

Guidelines for

# LEGIONELLA CONTROL

in the operation and maintenance  
of water distribution systems  
in health and aged care facilities



**en**HEALTH

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# Introduction

## Legionnaires' disease

Legionnaires' disease is caused by colonisation of the respiratory tract with *Legionella* bacteria. It is characterised by severe pneumonia. Unless diagnosed and treated rapidly, the disease can be serious or even fatal, especially in vulnerable people. In health and aged care settings, the mortality rate from Legionnaires' disease is as high as 40 per cent.

Pontiac fever is a milder infection caused by *Legionella* that presents with similar respiratory symptoms as Legionnaires' disease but does not result in pneumonia. Pontiac fever usually resolves without treatment in 2–5 days.

## Legionella bacteria

*Legionella* are small – less than 1 micrometre ( $\mu\text{m}$ ) in width and 3  $\mu\text{m}$  in length – gram-negative bacteria. They can be found in water, in host organisms such as amoeba, and adhering to the surface of pipes or other plumbing infrastructure (often in a layer formed with other microorganisms called a 'biofilm'). *Legionella* can also be found in organic material such as soil, compost and potting mix.

To date, around 60 species of *Legionella* bacteria have been formally identified, and just under half are suspected to cause infections in humans. *Legionella pneumophila* is known to cause most of the water-related *Legionella* infections that lead to serious illness. However, in health care facilities, non-*Legionella pneumophila* species may also cause disease.

## Infection by Legionella

Infection by *Legionella* occurs following inhalation or aspiration of aerosol droplets containing *Legionella* bacteria or host organisms infected with *Legionella* bacteria. The incubation period for Legionnaires' disease is usually 2–10 days before the onset of illness, but is typically 5–6 days. However, evidence from some point-source outbreaks shows that the range can be 1–19 days, with a median of 6–7 days, and that some severely immune-suppressed patients may take longer than 10 days to develop symptoms.

## Why Legionella is a particular problem for health care

When exposed to *Legionella*, most healthy individuals will not develop an illness, or will develop Pontiac fever rather than Legionnaires' disease, but newborn babies, the very old and people with compromised immune systems are at increased risk of *Legionella* infection.

*Legionella* is therefore of significant concern in health and aged care facilities because of the presence of people with clinical risk factors that increase both the likelihood and the potential severity of *Legionella* infection.

In health and aged care settings, patients with significant clinical risk factors include:

- newborn babies (water birthing is a particular risk)
- older people (the disease is rare in children and most cases occur in people over the age of 50)
- males (in 2013, 54 per cent of Legionnaires' disease notifications in Australia and 67 per cent in New Zealand were for males)
- smokers
- people with
  - chronic obstructive pulmonary disease
  - diabetes
  - therapeutic immunosuppression
  - transplant immunosuppression
  - diseases that result in immunodeficiency (eg HIV/AIDS)
- people undergoing chemotherapy.

### **These guidelines**

The design and function of the water distribution system within a health or an aged care facility can affect the potential health risks posed by *Legionella* within the facility.

These guidelines are designed to assist facility managers to assess and manage the risk from *Legionella* in health and aged care facilities. They are aimed at facility managers and the members of a facility's *Legionella* risk management team to support the development of a *Legionella* risk management plan. A plan template is provided separately. The guidelines and template are provided as non-prescriptive guidance materials only and where possible they should be adapted to fit with existing facility risk management processes and regulatory requirements, where appropriate.

Although the principal focus of these guidelines is *Legionella pneumophila*, the advice provided about its control will also result in effective control of other *Legionella* species and many other microbial hazards that can be present in the water infrastructure of health and aged care facilities.

These guidelines apply to all water distribution systems in health and aged care facilities with the exception of cooling towers, which are not within the scope of this document. Facility managers should consult relevant state or territory legislation and guidelines for the management and control of *Legionella* in cooling towers.

## Structure of these guidelines

These guidelines take you through the steps required to manage *Legionella* risk within your facility.

