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Controlling legionella risk in a newly commissioned hospital building

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Abstract

We describe the risk assessment and interventions used for *Legionella* spp. in potable water in a new building commissioned in 2007. Water systems were designed to be compliant with Health Technical Memoranda 04-01 and the approved Code of Practice and Guidance for the control of legionella bacteria in water systems, known as L8. Monitoring of cold-water outlets showed temperature greater than 20°C. Water samples were cultured for legionella. Control measures used increased flushing and a copper–silver ionization system. Nocturnal heat gain was noticed in the cold-water system. *Legionella pneumophila* serogroup 1 was cultured from one representative outlet. The copper–silver ionization system reduced legionella colony counts. Water consumption was 71% of the original design estimate. No clinical cases due to *Legionella* spp. were detected. Reduced water consumption may lead to heat gain even in well-insulated systems, thus breaching control guidance. Additional control methods will then be required.

Introduction

Legionella pneumophila, a Gram-negative, motile rod, was discovered by Joseph McDade in 1976. It caused an outbreak of severe pneumonia amongst American World War II veterans and other visitors attending a bicentennial convention and other visitors in a Philadelphia hotel (McDade et al, 1977). Subsequent investigations showed that the previously unidentified bacterium was part of normal flora in natural and man-made water resources (Fliermans et al, 1981). Although ubiquitous, the organism is fastidious and requires special media and up to 7 days of incubation for laboratory isolation. It can grow in the temperature range of 29–40°C. The principle mode of acquisition of infection is by inhalation of aerosols containing viable bacteria. Unlike other respiratory infections such as tuberculosis and influenza, legionella is not transmitted from person to person. Infection with *Legionella pneumophila* and other legionella species may follow exposures to natural and artificial water. Facilities such as swimming pools, thermal spas and natural hot springs, saunas, whirlpools and sprinklers (Benin et al, 2002; Den Boer et al, 2002; Sukthana et al, 2005; Modi et al, 2008), cooling towers, display fountains (O'Loughlin et al, 2007; Ferré et al, 2009) and hot-water systems in hospitals (Colville et al, 1993) have been implicated in outbreaks of infections caused by legionella. In 1985, a large outbreak of Legionnaire's disease was attributed to a cooling tower in a large district general hospital in the United Kingdom; there were 68 confirmed and 35 suspected cases, and 22 people died. *L. pneumophila* serogroup 1 was isolated from the cooling water system of one of the air-conditioning plants serving the hospital and investigations revealed faults in the design of the ventilation system (Committee of Enquiry, 1986; O'Mahony et al, 1990). Contaminated rinse water was implicated in a nosocomial outbreak of *L. pneumophila* in three patients who underwent a transoesophageal echocardiography with a probe rinsed in contaminated water (Levy et al, 2003). Although the infection is rare in immunocompetent children, nosocomial and community acquired legionellosis has been reported in neonates exposed to contaminated water in birthing pools and contaminated humidifiers within incubators (Levy and Rubin, 1998; Franzin et al, 2001; Nagai et al, 2003).

The various sources of infection have implications not only for infection control investigations during suspected outbreaks but also for legislations such as Health and Safety at Work Act 1974, Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) 1995 and Control of Substances Hazardous to Health Regulations (COSHH) 1999 as described in L8 (Health and Safety Executive, 2000) and HTM 04-01 (Space for Health, 2006).

Over 50 species of legionella are known but so far 21 have been isolated from clinical samples (Diederen, 2008). *L. pneumophila* is responsible for about 90% of cases of legionella infection. Within *L. pneumophila*, there are 16 serogroups but clinical infection is most commonly caused by *L. pneumophila* serogroup1. Clinical infection with species other than *L. pneumophila* is rare except in immunocompromised patients.

Clinical features

The mode of transmission of infection is by the inhalation of infectious aerosols generated from contaminated natural and artificial water sources. Risk factors include age over 45 years, smokers, alcoholics,

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diabetics, immunocompromised, cancer or patients with chronic respiratory or kidney disease; men are more commonly affected than women (Health and Safety Executive, 2000).

