Safety review

Lessons learned from recent *Legionella* bacteria outbreaks

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Summary

This article introduces Legionnaires' disease, its causes, and health related hazards. It discusses the recently reported occurrences of *Legionella* spp. at a pharmaceutical company; a distillery; a discount warehouse; a high-end hotel; a five-storey building; a leisure centre; a nursing home; and an arts and leisure facility. It then examines the immediate causes of the *Legionella* bacteria outbreaks as established through various documented sources, discussing the lessons learned from the outbreaks together with the responses to them. Wider conclusions and methodologies of risk limitation and financial loss prevention are highlighted.

Keywords: Aerosol; Bacteria; Legionnaire's disease; Pneumonia; Temperature

Introduction

Legionnaires' disease infection was first known in the United States in Minnesota in 1957. Its public acknowledgement took place in 1976 after a cooling tower outbreak in Philadelphia at an American Legion Convention in Bellevue Stratford Hotel[1, 2, 3, 25]. There were 221 reported cases of pneumonia and 34 deaths. Legionnaires' disease bacteria (LDB) cause the disease. It is a form of pneumonia which affects the lungs[4]. There are at least 43 identified species of Legionella with more than 20 linked with human diseases[5]. LDB also causes a flu-like disease called Pontiac fever[6]. Legionnaires' disease takes anytime between three and ten days to incubate[7, 8], whereas Pontiac fever takes only one or two days.

Legionnaires' disease primarily affects office and apartment dwellers such as smokers, diabetics, cancer patients, elderly, weakened immune systems, etc[4, 9]. Breathing in the small droplets of water contaminated with bacteria causes the infection[1, 2, 25]. Legionnaires' disease symptoms include fever, fatigue, severe headache, chills, muscle pain, abdominal pain, diarrhoea, redness in the eyes, jaundice, pneumonia, haemorrhages in the skin and mucous membranes, vomiting, mental confusion, and severe prostration[10]. The patient usually has a high temperature (102-105 °C). The major cause of fatality in patients with Legionnaires' disease is respiratory failure[10].

Prior to the 1900s, before central building systems and hot water storage became common, there was little potential for *Legionella* colonisation in building water systems[9]. Potable water storage, heating and distribution systems in buildings have provided the mechanism for the *Legionella* bacteria to grow to disease-causing levels. Because of this, Legionnaires' disease has been called 'the disease of modern plumbing systems'[9].

Biofilm is a crucial factor in *Legionella* growth. Factors promoting biofilm growth are low/stagnant water flow, porous materials and plumbing components that are easily fouled. These building water plumbing components include extremely low flow and laminar flow faucet aerators/restrictors, shower heads and hoses, infrared valves, thermostatic control valves and water hammer arrestors to name a few[9]. Janitor sink chemical mixing connections that allow cross flow between hot and cold systems or leaking thermostatic shower mixing valves can be a risk. Building potable water systems including changes in regulations, construction codes, designs, and plumbing components can help to reduce the risk of Legionnaires' disease[9].

Legionella bacteria will survive and thrive at low temperatures between 20-45 degrees provided the conditions are right, including the supply of nutrients such as sludge, rust, algae, scale and other bacteria[4]. The optimum temperature for multiplication is around 37 degrees centigrade. *Legionella* bacteria are killed by high temperatures, and at 46 degrees centigrade multiplication ceases[4].

A typical water system includes feed tanks, pipe-work, valves, pumps, showers, quench tanks, heat exchangers, chillers, cooling towers, dead legs, parts of the system used intermittently, test loops, etc[1,12,25]. *Legionella* bacteria is typically found in cooling towers, evaporative condensers, hot and cold water systems[12].

Legionella has also been found in more unusual locations[13], such as:

- indoor fountains and water features;
- car/bus/truck/machinery washing systems;
- horticultural misting/sprinkler/irrigation systems;
- air handling units;
- ice machines/water softeners/water filters;
- car window screen washer bottles;
- temporary site facilities.

Approximately 300 cases of Legionnaire's disease are reported annually in the UK with 14% fatalities. There are more deaths attributed to Legionnaire's disease in the USA than any other cause of death in the workplace[13].

