

OVERVIEW OF LEGIONELLA BACTERIA INFECTION; CONTROL AND TREATMENT METHODS

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ABSTRACT

Since the first recognized outbreak of Legionnaires' disease (LD) in 1976, it has become an increasing problem around the world especially in poor countries. Legionella (L) causes an estimated 15,000 annual cases of pneumonia in USA, and leads to death in about 20% of the cases. L is found worldwide in both natural and artificial environments e.g. spa pools, cooling towers. It infects people by inhaled contaminated aerosols that can transmit several km. The optimal temperature for L growth is 20-45C. Control of L is therefore an important health issue. Many treatment methods are used; biocides, ionisation, ozone, UV-radiation, pressure, and thermal treatment. Only thermal treatment can completely eliminate L, which is killed almost instantly at 70C. Current paper gives an overview of the Legionella problem and treatment methods.

1. INTRODUCTION

Substandard water associated with the presence of bacteria called Legionella (L) is one of the major sources of infection diseases around the world. L bacteria (LB), which emerged in 1976 (Diederer, 2007), causes Legionnaires' disease (LD) (pneumonic legionellosis) and Pontiac fever (Kima et al., 2002), is identified as a collection of infections. Consequently L is known as one of tropical diseases spread through 'global warming' (Monckton, 2007) i.e. due to the human alteration of the environment (Bartram et al., 2007). It is considered responsible for epidemic and sporadic cases of pneumonia (Diederer, 2007 and Cloud et al., 2000) especially during summer and autumn because warm weather encourages proliferation of the bacteria in water. LD is normally acquired by inhalation of L from a contaminated environmental source (Borella et al., 20004 and Majid et al., 2007). L may be free-living or living within amoebae and other protozoa or within biofilms (Desia et al. 1999 and Pond 2005). There are currently more than 50 known species of L, twenty separate species of these organisms occur in the respiratory tract (Diederer, 2007, Bartram et al., 2007 and Cloud et al., 2000).

L infection, see Fig 1, may occur directly from the environment to humans or by wound infections (Bartram et al., 2007 and Hoge et al., 1991) or even in buildings (hotels, hospitals, houses...) with municipal water (Donald, 2007). More than 50% of all houses using district heating systems were colonized by L, their significantly lower hot water temperature is

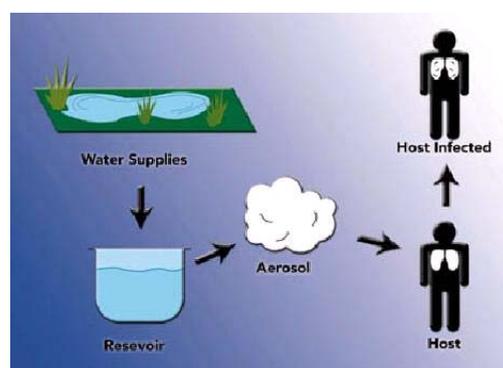


Fig.1. The cycle of infection with Legionella bacteria

thought to be the key factor leading to intensified growth of L (Mathys et al., 2007).

LD is not passed from person to person and does not occur by drinking water contaminated with LB. The risks occur when people inhale contaminated aerosols (Diederer, 2007, Brundrett, 2003, A.D.A.M, 1997 and Konishi et al., 2006). LB has been traced to contaminated aerosols generated at distances of up to 3.2km (Sartory et al., 2002). Particles of a size less than 5 µm can be deeply inhaled, and the individual could receive up to 1,000 or more LB at one time (Broadbent, 2003). This might happen during daily activities such as having a shower, toilet flushing. Humidifiers and nebulizers can also spread LB and have been reported as a source of infection in several cases (Bartram et al., 2007).

2. OCCURRENCE OF LEGIONELLA

LB can be found in both natural reservoirs such as water, soil and air see Fig 1, (Diederer, 2007, Hoge et al., 1991, EPA, 2001, Rathore, 2007 and Yi Yu et al., 2007). It occurs in artificial aquatic environments e.g. spa pools, hot tubs, hot water storage tanks, cooling towers, cold and hot-water distribution systems, potable water, and industrial processes and equipment.

LB can be free floating or preferably attached to surfaces. Bio-films are complex microbial communities which offer protection and provide essential growth requirements for L. So, biofilm prevention is an important control measure against proliferation of L because they are difficult to remove from complex piping systems. Biofilms offers poor biocide penetration and L in such surfaces are therefore difficult to control.