The incubation period varies from 2 to 10 days. The symptoms begin as a flu-like illness with muscle aches, tiredness, headache, dry cough and fever. One third of patients develop diarrhoea and vomiting and about half develop mental status disturbances such as confusion and delirium (Health and Safety Executive, 2000). The mortality is reported to be 10–15% in otherwise healthy individuals but can be higher in the risk groups (Health Protection Agency, 2010). Not all persons exposed to contaminated aerosols develop Legionnaires' disease. For example Pontiac fever, of which the exact pathogenesis is not fully understood, is a mild non-pneumonic influenza-like illness caused by *L. pneumophila* with an incubation period of 24–48 h (Health and Safety Executive, 2000). Unless rapid and specific diagnostic tests are requested such as the urine antigen test which detects *L. pneumophila* serogroup 1, the diagnosis of legionellosis may be missed.

The study hospital

The building described is a purpose-built extension of a large district hospital, covering over 9000 m^2. The new centre was built in order to relocate and reconcile maternity services and the main hospital services into a single site. It houses maternity, gynaecology, gynaecology–oncology and neonatal services and was commissioned in March 2007 (Figure 1). As part of the existing acute care and teaching hospital, it serves a catchment population of 350,000 from the South West of England and employs over 400 staff.

The centre has a 33-bed gynaecology ward with 10-bed day case unit; the obstetric ward has 10 delivery rooms including one water-birthing facility. Of three operating theatres, two are dedicated to gynaecology. Most rooms have en-suite facilities and washrooms are provided between the delivery rooms. The neonatal unit has a level III nursery with a capacity for 25 babies: six intensive care cots, six high-dependency cots and also low-dependency unit and transitional care cots. In 2007–2008, 2988 babies were born including 37 water births. There were 561 admissions to the neonatal unit. The water systems were designed to comply with HTM 04-01 (Space for Health, 2006).

Figure 1. The new maternity–gynaecology extension

Water distribution systems

The building is supplied by the mains water supply at a temperature between 15 and 16°C which is stored in two linked tanks made of glass reinforced plastic (GRP) with a capacity of 13,000 litres and a daily turn-around of 19,000 litres, maintained at below 20°C. From the storage tanks, water is supplied into two distribution systems: the cold-water distribution system which is a direct, gravity-boosted system with the water being drawn off at the outlets, and the hot-water distribution system which is in continuous circulation. For the hot-water supply, the mains water from the storage tank is heated in calorifiers. The building has two calorifiers. Low-temperature hot water (LTHW) at 80°C is used to heat the incoming cold water to 60°C before circulation in insulated copper pipes.

Controls used for legionella

Temperature control is the traditional method for controlling legionella in water distribution systems in the UK (Health and Safety Executive, 2000).

Sentinel cold-water taps are defined as the nearest and furthest tap from the storage tank and the sentinel hot water taps are defined as the first and last tap in the distribution system. Legionella control is normally assured by complying with the standards recommended in Table 1 (Health and Safety Executive, 2000).

A minimum hot water temperature of 55°C should be achieved within 1 minute at the most distal draw-off point (Space for Health, 2006). In order to maintain a constant supply, the hot water from the outlets is returned to the calorifier at a temperature not less than 60°C (Space for Health, 2006). For cold water, a 2-minute period is permitted to obtain a minimum temperature equilibrium of below 20°C (Health and Safety Executive, 2000).

Thermostatic mixer valves (TMVs) which allow water at a pre-selected temperature to flow through the outlet in order to prevent scalding from hot water at 60°C, are incorporated into the body of the taps and showers. Flexible connectors were not used.

Methods

The building was commissioned in March 2007. As part of commissioning checks, water temperature was monitored daily in six sentinel hot-water and cold-water outlets before occupation. It was found that the cold-water control was not satisfactory and the sentinel cold-water outlets showed a temperature of greater than 20°C on several

Table 1. Temperature standards for the control of legionella in water distribution systems

Water supply	Control	Monitoring Frequency
Calorifier outlet	60°C	Monthly
Sentinel hot-water outlet	55°C within 1 minute	Monthly
Sentinel cold-water outlet	Less than 20°C within 2 minutes	Monthly
Hot water return to calorifier	Not less than 50°C	Monthly

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occasions (data not shown). It was decided that enhanced monitoring of cold-water distribution should be undertaken after the building was occupied and in full use. The water distribution system was disinfected twice by hyperchlorination prior to the occupation of the building in June 2007. Following occupation, temperature monitoring of the sentinel cold water taps was undertaken twice daily. In addition, sampling by culture for legionella was commenced, as described in L8 (Health and Safety Executive, 2000).