These are:

- establishing a *Legionella* risk management system (see Chapter 1), including
  - assembling a risk management team
  - developing, documenting and reviewing a risk management plan
- analysing your risk (see Chapter 2), including
  - undertaking a system analysis
  - identifying hazards, hazardous events and risk
- managing your risk (see Chapter 3), including
  - implementing controls
  - monitoring
- responding to detections or cases (see Chapter 4), including
  - undertaking corrective measures
  - responding to a suspected case of Legionnaires' disease
  - deciding what to do if the problem persists
- reviewing your *Legionella* risk management plan (see Chapter 5).

# 1. Establishing a *Legionella* risk management system

Two main components are needed in any system to manage *Legionella* risk. First, there are the suitably trained and experienced leaders and staff who are aware of the risks and able to act to manage them. Second, there must be an effective and documented *Legionella* risk management plan that can be followed by the risk management team and other key staff.

## 1.1 Assembling the risk management team

The responsibility for managing *Legionella* risk in a facility is a shared one. A facility's risk management team needs to include people who have sound understanding of the risks and control of *Legionella* involved in the day-to-day management of the water distribution system and people responsible for the care of patients or residents. These people should be selected on the basis of their possessing appropriate skills and knowledge to understand *Legionella* risk and coordinate responses to incidents, such as cases or *Legionella* detections in water samples. These often require a 'whole of facility' response that affects staff, patients or residents, and the facility's water distribution system.

A multidisciplinary approach is recommended, and the team should include representatives from:

- **infection control:** to contribute expertise on microbial disease risks and management measures for residents or patients
- **clinical areas (eg nursing or care staff):** to contribute expertise on patients' or residents' conditions and the practicality of management measures
- **facilities management (eg maintenance staff):** to contribute expertise on the layout and operation of the facility's water distribution system
- **health, safety and environment:** to ensure that the procedures developed are consistent with work health and safety and environmental risk management systems, and do not inadvertently create unintended and unacceptable risks
- **executive team:** to provide the necessary approval and resources to manage *Legionella* and respond to incidents or cases.

The purpose of the risk management team is to ensure that operational, clinical and engineering matters are considered in a coordinated, cohesive, cooperative and holistic way during the process of developing and implementing a *Legionella* risk management plan, thus increasing the likelihood of achieving effective *Legionella* risk management.

To avoid unnecessary administrative burden, health and aged care facilities could use an existing committee (eg work health and safety committee) if it is representative of the skills and knowledge base needed and has the authority to ensure effective implementation.

### 1.1.1 Skills and knowledge

Everyone responsible for *Legionella* monitoring, preventive maintenance, responding to *Legionella* detections, and developing or instituting the facility's risk management and

mitigation strategies should have the skills, knowledge and experience to assume these responsibilities. All staff members should be made aware of their expected roles and responsibilities regarding water management and infection control. The roles, responsibilities and contact details of all team members should be documented in the *Legionella* risk management plan.

It is likely that some facility staff and risk management team members will require targeted training appropriate to the *Legionella* risk management tasks, roles and responsibilities allocated to them. Staff orientation and mandatory training programs should make reference to the *Legionella* risk management plan.

In facilities where there is limited in-house expertise to identify risks or strategies to control the growth of *Legionella*, assistance can be sought from specialists such as:

- water quality specialists (eg scientists, engineers and microbiologists)
- state and local government environmental health officers (Australia) or health protection officers from district health boards (New Zealand)
- clinicians from other facilities with expertise in risk management for *Legionella* infection
- suitably trained and experienced plumbers
- suitably trained and experienced water treatment service providers.

Even in circumstances where external expertise is sought, it is important that staff in the facility establish and maintain a sound understanding of *Legionella* risk and their obligations under the *Legionella* risk management plan.

## **1.2 Developing and documenting procedures – the *Legionella* risk management plan**

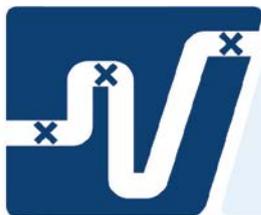
The risk management team should be responsible for ensuring that suitable written procedures are prepared for *Legionella* risk management, and for making them available to all relevant staff members. Since the risk and associated procedures will vary from facility to facility, it is important that the risk management team takes an active role in their development to ensure that the procedures adopted are proportionate to the risks identified and, where possible, aligned with other facility operational practices.

These guidelines are intended to assist the development of such procedures by describing a stepwise process for analysing risk, identifying risk management measures, establishing a monitoring program to confirm that management measures are effective, and describing how to respond to incidents identified through monitoring or a case of disease.