Cases of LD have been reported in North and South America, Asia, Australia, New Zealand, Europe, and Africa. More than 80% of reported cases are sporadic through the year, while the rest occur during the summer and early fall (Rathore, 2007). Fig 2 shows the increase in reported cases of LD (Ricketts et al., 2007). Low temperature heating systems at temperatures 40-45C offers an ideal situation LB growth.

3. MORTALITY AND SURVIVAL

The case–fatality rate is 5-30% but can be as high as 80 % depending on risk factors such as age, cigarette smoking, alcoholism, and cancer (BRE, 2003). LD can strike at any age; Fig 3 shows that LD tends to occur in the middle age and elderly though it is more common in over ages over 50 (Laurance, 2007). The LD infection rate is 2-3 times greater among men than for women (Desia et al. 1999 and Rathore, 2007).

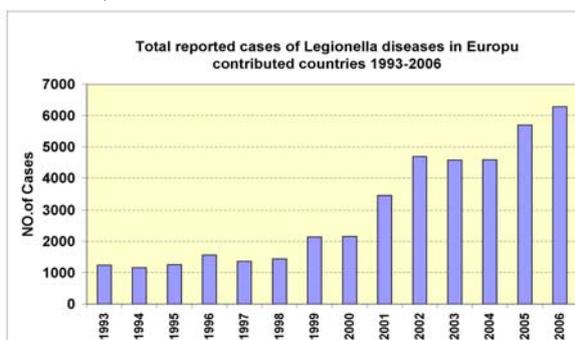


Figure 2. Total reported cases of Legionella diseases in contributed Europe countries 1993-2006

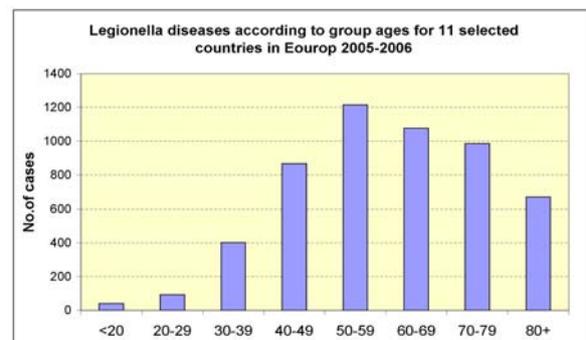


Figure 3. Legionella diseases according to group ages in 11 European countries 2005-2006

4. WATER TEMPERATURE AND LEGIONELLA GROWTH

LB proliferates and thrives in warm water and warm damp places (Bartram et al., 2007, Pond 2005 and Konishi et al., 2006). The temperature of the water is probably the most important or perhaps the only determinant factor for multiplication of L. Fig 4, (Diederer, 2007, Bartram et al., 2007, Mathys et al., 2007, Konishi et al., 2006, Rathore, 2007 and Cooke, 2004), shows that:

- The optimal growth temperature of LB is 20-45°C.
- LB is dormant below 20°C, but still alive.
- LB is completely killed at temperatures above 60°C (90% are killed within 2 min).

There is little or no growth of bacteria below 20 °C, but L will survive for long periods at low temperatures and proliferate when the temperature increases (Bartram et al., 2007). L is able to withstand temperatures of 50 °C for several hours though 90% are killed within 2 h (Cooke, 2004). At temperatures higher than 55°C there is a break point, but in some cases L strains have been isolated from hot-water systems up to 66 °C. However, at temperatures above 70°C they are destroyed almost instantly (Kima et al., 2002 and Bartram et al., 2007). Water systems are increasingly using water in the temperature range that enhances L growth. These systems can produce aerosols and thereby increasing spread of the LB. Fig 5 shows the high risks of LD outbreak in hot water systems at temperatures of 40-45, which are suitable for L multiply.