The hot-water control was found to be satisfactory and is not considered further in this paper.

Results

Table 2 shows the temperature monitoring results of the sentinel cold-water taps during one of the weeks following occupation of the building in June 2007. Despite the main supply and the main tank temperature of below 20°C, temperature in some of the cold-water outlets was greater than 20°C. A pattern of heat gain was observed in that the temperature of the cold-water outlets was greater in the morning (AM) than in the evening (PM) (Figure 2).

Weekly water samples from sentinel and representative outlets in the building were sent to a United Kingdom Accreditation Service (UKAS)-accredited Food, Water and Environmental Laboratory (Microbiology Laboratory, RD&E NHS Foundation Trust, Exeter EX2 5AD, UK) for legionella culture. All of the water samples were culture negative for *Legionella* spp. on repeated occasions except for one representative mixer tap located in a room ANC-23, which is an antenatal clinic ultrasound examination room. *L. pneumophila* serogroup 1 was isolated on two separate occasions from this outlet (Table 3) initially 6 months after occupation.

In view of the anticipated temperature control problem, risk reduction and control measures were instituted at the time of occupation of the building in June 2007. A flushing log was maintained and all of the taps in the building were flushed daily for 3 minutes. The flushing log was verified and signed by the estates department.

Table 2. Temperature monitoring of the sentinel cold-water taps following occupation of the building in June 2007

Monitoring Location	**Temperature equilibrium (°C) at the end of 2 minutes of sentinel cold-water draw-off**									
Time of the day	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**
Date	**20/8/07**	**20/8/07**	**21/8/07**	**21/8/07**	**22/8/07**	**22/8/07**	**23/8/07**	**23/8/07**	**24/8/07**	**24/8/07**
ANC 33	**22.2**	**20.5**	**22.2**	**21.1**	**22.6**	19.9	**20.5**	**20.5**	**20.4**	**21**
NE 31	**22.1**	**20.2**	**20.3**	20	**21.3**	19	**22.5**	**21.8**	**20.8**	**21.9**
DS 22	**20.7**	18.6	19.9	17.9	19.9	18.9	**20.3**	19.3	**20.5**	19.8
DS 86	**20.7**	18.5	19.5	17.5	**20.9**	18.9	**20.2**	19.5	**20.4**	18.3
DS 99	20	18.4	19.8	17.3	19.8	20	**20.2**	**22**	NA	NA
DS 55	19.7	19.1	19.7	18	20	19	**20.2**	19.5	**20.9**	19.5
Main tank	16.2	16.1	16.3	16.4	16.2	16.4	16.5	16.5	16.5	16.7
Mains water supply	15.9	15.7	15.4	15.8	15	15.8	15.5	16	16	15.5
Average	**20.90**	19.22	**20.23**	18.63	**20.75**	19.28	**20.65**	**20.43**	**20.60**	**20.10**
Highest	**22.2**	**20.5**	**22.2**	**21.1**	**22.6**	20	**22.5**	**22**	**20.9**	**21.9**

Bold values indicate a temperature of greater than 20˚C.

