturer with every cooling tower/evaporative condenser installation. Such instructions should be strictly followed by the operator.

14. Advice on appropriate water treatment should always be sought by the operator from specialists and followed for all cooling towers and evaporative condensers.

15. Cold water pipes and tanks should be lagged (insulated) and kept as cool as practicable, away from hot pipes and heating systems.

16. Each outbreak of legionellosis should be investigated to identify the source so that speedy and accurate control measures can be taken.

17. When an outbreak of legionellosis occurs and contamination through cooling towers or water tanks is suspected, the following action should be taken:

    (a) Drain down and wash out mechanical equipment while avoiding production of aerosols. Cleaning procedures should be carried out by personnel wearing suitable masks. Cleaning should include filters and ion-exchange units.

    (b) Refill and chlorinate with 5–10 ppm of free residual chlorine for 48 h. Comparator measurements give an acceptable level of accuracy for the measurement of chlorine for this purpose. Check for disappearance of legionellae.

    (c) Thoroughly flush the equipment and fill with fresh water containing 1.5 to 2.0 ppm of free residual chlorine.

Further research

Methods should be developed for the quantification of legionellae in the environment and for evaluating their pathogenic potential. Steps should be taken to alter the environment so *Legionella* spp. will not grow.

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