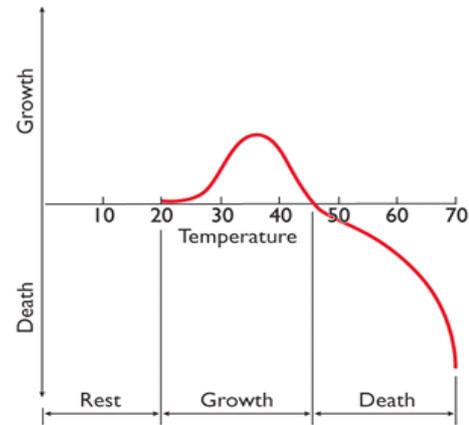


Figure 4. Influence of different temperatures on Legionella growth

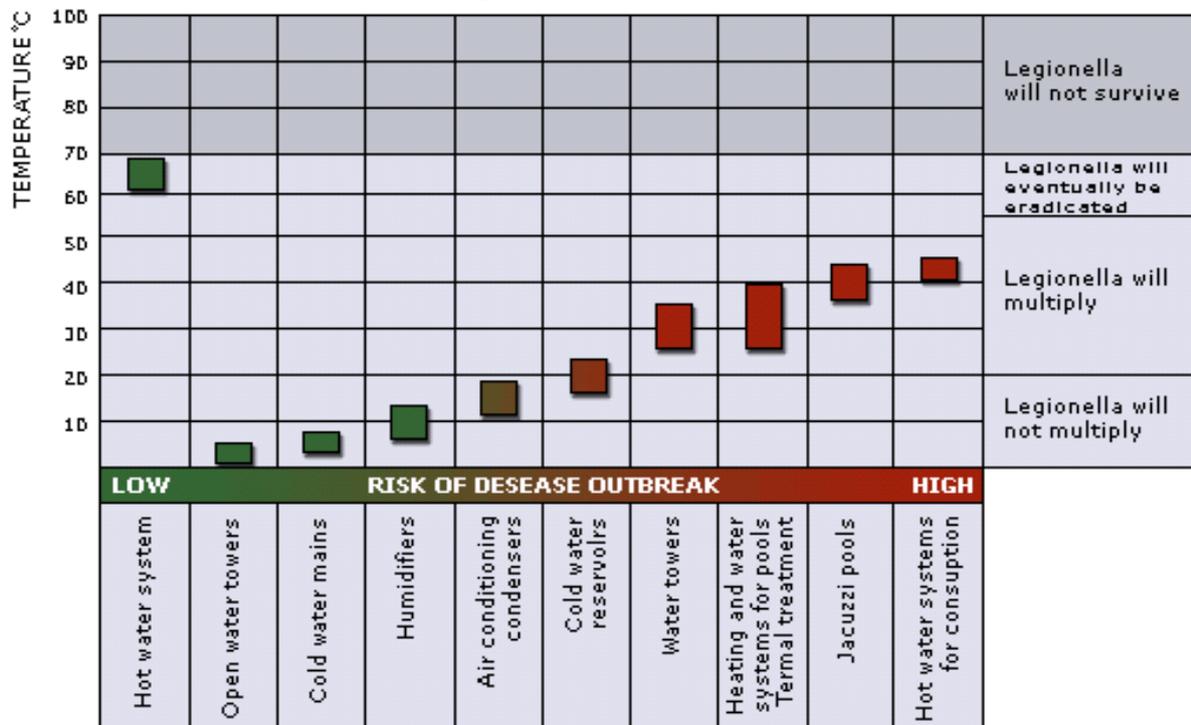


Figure 5. Influence of different Temperatures on the growth of or exposure to Legionella in many complex water systems

5. PREVENTION OF LEGIONELLA RISKS

Maintaining the temperature of hot and cold-water systems to prevent or minimize the growth of L is an important control measure to prevent the risk of L infection. Water systems should (Bartram et al., 2007):

- Avoid temperatures between 25-45 °C to prevent L colonization.
- Ideally, maintain cold water below 20 °C.
- Ideally, maintain hot water above 50 °C.

However, this is not possible always because of the nature of these systems i.e. control measures for reducing the proliferation of L must not increase the risk of scalding, particularly for children and elderly people (Bartram et al., 2007).

6. TREATMENT METHODS

There are several control methods available for disinfection of water distribution systems (Kima et al., 2002). The resistance of LB to disinfectants depends on the culture conditions (Cargill et al., 1992). Some methods have not always proven to give complete or permanent protection from recolonization of LB, but a combination of such methods may be the most effective way of managing water systems and preventing future outbreaks. These methods are classified into six groups according to the method's principle and are listed according to how commonly used they are, Fig 6 (BRE, 2003):

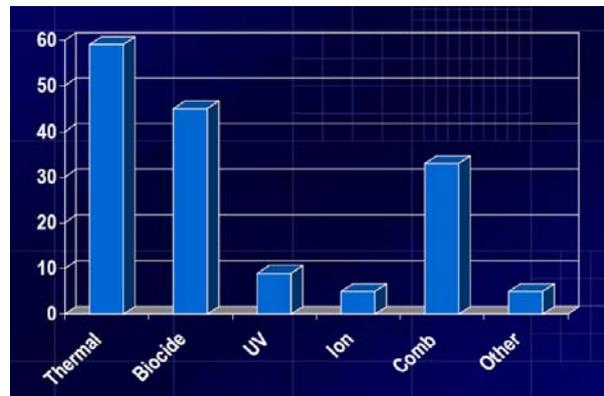


Figure 6. Control methods for disinfection of water distribution systems.