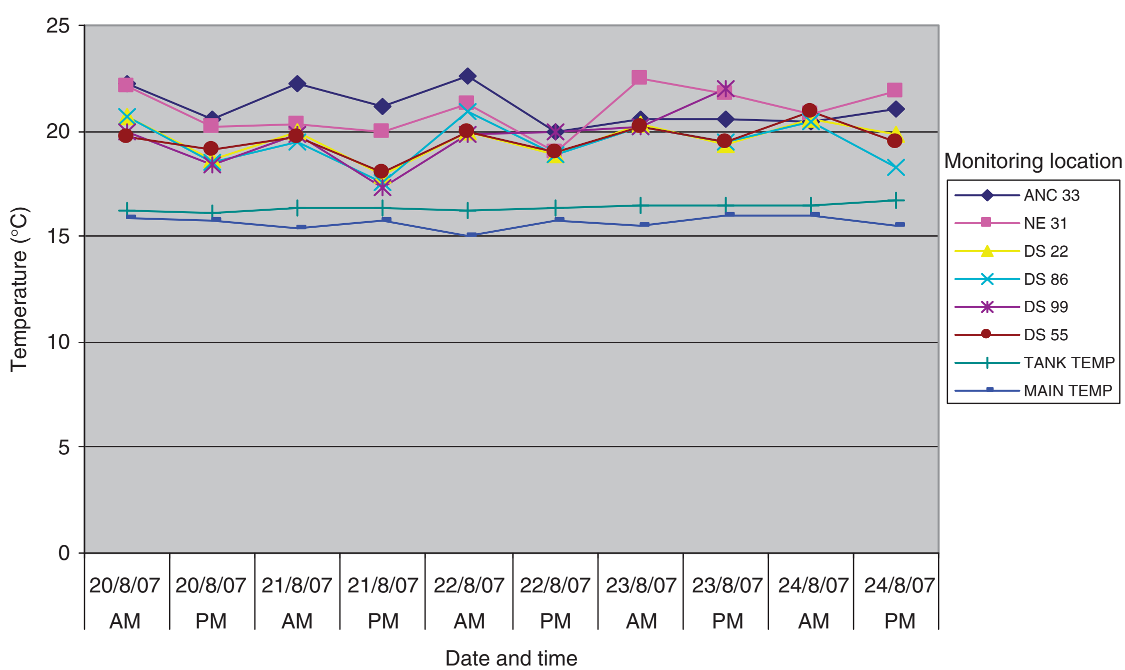

Figure 2. Temperature fluctuation (°C) of the cold-water outlets in the morning and evening following occupation of the building in June 2007

Table 3. Legionella colony count from the representative mixer outlet in ANC-23 before and after installation of the copper–silver ionization system

DATE	SAMPLE	CFU/l	SEROGROUP
Colony count following occupation of the building in June 2007			
28/11/07	ANC-23	1600	*L. pneumophila* serogroup 1
30/01/08	ANC-23	1200	*L. pneumophila* serogroup 1
Colony count following installation of the copper–silver ionization in February 2008			
06/02/08	ANC-23	60	*L. pneumophila* serogroup 1
27/02/08	ANC-23	80	*L. pneumophila* serogroup 1

Figure 3. Copper–silver ionization system showing two copper and two silver electrodes

A system of copper–silver ionization (ProEconomy Limited, Bedfordshire, UK) was installed in February 2008, at the point of the mains water supply prior to entering the storage tanks (Figure 3). Table 3 shows the water analyses results of ANC-23 following installation of the copper–silver ionization system.

The cold-water tap in ANC-23 continued to show a temperature of greater than 20°C on several occasions after installation of the copper–silver ionization. The tap was dismantled and found to have a faulty thermostatic mixer valve, which allowed hot water to mix with the cold water in the body of the tap and raise the temperature of the cold water. The tap was subsequently replaced.

Table 4 shows results of temperature monitoring (°C), copper and silver ions concentration (μg/l) and legionella colony forming units of representative outlets during February 2008, prior to installation of the copper–silver ionization system, and January 2009, after installation of the copper–silver ionization system. In our report, the range of copper ion concentration was 142–234 μg/l and the range of silver ion concentrations was 9–41 μg/l when monitored at the sentinel hot- and cold-water taps.

Table 5 shows the summary of the water analyses results from representative cold- and hot-water outlets monitored by ProEconomy Limited in association with a UKAS-accredited Food, Water and Environmental Lab (ALcontrol Laboratories, Bradford Laboratory, George Street, Bradford BD1 5AU, UK) over a 1-year period. This shows that small colony counts of *Legionella spp.* continue to be isolated intermittently. However, *L. pneumophila* has not been isolated since February 2008.

The water consumption of the obstetric, gynaecology and neonatal units at their old accommodation, prior to relocation, averaged 42 m^3/24 h. Planning and design specification at the new site was based on an estimated consumption of 26.2–30.5 m^3/24 h. However, even after full occupation of the building, the water consumption only reached an average of 20.5 m^3/24 h. The actual water consumption in the new building is only 71% of what was originally estimated. No clinical cases of legionellosis have been detected.