The documentation of these processes and procedures, and their outcomes, forms a *Legionella* risk management plan. Changes to the plan as a result of review, system modifications, cases of disease or detections of *Legionella* should also be documented, so that past patterns and possible causes can be identified and future interventions can be targeted more precisely.

## 2. Analysing your risk

When considering *Legionella* control, it is important to distinguish between ‘water system risk’ and ‘health risk’.



**Water system risk (or contamination risk)** refers to the risk of contamination of water, microbial colonisation of facility water infrastructure and subsequent proliferation of *Legionella* bacteria within the water distribution system of a health or an aged care facility.



**Health risk (or infection risk)** refers to the risk of a person contracting Legionnaires' disease from a water distribution system.

Hazards and hazardous events within health and aged care facilities can be largely grouped into those that increase the likelihood, distribution and severity of *Legionella* colonisation within the facility's water distribution system, and those that increase the likelihood of exposure through inhalation of an aerosol or aspiration of water containing the bacteria.

As risks will vary between different locations within health and aged care facilities, measures to control these risks will also vary. This means that controls suitable for one part of a facility may not be suitable or necessary in other parts. This is why it is vital to understand both the nature of the water distribution system and the susceptibility of the facility's occupants, so that control measures can be appropriately and effectively targeted.

### 2.1 Undertaking a system analysis

Understanding the water distribution system and the patients or residents most at risk is the first step in identifying and managing the hazards associated with the growth of *Legionella* in a water distribution system.

#### 2.1.1 Water distribution system

To undertake a proper system analysis, it is essential that accurate plans of the water distribution system (including any modifications to the original system installed) are held, although it is acknowledged that, in older or larger buildings, obtaining accurate ‘as built’ plans may be difficult. The accuracy of plans should be confirmed using physical inspections to identify and highlight where components of the water distribution system may increase the risk of *Legionella* growth.

Such system components include areas where water may be warmed (eg cold water pipes installed near hot water pipes), or areas of low or no flow where water may stagnate (eg bathrooms that are infrequently used, or lengths of pipe cut off and/or capped during renovations).

In cases where plumbing diagrams are difficult to read, incomplete or inaccurate, a generalised schematic (eg a flow chart) can also be helpful.

The water distribution system analysis should cover the entire process from where the water enters the facility to distribution throughout the facility to its final uses. The analysis should be based on identifying the factors that increase the risk of *Legionella* colonisation, growth and exposure (see Section 2.2.3), as well as identifying all points of contact between the water and patients, residents, staff and visitors.

On that basis, the analysis will typically include:

- the source and quality of water supplied to the facility (eg town or private, presence of on-site water storage tanks, type and concentration of any disinfectant present). The supply source will influence the quality of the water entering the water distribution system. Supplies that are untreated or stored for extended periods may increase the risk of growth of *Legionella*
- the water distribution system, based on the original detailed drawings (if available) and any other available or prepared drawings or schematics and physical inspection of the existing systems, including areas of access for maintenance and treatment
- the components of the systems, particularly those related to temperature and disinfection, such as hot or warm water systems, cold water pipes, looped and recirculating systems, thermostatic mixing valves (TMVs), tempering valves, backflow prevention devices, thermal insulation of pipes, dosing systems for disinfectant or other chemicals and filters
- systems connected to the water distribution system (eg fire protection and firefighting systems, irrigation systems, water features, garden fountains, birthing pools, spa baths, hydrotherapy pools and systems for the treatment of patients such as nasogastric or end tubes and dialysis equipment), particularly where these systems may result in water being held for extended periods
- all outlets and their locations (eg showers, basins, washing machines, dishwashers, ice machines, chilled water dispensers)
- materials used in constructing the systems
- the temperature of water throughout the water distribution system, particularly identifying where water is regularly or seasonally present in the range of >20°C to <60°C for extended periods of time, whether intentionally or unintentionally
- details of any previous *Legionella* testing results from previous sampling and testing of the system
- details of any previous cases of *Legionella* infection suspected or found to be associated with the system.

In many cases, simplified flow diagrams will be useful in understanding risks and the potential for effective controls.

