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Risk Assessment for Legionella in Building Water Systems

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Building water systems present a significant risk of community acquired and nosocomial Legionella infections. Published data suggest that health risks from these systems are peculiar to their design and operation and distinct from other sources of Legionella infections. This paper uses the currently available evidence base to assess the health risks associated with these systems and to make recommendations for risk management.

Key words: *Building Water Systems; Legionella; Risk Assessment*

Legionella infections are almost exclusively associated with the built environment. A range of devices and applications have been associated with disease including building water systems, cooling water systems, spa pools, fountains and respiratory equipment. Each of these systems constitutes unique environments that carry their own risk potentials (Atlas 1999; Joseph 2002). Recent reports suggest that the incidence of disease is underestimated and a significant proportion of all Legionellosis cases identified each year are attributable to contaminated building water systems (Joseph 2002; Ruef 1998). These systems may include hot, warm and cold water systems and their outlets (showers, faucets and so on).

This paper reviews the unique characteristics of building water systems (BWS) as distinct from other water systems and their associated health risk. Haas et al. (1999) identified four key steps in assessing microbial health risks: hazard assessment, exposure assessment, dose-response analysis, and risk characterisation. They concluded that the integration of risk assessment with risk management to develop a risk assessment framework was a multidisciplinary process.

Hazard Identification

There are two proposed routes of infection associated with BWS; the inhalation of aerosol and the aspiration of contaminated water droplets (Dennis et al. 1984; Yu 2000). Generation of aerosol containing Legionella has been demonstrated from showers and faucets (Dennis et al. 1984). Aerosol is not generated in the same quantities as in cooling water systems, and is rarely transported over distances of a few metres (Bollin et al. 1985). Reports of infection and outbreaks from these sources suggest that either aerosol is not transmitted over the great distances associated with cooling water systems or that they are the result of an alternate route of infection, such as aspiration (Yu 2000). Current research data have not implicated oropharyngeal colonisation by *Legionella* bacteria as a step in the aspiration route of infection (Pedro-Botet et al. 2002).

Nosocomial infections may include wound infections from contaminated water applied to the wound site. These instances are unusual and may include a range of Legionella species not commonly associated with respiratory disease. This is presumed to be a function of the host immune status (Ampel, Ruben & Norden 1985; Lowry et al. 1991).

Until recently, reports of infection and outbreaks have predominantly been associated with health care premises (nosocomial) (Yu 2000). More recently in Europe, there have been reports of disease outbreaks associated with contaminated water systems in holiday resorts (Albrechtsen et al. 1990; Joseph 2002). In these instances *Legionella pneumophila* Serogroup 1 infection has predominated. Disease associated with hotels and holiday resorts has not been reported in Australia. Travel related clusters might be impossible to detect without adequate disease surveillance systems capable of tracking cases across national and international boundaries (Albrechtsen et al. 1990; Benin et al. 2002; Joseph 2002).

Cases of nosocomial disease have been widely reported and are more frequent than cooling tower outbreaks (Yu 2000). Some reports suggest that between 15 and 20% of all Legionella infections are nosocomially acquired (Ruef 1998), though more recent data from the European community suggest a lower incidence (Joseph 2002). Disease ranges from single sporadic cases to protracted outbreaks over months and years (Rangel-Frausto et al. 1999; Rudin, Wing & Yee 1984). In these instances the numbers of individuals infected are usually quite low when compared to other sources such as cooling water systems or spas. The low number of cases over a lengthy duration may delay recognition of an outbreak. Nosocomial outbreaks may also include wound infections after exposure to contaminated water (Lowry et al. 1991).

BWS-associated outbreaks of disease include a more diverse range of *Legionella* species and serogroups than other sources. Species include *L. pneumophila* SG1 and other serogroups (2, 4, 5, 6, 12) and other species such as *L. micdadeii*, *L. bozemanii*, and *L. feeleeii* (Ampel, Ruben & Norden 1985; Rudin, Wing & Yee 1984) this is probably due to the combination of the exposure route and, especially in the nosocomial cases the exposed susceptible

population. A number of species associated with disease contracted from building water systems have no reported association with other water systems (Fang, Yu & Vickers 1989; Wilkinson et al. 1987).

Investigations have shown multiplication of Legionella in sediments of water heaters and calorifiers of hot water systems. Some evidence suggests that Legionella multiplication may be enhanced by the presence of amoebae or other bacteria in these sediments (Fields et al. 1989; Wadowsky & Yee 1985; Wadowsky et al. 1991). Strong positive associations have been shown between amoebae colonisation of hot water systems and cases of Legionellosis (Breiman et al. 1990).

Dose Response Relationship

No infectious dose has been established for Legionella infections (O'Brien & Bhopal 1993). Aerosol containing Legionella has been shown to be generated during normal operation of shower heads and hot water faucets (Bollin et al. 1985; Dennis et al. 1984). The possibility of aspiration as an alternate route of infection to aerosol inhalation introduces a further unknown quantity regarding infectious dose from building water systems (Yu 2000). It is possible that infection via this alternate route may be initiated by lower dose concentrations in the contaminated water source (Ruef 1998). It has been argued that there is more conclusive evidence for infection from building water systems via aspiration than via aerosolisation. This viewpoint and the debate surrounding routes of transmission remain unresolved and contentious (Yu 2000).