Discussion

Legionella can be isolated from all kinds of natural and man-made aquatic settings when the temperature of the water body is between 20 and 40°C. While they are fastidious *in vitro*, their ability to survive in a low-nutrient natural environment is explained by their parasitism on protozoal organisms such as acanthamoeba. The natural environment is a complex niche of organisms comprising algae, other bacteria and protozoa called a biofilm. Both parasitism and biofilm confer survival advantage to legionella, providing protection from environmental extremes, for example pH, temperature, and chemical disinfectants and also supply nutrients (Harrison, 2005).

Surveillance data for the period 1980–2008 showed that among the residents of England and Wales, there were 233 definite cases of Legionnaires' disease that were acquired nosocomially out of which 151 were associated with outbreaks; 2754 definite cases were associated with travel abroad and 3250 cases were community acquired (Health Protection Agency, 2009). In our report, there were no cases of Legionnaires' disease or Pontiac fever either during the commissioning or following occupation of the building. L8 (Health and Safety Executive, 2000) gives guidance on the requirements of the Health and Safety at Work Act 1974 and COSHH 1999 with reference to the risks of exposure to legionella. It highlights the legal duties of employers and those with responsibilities for the control of premises to reduce the risk from legionella bacteria which may arise from work activities.

HTM 04-01 (Space for Health, 2006) gives comprehensive advice and guidance to healthcare management, design engineers, estate managers and operations managers on the legal requirements, design applications, maintenance and operation of hot and cold water supply, and storage and distribution systems in all types of healthcare premises. The approved methods of water disinfection for preventing colonization with legionella include chlorine dioxide, copper-silver ionization, ozone and ultra-violet radiation and filtration (Health and Safety Executive, 2000). Chlorine dioxide is an oxidizing biocide and acts as a free radical which binds to amino acids resulting in the destruction of living cells. It can destroy and remove biofilms. The levels need to be monitored and it has a tendency to evaporate from

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Table 4. Water analyses results from representative hot- and cold-water outlets during February 2008 and January 2009 showing temperature (°C), copper and silver ion concentrations (µg/l) and *Legionella* spp. (CFU/l) before and after installation of the copper–silver ionization system

Date	Location of the representative outlet	Temperature (°C)	Silver ions (µg/l)	Copper ions (µg/l)	*Legionella* spp (CFU/l)
Before installation of the copper silver ionization system					
04/02/08	APN 49 C	16.2	<0.3	43	100
04/02/08	APN 49 H	39.3	<0.3	56	1100
04/02/08	DS 82 Shw H	33.8	<0.3	42	Not detected
04/02/08	DS 55 C	20.3	<0.3	29	Not detected
04/02/08	DS 50 H	38.8	<0.3	44	Not detected
04/02/08	ANC 28M	14	<0.3	109	Not detected
04/02/08	GW 25 Shwr H	40.8	<0.3	59	Not detected
One year after installation of the copper–silver ionization system					
23/01/09	APN 49 C	13	41	179	100
23/01/09	APN 49 H	39	22	145	100
23/01/09	DS 82 Shw H	41	24	147	Not detected
23/01/09	DS 55 C	13	40	175	Not detected
23/01/09	DS 50 H	41	22	142	Not detected
23/01/09	ANC 28M	44	9	234	Not detected
23/01/09	GW 25 Shwr H	37	32	185	Not detected

Table 5. Summary of water analyses results for *Legionella* spp. colony forming units (CFU/l) for the period from February 2008 to January 2009

Location/Month	Feb 08	Mar 08	April 08	May 08	Jun 08	Jul 08	Aug 08	Sep 08	Oct 08	Nov 08	Dec 08	Jan 09
APN 49 C	100	nd	100	nd	nd	nd	nd	nd	nd	300	nd	100
APN 49 H	1100	nd	700	nd	nd	nd	200	nd	nd	nd	nd	100
DS 82 Shw H	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
DS 55 C	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
DS 50 H	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
ANC 28 C	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
GW 25 Shw H	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

nd: not detected.

water at a temperature of 60°C (Space for Health, 2006). It can result in a high concentration of copper if copper pipes are used for distribution, as in the building in our report.