Analysis of water uses should include specific physical and microbial requirements of the use, including water temperature and whether the water is required to be of drinking water

standard or, for severely immunocompromised patients, above drinking water standard (eg cooled, boiled water or microfiltered water).

### 2.1.2 At-risk patients

The next step is to review the functioning of the facility to identify areas where there is a higher risk of infection to patients, residents or staff, based on the known risk factors listed in the Introduction. For example, the presence of newborns, older people or immunocompromised patients will require more stringent control measures.

The at-risk patient analysis will typically include:

- clinical functions (eg maternity, oncology, intensive care)
- patient risk (high risk of infection through inhalation or aspiration)
- specialist needs (eg sponge bathing, hydrotherapy, dental).

## 2.2 Identifying hazards, hazardous events and risk

Once you have collected plumbing system and patient information, this will allow you to systematically identify water system and health risks, and devise and implement control measures to address them.

The measures used to control the growth of *Legionella* bacteria in a water distribution system can also assist in controlling other microbial hazards, including opportunistic pathogens such as *Pseudomonas aeruginosa*, non-tuberculous mycobacteria, *Acinetobacter* spp. and *Stenotrophomonas maltophilia*.

### 2.2.1 Hazards and risks

Effective risk management requires identification of hazards, sources of hazards and potential hazardous events, and assessment of the level of risk presented by each. In this context:

- a **hazard** is an agent that has the potential to cause harm (eg *Legionella pneumophila*)
- a **hazard source** is a location or condition that can give rise to, or increase, a hazard (eg biofilm is a hazard source for *Legionella* bacteria as it protects *Legionella* from being controlled by disinfectants)
- a **hazardous event** is a situation that can lead to the presence of a hazard (eg a decrease in temperature in a hot water system to below 60°C provides conditions conducive to *Legionella* growth)
- a **risk** is the likelihood that a hazard will cause harm to people in a specified timeframe, combined with the magnitude of that harm and its consequences.

Reviewing the system analysis to identify areas of hazard, hazard sources and potential and previous hazardous events will allow a better appreciation of the risks and how to control them in a manner that is appropriate to the facility.

In the case of *Legionella*, the risk management team must also be mindful that processes to control *Legionella* or address incidents may in themselves create a hazard (eg increasing water temperature may create a scalding hazard; adding high levels of chemical disinfectant

may create a burn, irritant or environmental hazard at the point of use or discharge). Managing *Legionella* in a health or aged care facility requires balancing these hazards with that of *Legionella*. This needs to be considered in the facility risk assessment so that controls appropriate to the circumstances can be implemented.

### **2.2.2 Risk assessment**

The system analysis should form the input to the risk assessment process. It is important that the risk assessment process considers the water system risks and health risks. An overview of these risks are provided in Figure 1. Specifically, the process should consider the likelihood of *Legionella* colonisation and infection, and the consequence of colonisation or infection (the presence of at-risk patients and the consequences should the at-risk group become infected).