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Year	Type of Establishment	Place	Associated Element	Fatalities	Reference
2012	Pharmaceutical company	Edinburgh, Scotland	Cooling towers	1 death, 4 suffered ill health	**(35)**
2012	Distillery	Edinburgh, Scotland	Industrial cooling towers	4 deaths, 101 suffered ill health	**(31; 34)**
2012	Discount warehouse	Stoke-on-Trent, England	Hot tub on display	1 deaths, 18 suffered ill health	**(26; 27)**
2012	High-end hotel	Chicago, USA	Decorative fountain located in hotel's lobby; including hotel's pool, spa whirlpool, men's and women's locker rooms	3 deaths, 10 suffered ill health	**(32; 33)**
2012	Five-storey hotel	Quebec, Canada	Stagnant water in high-rise cooling systems (129 cooling towers in the outbreak zone)	13 deaths, 176 suffered ill health	**(28; 29; 30)**
2008	Leisure centre	Hayes, England	Water distribution systems	Nil deaths, Nil suffered ill health	**(20; 21; 24)**
2005	Nursing home	Toronto, Canada	Cooling towers	21 deaths, 127 suffered ill health	**(29; 30)**
2002	Arts and Leisure facility	Cumbria, England	Cooling towers	7 deaths, 180 suffered ill health	**(14)**

Table 1: Recently reported occurrences of Legionella *spp.*

Recently reported occurrences of *Legionella* spp.

Table 1 shows published reports of the occurrence of *Legionella* spp. in various facilities.The general category of risk of these buildings/elements considered in this article was very high. Water systems that are not appropriately designed, installed and maintained or adequately controlled, allow bacteria such as *Legionella* to grow[25]. Negligence or ignorance, or both are perhaps the main reasons why outbreaks occur.

Events leading to the *Legionella* bacteria outbreak

Matters of evident concern in the reported occurrences of Legionella spp. considered in this article are as follows:

- thermostatic mixing valves supplying long pipe runs or multiple outlets;
- dead legs present;
- toilets with dedicated wash hand basins present;
- presence of steel/galvanised pipe-work/cisterns/calorifiers;
- showers present;
- cooling towers;
- decorative fountain;
- pool;
- spa whirlpool.

If cooling towers/pools/tubs/fountains/spa whirlpools/locker rooms are properly maintained, the risk of infection is low. However, in situations where cases of Legionnaires' disease bacteria are detected, this results in a clean-up of the system at a cost[22, 24].

Lessons learned

There are important lessons which can help to strengthen existing management arrangements. The key findings from these incidences are as follows:

- A review of factors affecting the risk of proliferation shows that management of the log book and record keeping, the monitoring and control regimes must be properly implemented[20].
- The aim is to avoid conditions which create a spray or aerosol and permit *Legionella* bacteria to proliferate.

  There are various ways to prevent the risk of exposure, for example[1, 12, 23, 25]:
  - using adiabatic cooling systems;
  - dry cooling plant;
  - point-of-use heaters;
  - engineering controls;
  - cleaning protocols and other control strategies.

  Options exist to supplement these measures by chemical disinfection.
- Older buildings with a significant history of replacements or additions are characterised by a higher level of *legionella* risk associated with complicated plumbing. This can lead to long pipe runs, cross connections, dead-legs, and warm cold water pipes as a result of the warm premises environment. Adequate disinfection with high temperature or chemicals can be difficult under such circumstances. The fact that some premises need to continue to function for 24 hours every day does not help the situation[11].

There are costs (which can be avoided) associated with the occurrences of *Legionella* spp. and typically these are:

- The costs associated with an improvement notice issued by the relevant enforcing authority where it believes there has been a contravention of health and safety law.
- The costs associated with taking the cooling towers offline and halting production or service.
- The costs of training for improvement.
- The potential costs of victim compensation.