Copper–silver ionization is based on releasing copper and silver ions by passing an electric current between the electrodes placed in water. The ions act synergistically; copper ions attach to the negatively charged cell wall of bacteria and distort the cell wall and the silver ions bind to the DNA, RNA, proteins and enzymes in the cell and inhibit protein synthesis leading to cell death (Space for Health, 2006). The ions also prevent biofilm formation and reduce the number of bacteria present in biofilms. The biocide effect of ions is present at 35°C.

However, the generation of ions is susceptible to pH and scale formation at the electrodes. Use of ionization on hard water is associated with staining of sanitary ware. The copper ion concentration should be maintained at approximately 400 µg/l and the silver ion concentration should be approximately 40 µg/l (Space for Health, 2006). In our report, the concentration of copper ions was maintained lower than the recommendation due to the presence of phosphate in the mains water supply which formed a precipitate with higher levels of copper and led to discolouration of the water (Birgitta Bedford, Technical Director ProEconomy, personal communication).

The use of ozone and ultra-violet radiation is not effective in water distribution systems because the microbicidal action is not dispersive and hence, must be applied at the point of use. Filters are susceptible to bacterial colonization and require regular maintenance of the filter membrane (Space for Health, 2006). The above-mentioned methods are recommended in addition to temperature control measures for controlling the risk of legionella.

In our report, some of the representative cold-water outlets showed a temperature of greater than 20°C after 2 minutes of running the tap. Inadequate water consumption compared with design specifications can affect the ability of the system to maintain a low temperature when large quantities of supplied water remain un-utilised even without dead-legs. The use of alcohol hand rubs could be an emerging cause of inadequate water consumption.

Conclusion

This report highlights the importance of ongoing risk assessment and monitoring the performance of potable water distribution systems during commissioning and following occupation of a new building. During commissioning of the building in our report, temperature monitoring of sentinel cold-water outlets showed inadequate temperature control attributed to under-utilization of the water supply pending occupation of the building. Following occupation of the building, recommended measures such as flushing failed to prevent colonization of the cold-water outlets with legionella. *L. pneumophila* serogroup 1 was detected in a faulty thermostatic mixer outlet. Unanticipated problems such as inadequate water consumption compared with the design specifications led to the failure to control temperature and colonization of water systems. We were able to reduce and control the risk within acceptable limits by introducing an additional control in the form of a copper–silver ionisation system. The faulty thermostatic mixer outlet was replaced. A recent difficulty in maintaining recommended copper ion concentration due to a high concentration of phosphate ions in the mains water supply was observed. No further isolates of *L. pneumophila* serogroup 1 were detected after 1 year of monthly monitoring of representative hot- and cold-water outlets in the building although non-pneumophila legionella species continue to be isolated.

The overall risk of legionellosis to the population using the building was reduced. Ongoing monitoring of water temperatures and ionization performance in addition to culture of water samples is essential after installation of control measures. Decreased water consumption may have been caused by the substitution of alcohol hand rubs for handwashing with soap and water and this needs to be explored in further studies.

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Conflict of interest statement

None declared.

References

Benin AL, Benson RF, Arnold KE, Fiore AE, Cook PG, Williams LK, Fields B, Besser RE. (2002) An outbreak of travel-associated Legionnaires disease and Pontiac fever: the need for enhanced surveillance of travel-associated legionellosis in the United States. *Journal of Infectious Diseases* **185**(**2**): 259–61.

Colville A, Crowley J, Dearden D, Slack RCB, Lee JV. (1993) Outbreak of Legionnaires' disease at University Hospital, Nottingham. Epidemiology, microbiology and control. *Epidemiology and Infection* **110**(**1**): 105–16.

Committee of Inquiry (1986) *First report of the committee of inquiry into the outbreak of Legionnaires' disease in Stafford in April 1985*. London: The Stationary Office.

Den Boer JW, Yzerman EPF, Schellekens J, Lettinga KD, Boshuizen HC, Steenbergen JEV, Bosman A, Van den Hof S, Van Vliet HA, Peeters MF, Ketel RJV, Speelman P, Kool JL, Conyn-Van Spaendonck MAE. (2002) A large outbreak of Legionnaire's disease at a flower show, the Netherlands, 1999. *Emerging Infectious Diseases* **8**(**1**): 37-43.

Diederen BMW. (2008) Legionella spp. and Legionnaires' disease. *Journal of Infection* **56**(**1**): 1–12.