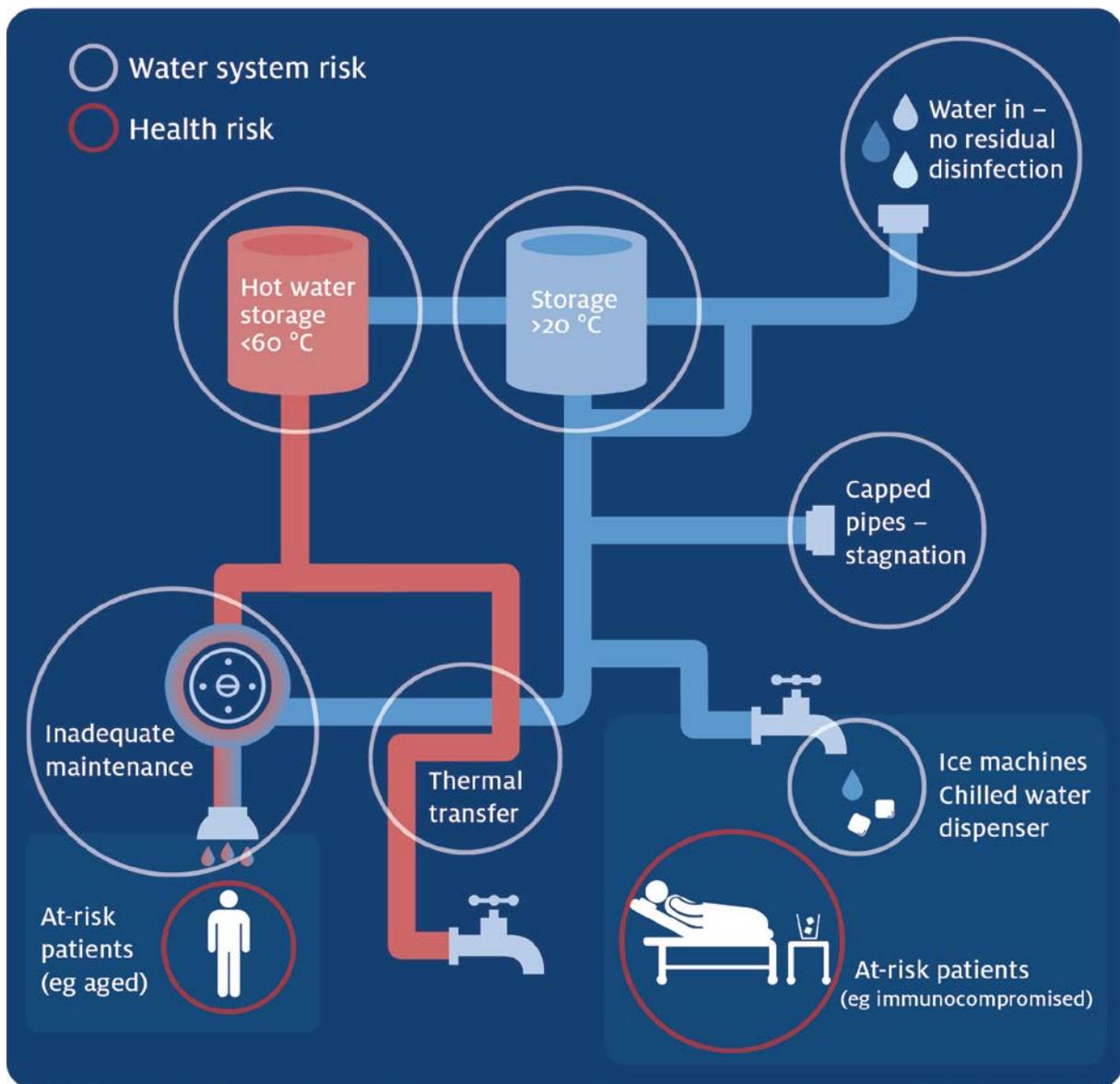
Risk assessment methodologies are widely used in health and aged care facilities, and can be adapted to this process. The system analysis should provide the basis to work through the likelihood of *Legionella* growth, all the potential routes of exposure, the likelihood of an exposure of a susceptible person and the potential consequences of such an exposure. This information can be applied to a standard risk matrix for risk management prioritisation by identifying appropriate actions and their timing based on the matrix (ie the higher the risk and the more significant the consequences, the more urgently an immediate control measure is required). Some examples of risk assessment tables are provided in Appendix 1.

Risk assessment is intended to provide facility managers and care staff with sufficient information to ensure that decisions made protect the occupants of their buildings, while being proportionate to the risk.

### **2.2.3 Risk assessment based on system analysis**

Having undertaken a system analysis to better understand how the plumbing system in the facility is configured, the risk management team will be in a position to identify possible hazard sources and hazardous events, and the risk to which vulnerable people will be exposed. The following section describes hazards and hazardous events related to the plumbing system that should be considered as part of the risk assessment.

Figure 1 Schematic Overview of Water Distribution System Risks and Health Risks



### ***Incoming water quality***

Water can be provided to health and aged care facilities through either a:

- town water supply, where water is provided to the facility by a water service provider
- private water supply, where the facility directly obtains its own water through bore supplies, rainfall capture or other methods.

It should be remembered that *Legionella* is present in natural water bodies and that water treatment before distribution will usually not eliminate all *Legionella* present. Water supplies containing high concentrations of microbes – such as algae, amoebae and other bacteria – can contribute to *Legionella* growth by sheltering it from disinfection in biofilms or by providing nutrients for its growth.