Reactive 'quick fix' approaches often deliver less than satisfactory results and are often expensive. A proactive methodical approach is recommended such as the following:

- A technical survey provides the foundation of understanding the current operational conditions of the system[16].
- Conventional cleaning and disinfection do not appear to work to clear the problem in all cases. Hence, the supply and installation of such equipment as a VG2000 Chlorine Dioxide dosing machine as a permanent solution is recommended. It is argued that the installation of the unit provides the necessary confidence that the system would be free from *Legionella* in the future. The installation of this unit saves the costs of cleaning the system after any positive *Legionella* test[24]. The purchase of the VG2000

Chlorine Dioxide dosing machine is more effective and less costly.
- Understanding the service system in a building and addressing any existing or potential problems with pathogens is the first critical step.
- The first design criterion is to determine the management issues for which water quality data are required[17]. Temperature, flow, multiple storeys, complex systems and intermittent use are critical design factors to consider as they impact growth of *Legionella* in building water systems[18].
- While pathogenic waterborne bacteria such as *Legionella* may be ubiquitous in nature, their presence can be related directly to the design of the water systems[16].
- To minimise the health risk associated with pathogenic bacteria in building water systems, a thorough understanding of the current design of the hot and cold water service system is required. This service system can be a complex technical system, much like heating, ventilation and air conditioning systems in buildings[16].

Conclusions

Studies conducted in both the USA and UK have documented that systems treated and operated properly will significantly minimise the potential health risks from waterborne pathogens. In addition, well-designed and maintained systems using this strategy will have lower maintenance, repair, replacement and energy costs[16]. Problems associated with poorly designed or oversized systems when built can be costly to address[16].

The control of *Legionella* bacteria in water systems requires the appointment of a responsible person with sufficient authority, competence, knowledge of installations, and experience of the water systems to effectively manage the scheme[15]. Such a person:

- can constitute the prime resource in health protection;
- can have the principal responsibility for advice and enforcement and thereby reducing the risks from *Legionella*;
- is able to recover the situation in the event of an outbreak[15];
- can fully review the incident and prevent recurrence;
- is able to provide expert witness and support to mitigate any consequential prosecution[15];
- can liaise with the designer to pay close attention to the critical points in the system and try to calculate as closely as possible the water consumption, minimise dead legs, install means to remove possible accumulated solids.
- can liaise with the designer to review the water system; where a facility is to be removed, to ensure that the water system chosen is suitable for the new operating conditions[16];
- can certify that the water system meets requirements drawn up by the building code authority and other experts.

While we strive in all we do to prevent emergencies occurring, we know that they can never be eradicated entirely. However, we can learn lessons from the way past emergencies were dealt with, which will help us deal better with such events in future (see Table 2).

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Year	Type of Establishment	Place	Associated Element	Mitigation at a cost	Reference
2012	Pharmaceutical company	Edinburgh, Scotland	Cooling towers	Compliance with clean-up directives; Disinfection; emergency dosing of chemicals	(35)
2012	Distillery	Edinburgh, Scotland	Industrial cooling towers	Temporarily ceased distillation Compliance with clean-up directives; Disinfection	(31; 34)
2012	Discount warehouse	Stoke-on-Trent, England	Hot tub on display	Compliance with clean-up directives; Disinfection	(26; 27)
2012	High-end hotel	Chicago, USA	Decorative fountain located in hotel's lobby; including hotel's pool, spa whirlpool, men's and women's locker rooms	Compliance with clean-up directives; Disinfection to remediate 'possible exposure settings, its environment; Working with a water safety consulting company to install new clean water systems	(32; 33)
2012	Five-storey hotel	Quebec, Canada	Stagnant water in high-rise cooling systems (129 cooling towers in the outbreak zone)	Compliance with clean-up directives; Disinfection; Dosing the towers with a 'shock treatment' of bromine to kill of any lingering bacteria	(28; 29; 30)
2008	Leisure centre	Hayes, England	Water distribution systems	Compliance with clean-up directives; Disinfection; the purchase and installation of a VG2000 Chlorine Dioxide dosing machine	(20; 21; 24)
2005	Nursing home	Toronto, Canada	Cooling towers	Compliance with clean-up directives; Disinfection	(29; 30)
2002	Arts and Leisure facility	Cumbria, England	Cooling towers	Compliance with clean-up directives; Disinfection	(14)

Table 2: The technical mitigation measures

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