Ferré MR, Arias C, Oliva JM, Pedrol A, García M, Pellicer T, Roura P, Domínguez A. (2009) A community outbreak of Legionnaires' disease associated with a cooling tower in Vic and Gurb, Catalonia (Spain) in 2005. *European Journal of Clinical Microbiology and Infectious Diseases* **28**(**2**): 153–9.

Fliermans CB, Cherry WB, Orrison LH, Smith SJ, Tison DL, Pope DH. (1981) Ecological distribution of Legionella pneumophila. *Applied and Environmental Microbiology* **41**(**1**): 9–16.

Franzin L, Scolfaro C, Cabodi D, Valera M, Tovo PA. (2001) *Legionella pneumophila* pneumonia in a newborn after water birth: a new mode of transmission. *Clinical Infectious Diseases* **33**: e103–4.

Harrison TG. (2005) Legionella. In: *Topley and Wilson's Microbiology and Microbial Infections* Borriello SP, Murray PR and Funke G eds. London: Hodder Arnold, pp. 1761–85.

Health and Safety Executive (2000) *Legionnaires' disease: The control of Legionella bacteria in water systems*. Approved Code of Practice and Guidance (L8).

Health Protection Agency (2009) *Legionnaires' disease in residents of England and Wales, nosocomial, travel or community acquired cases. 1980–2008*. Available online: http://www.hpa.org.uk/webw/HPAweb&HPAwebStandard/HPAweb_C/1195733748327?p=1191942128217 (accessed 6 February 2010).

Health Protection Agency (2010) *Legionnaires' Disease. General information and FAQs*. Available online: http://www.hpa.org.uk/HPA/Topics/InfectiousDiseases/InfectionsAZ/1191942128209/?printable=true (accessed 7 February 2010).

Levy I, Rubin LG (1998) *Legionella* pneumonia in neonates: a literature review. *Journal of Perinatology* **18**(**4**): 287–90.

Levy PY, Teysseire N, Etienne J, Raoult D. (2003) A nosocomial outbreak of Legionella pneumophila caused by contaminated transesophageal echocardiography probes. *Infection Control and Hospital Epidemiology* **24**(**8**): 619–22.

McDade JE, Shepard CC, Fraser DW, Tsai TR, Redus MA, Dowdle WR and the laboratory investigation team. (1977) Isolation of a bacterium and demonstration of its role in other respiratory disease. *The New England Journal of Medicine* **297**(**22**): 1197–203.

Modi A, Gardner J, Lighton L, Coetzee N. (2008) Pontiac fever outbreak associated with a spa-pool, United Kingdom. *Euro Surveillance* 13(30): 18934. Available online: http://www.eurosurveillance.org/ViewArticle.aspx?ArticleId=18934 (accessed 6 February 2010).

Nagai T, Sobajima H, Iwasa M, Tsuzuki T, Kura F, Amemura-Maekawa J, Watanabe H. (2003) Neonatal sudden death due to *Legionella* pneumonia associated with water birth in a domestic spa bath. *Journal of Clinical Microbiology* **41**(**5**): 2227–9.

O'Loughlin RE, Kightlinger L, Werpy MC, Brown E, Stevens V, Hepper C, Keane T, Benson RF, Fields BS, Moore MR. (2007) Restaurant outbreak of Legionnaires' disease associated with a decorative fountain: an environmental and case–control study. *BMC Infectious Diseases* 9(7): 93. Available online: http://www.biomedcentral.com/1471-2334/7/93 (accessed 6 February 2010).

O'Mahony MC, Stanwell-Smith RE, Tillett HE, Harper D, Hutchison JG, Farrell ID, Hutchinson DN, Lee JV, Dennis PJ, Duggal HV, Scully JA, Denne C. (1990) The Stafford outbreak of Legionnaire's disease. *Epidemiology and Infection* **104**(**3**): 361–80.

Space for Health (2006) *Health Technical Memorandum 04-01: The control of legionella, hygiene, "safe" hot water, cold water and drinking water systems*. London: The Stationary Office.

Sukthana Y, Lekkla A, Sutthikornchai C, Wanapongse P, Vejjajiva A, Bovornkitti S. (2005) Spa, springs and safety. *Southeast Asian Journal of Tropical Medicine and Public Health* **36**(**Suppl 4**): 10-16.

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