As water passes through the distribution network of a town water supply, it can be subject to factors that can increase the risk of *Legionella* colonisation and growth. For example, the risk of *Legionella* growth within water networks is increased if temperatures are between 20°C and 45°C. Also, the amount of residual disinfection (ie the amount of free residual chlorine or chloramine originally added to water supplies remaining in the water as it makes its way through the distribution network) can vary substantially, depending on a facility's location on the network. Facilities further away from the point of disinfection in the network may not receive water with the same concentration of residual disinfectant as facilities that are closer. If free residual chlorine or total chlorine (in the case of chloraminated supplies) is below 0.5 mg/L in the incoming water, there is a greater risk that *Legionella* will proliferate.

For chlorinated drinking water supplies, the Australian Drinking Water Guidelines states that free residual chlorine of between 0.2 and 0.5 mg/L in the distribution network is adequate, and the Drinking Water Standards for New Zealand requires only a minimum of 0.2 mg/L free residual chlorine in water leaving the treatment plant.

On that basis, health and aged care infrastructure managers need to be aware that even a well-managed water supply from a water service provider does not guarantee *Legionella*-free water or free residual chlorine of 0.5 mg/L in the supplied water at the point of entry to the facility. *Legionella* risk management plans will still be needed to analyse and manage *Legionella* risk within each facility.

Water supplied to the facility through private supplies or sourced on site (eg rain or bore water) is typically the responsibility of the facility itself. The facility manager should manage this supply in accordance with local drinking water regulatory requirements and this document to minimise the risk of *Legionella* growth.

### **Plumbing systems**

Complex plumbing systems, as are often found in health and aged care facilities, may create optimal conditions for *Legionella* proliferation. Common hazard sources include the following:

- **Pipework that allows heat transfer:** *Legionella* may be present in the town water supply but, where temperatures are below 20°C, growth is typically very slow and the concentration of *Legionella* is usually below the limit of detection using culture methods. In a facility, water temperatures within the range of 20–45°C create conditions where *Legionella* is able to grow, with maximum proliferation in the range of 37–43°C. Poorly designed or improperly installed water systems may allow transfer of heat to cold water piping from heated water systems, other equipment or the environment, when the piping is within roof spaces, poorly insulated or subject to direct sunlight or other forms of external heating. Any of these situations can result in cold water temperatures greater than 20°C, increasing the risk of *Legionella* growth.
- **Pipework that allows water stagnation:** Pipework can allow water to stagnate if it has been improperly installed or has been modified over time in a way that allows water to remain in it for extended periods (eg lengths of pipes cut off and capped

during the transformation of a ward to offices). Some common practices, such as installing capped pipes to allow for future facility expansion, and bypass valves on filters and ultraviolet (UV) systems, can also result in stagnation. Sections of a water distribution system that do not allow the flow of water are known as dead legs.

Another stagnation concern is idle legs, which are pipe lengths that are not regularly flushed (eg when a patient bathroom is unused for 7 days). In all cases, low flow or stagnant water can provide conditions that contribute to the growth of *Legionella*.

- **Age or condition of pipes:** The presence of biofilms, scale, sediment, sludge, corrosion products or organic matter in pipes can provide environments for *Legionella* to grow. Certain plumbing materials (eg fittings made of rubber or some plastics) can provide attachment surfaces for biofilms and nutrients to support proliferation of *Legionella*. They can also affect the flow of water, again producing conditions that may contribute to *Legionella* growth.
- **Incorrect selection of pipework material:** A number of pipework materials have been shown to increase the growth of *Legionella* by enhancing the formation of biofilms or the supply of nutrients that encourage bacterial growth. These materials include rubber, acrylonitrile butadiene styrene (ABS), styrene butadiene rubber (SBR) and polyvinyl chloride (PVC), as well as corrosion products of iron and steel. It should be noted that the presence of these materials does not necessarily require their removal; however, their presence does increase the risk of *Legionella* and other microbial growth, and may require additional risk management. System materials should also be compatible with disinfection chemicals at the concentrations they are likely to be used.
- **Deficiencies in commissioning new pipework:** Following the installation of pipework, commissioning is undertaken to identify leaks and confirm that the system performs to requirements before normal operation begins. *Legionella* contamination and colonisation of pipework and other water infrastructure may occur during manufacture, transit, storage or construction. Pre-commissioning disinfection (eg chlorination) should be undertaken for all new plumbing installed in health and aged care facilities, and it is important that facilities ensure that this has taken place before handover of infrastructure.
- **Cold water storages:** Some facilities store water in tanks to ensure consistency of supply. Storage tanks may provide environments where residual disinfectant diminishes over time, or sludge or biofilm builds up, creating an environment conducive to *Legionella* growth. Storages located in or on roofs can also be subject to increased temperatures. Tanks should be monitored and cleaned periodically.