- Thermal (super heat and flush) (59%)
- Biocide (45%)
- Ultraviolet light sterilization (9%)
- Copper-Silver ionization (5.3%)
- Ozonation (8%)
- Other method of control in water system (3%)

Thermal disinfection (super heat and flush)

No other method than thermal treatment (super heat and flush) provides complete elimination and permanent protection from re-colonization of L. Thermal disinfection is the most commonly method in terms of controlling L in hot and cold water systems. Fig. 7 shows that the time necessary to kill LB is reduced by increasing temperature (Bartram et al., 2007). Elevation of water temperature to 70-80°C kills off LB within seconds (Donald, 2007, Brundrett, 2003 and EPA, 2001).

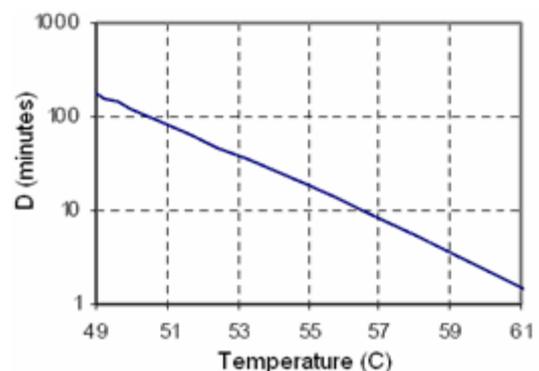


Figure 7. Time in minutes to kill 90% of the LB population.

Biocide (Chlorination)

Chlorination of water means raising chlorine levels in the system for one to two hours (EPA, 2001). Continuous chlorination requires the addition of chlorinated salts to the water.

Ultraviolet Light Sterilization

Ultraviolet light sterilization kills L by disrupting cellular DNA synthesis (EPA, 2001). UV radiation has not been widely used in drinking water disinfection because it leaves no residual to provide protection against potential downstream contamination. It has, however, been widely used in wastewater disinfection though studies indicate that UV radiation alone is insufficient to control LB. Therefore, e.g. periodic chlorination and heat pasteurization are used along with UV radiation for effective L control (Kima et al., 2002).

Copper-Silver Ionization

Copper-silver ionization distorts the permeability of the L cell, denatures proteins, and leads to lyses and cell death (EPA, 2001). Use of copper and silver ions indicated that 0.003 mg/L of Ag⁺ was sufficient to control the growth of Legionella in circulating warm water but it was difficult to eradicate Legionella from taps and showers (Kima et al., 2002).

Ozonation

Ozone which cannot be purchased, must be generated on site by ozonators, has been widely used in Europe to kill LB (EPA, 2001). Since the ozone does not stay in water sufficiently long to provide a residual effect against potential contamination in the distribution system, chlorine can be added after ozonation to provide the residual effect (Kima et al., 2002).

New Legionella Research at LTU

A new technology, which imitates a biological system, is currently being tested at LTU. It is a thermal shock treatment method that requires 90% less energy than conventional thermal treatment methods. It eradicates LB within seconds and can be heated by solar, biofuel, gas, electricity etc. The expected applications for this technology include domestic hot water, water disinfection in warm climate, and pasteurization of milk.

7. CONCLUSION

LB which was first identified in 1976 thrives in different aquatic environments. LB growth is sensitive essentially to the water temperature. Biofilms supports and offer protection for LB to stay alive even through severe conditions. LD is an increasing problem around the world and the increasingly common use of low temperature water systems provide ideal conditions for L. It should be noted that L is much more common in poor countries and that most cases of LD are not reported. The treatment methods of filtration, ozonation, and ultraviolet radiation serve to clarify the water and reduce the organic load. However no other method than thermal treatment (super heat and flush) provides both complete elimination and permanent protection from re-colonization of L. Thermal shock treatment at 70-80°C for short periods (seconds) is the safest method to eliminate L. Improved surveillance for LD is essential for the rapid and timely control of disease outbreaks.

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