Field studies in the US have suggested that there is no clear link between Legionella concentrations in water samples and incidence of infection from building water systems (Kool et al. 1999; Wadowsky et al. 1982). In these studies it was reported that the frequency of positive isolations from samples was a better indicator of risk of infection than numbers of organisms

isolated (Ruef 1998). It has also been reported that >30% of positive Legionella tests from a system has been associated with Legionella infections (Ruef 1998). This suggests that either sampling results from building water systems are not truly representative (Ruef 1998) or that the infectious dose is primarily a function of the susceptible population (Kool et al. 1999).

Exposure Assessment

Surveys of the prevalence of Legionella bacteria in building systems indicate that between 25 and 68% of systems are colonised (Atlas 1999). Because of the range of species represented in building related infections there is no clear differentiation between risks associated with each species or serotypes.

Water temperatures above 20°C and below 50°C present the major factor contributing to colonisation of BWS. Areas of poor circulation or stagnation also support colonisation of Legionella and other microorganisms (Fisher-Hoch, Smith & Colbourne 1982; Kool et al. 1999). Commonly in outbreak scenarios these areas are not maintained at the optimal thermal setting for the system (Wadowsky et al. 1982).

Colonisation of plumbing materials such as natural rubber fittings and shower hoses and roses has also been demonstrated. In some instances these fittings have been cited as contributing factors to disease outbreaks (Schofield & Wright 1984; Wadowsky et al. 1982).

Recent reports have suggested that the installation of thermostatic mixing devices with significant lengths of pipe between the valve and the hot water outlet may also inhibit disinfection and control of Legionella in hot water distribution systems. It has been reported that installation of thermostatic mixing devices will compromise control of Legionella in hot and warm water systems (Lee et al. 2002).

Risk Characterisation

Colonisation of buildings systems by Legionella is via the reticulated water system (Atlas 1999; Kool et al. 1999). Factors that influence the colonisation by Legionella include the presence of sediments and deposits within the water system, poor flows, temperatures between 20°C and 50°C, inadequate or no disinfection and, the presence of pipework, dead-legs or standby systems where stagnation can occur (Bartlett, Macrae & Macfarlane 1986; Ruef 1998)

Studies have shown that Legionella are continually introduced into building water systems (Rangel-Frausto et al. 1999). Once introduced a number of factors will determine whether the system becomes permanently colonised by these organisms (Rangel-Frausto et al. 1999). The colonisation of system by multiple strains of variable virulence is likely should conditions be suitable for multiplication (Rangel-Frausto et al. 1999; Zeitz et al. 2001).

Risk Management

Much attention should be focused upon system design. Low flow and stagnant areas in systems should be avoided; where possible temperatures should be maintained outside the 20-50°C temperature range throughout the system (Ruef 1998). Pipe lengths after thermostatic mixing valves should be as short as possible and routine maintenance of these fittings is essential (World Health Organization [WHO] 1990). System design should exclude materials that might be conducive to microbial colonisation, such as natural rubber compounds (Schofield & Wright 1984; Wadowsky et al. 1982).

In some systems significant volumes of water may remain below 50°C as part of normal operating procedures (e.g. after mixing valves or in shower hoses). In these applications some consideration should be given to either chemical or thermal disinfection protocols. Favourable reports have been published from field applications using temperature, halogen,

monochloramine, copper/silver ionisation and chlorine dioxide treatments (Kim et al. 2002; Lee et al. 2002). The correct design and application and pro-active maintenance systems appear to be the major factors in determining the efficacy of these treatments (Lee et al. 2002).

Due to the well publicised uncertainties surrounding Legionella culture methods and results, sampling for the bacterium should not be misinterpreted as a means of monitoring system control (Bentham 2001; Boulanger & Edelstein 1995). Monitoring of simply, readily, and reliably obtained parameters such as water temperature, and attention to system performance and operating parameters are of more practical value in determining the level of control in the system. Daily and even hourly assessment of system performance can be made based on these identified control measures.

Routine monitoring of building systems for Legionella has been recommended in those facilities where high risk populations are likely to be exposed (e.g. organ transplant units, Kool et al. 1999; Yu 2000). Direct exposure may occur through use of the contaminated water system or appliance (e.g. showering). Culture has been implemented as a routine monitoring tool and frequency of sampling has varied between weekly and quarterly intervals. It has also been proposed that fittings and appliances should be swabbed for biofilm (Yu 2000). This suggestion is derived from the knowledge that intermittent use of water systems may cause dislodgement of Legionella colonised biofilms causing sudden release of large numbers of organisms. Swabbing of biofilm cannot easily be used to provide quantitative data on Legionella colonisation, and overgrowth

of swab samples on culture media may result in false negative results (Bentham 2001). Once Legionella has colonised a BWS system it may be controlled but not eradicated (Lee et al. 2002). Primary emphasis should be placed upon control measures rather than sampling for the organism (Ruef 1998).

Numbers of positive samples have been shown to be better indicators of risk than the numbers of organisms cultured. Sampling regimens should be designed in response to system size and design (Kool et al. 1999). The numbers of positive results obtained as a proportion of the total samples taken, regardless of species or concentrations, should be used as a means of validating control measures. Positive culture results should be used as indicators for reassessment of system design, performance, and adequate monitoring of established control measures in the system. As with the control measures it is critical that Legionella sampling protocols be extensive enough to be representative, and should include areas of highest identified risk and areas of lowest identified control (Kool et al. 1999; Ruef 1998).

It should be stressed that health risk management of building water systems for Legionella is a multidisciplinary process, requiring input at all levels of system management. The establishment of a broad base of expertise and involvement with the system will be critical in identifying appropriate and reliable control measures (Haas, Rose & Gerba 1999). Implementation of a simple proactive plan with well established communication and feedback between those involved will be more likely to succeed than reactive responses to routine Legionella culture results.

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