### **Heated water systems**

Heated water is defined in Australian Standard AS/NZS 3500.0 as ‘water that has been intentionally heated. It is sometimes referred to as hot water or warm water’. AS/NZS 3500.4 requires that ‘heated water shall be stored and delivered under conditions that avoid the likelihood of the growth of *Legionella* bacteria’.

Two main designs for heated water systems dispense warm water for sanitary purposes to prevent scalding:

- those that deliver hot water through the majority of the system, including where TMVs are used close to the point of use, where the hot water is cooled to the desired (warm) dispensing temperature for sanitary purposes by mixing with cold water (hot water systems)
- those that distribute warm water throughout the majority or all of the system (warm water systems).

Of these, warm water systems have the highest potential for systemic *Legionella* colonisation, as they have a significant proportion of plumbing infrastructure containing water at a constant temperature suitable for the growth of *Legionella*.

This contrasts with hot water systems that deliver hot water ( $\geq 60^{\circ}\text{C}$ ) to TMVs located at or near the point of use. Temperatures  $\geq 60^{\circ}\text{C}$  will control *Legionella*. These systems are therefore generally regarded as the preferred design for minimising the risk of *Legionella* growth in health and aged care facilities. However, the TMV and the downstream plumbing fixtures will contain water below  $60^{\circ}\text{C}$ . Since cold water can contain *Legionella*, the TMV itself as well as the downstream plumbing can become colonised with *Legionella*, meaning that all systems should be considered a risk for *Legionella*. Monitoring the temperature of hot water returning to the boiler in recirculating loop hot water systems is recommended. Return temperatures  $\geq 55^{\circ}\text{C}$  should be maintained at all times.

Additional infrastructure may also produce and sometimes store heated water within the optimal range for growth of *Legionella* and other microbes. For example, in solar water heating and pre-heating systems, solar variability may prevent temperatures from reaching  $60^{\circ}\text{C}$  if a booster is not present and operating correctly. Where temperatures are consistently above  $60^{\circ}\text{C}$  and the booster is operating correctly, solar water heating systems are unlikely to present a major *Legionella* risk. However, if temperatures never reach  $60^{\circ}\text{C}$ , these devices may present a growth risk, particularly if large volumes of pre-heated water are stored in the system.

### **Cold water systems**

The rate at which *Legionella* can grow is reduced in cold water, but growth is not completely stopped, and *Legionella* can survive to grow in other parts of the system where conditions are conducive to growth. Therefore, there is a risk that *Legionella* can survive within these systems and subsequently proliferate when introduced to optimal growth conditions, such as inadvertent warming during distribution through the cold water plumbing.

In the ‘cold water’ supplies of many health and aged care facilities in tropical or subtropical climates in Australia, the temperature of water supplied to facilities by the drinking water service provider can be well above  $20^{\circ}\text{C}$ . This limits opportunities for temperature control within the facility and can be expected to make other controls significantly more important in limiting *Legionella* growth.

## **Equipment and installations**

Legionnaires' disease typically results from inhalation of aerosols or aspiration of water containing *Legionella* by a susceptible person. Aerosols may be generated through clinical devices, plumbing outlets, therapeutic equipment, water features or even garden irrigation. The risks associated with some of these items are, in no particular order, as follows:

- **Birthing pools:** These pools can harbor *Legionella* if the water is inadequately disinfected or where the water is heated and recirculated. Newborns may aspirate contaminated water, so the risk from such pools should be carefully assessed and managed in birthing facilities.
- **Decorative fountains and water features:** Commonly found in public spaces such as foyers and contemplation rooms, these devices can generate aerosols that may lead to infection of at-risk individuals. Aerosols from these devices can be drawn through open windows, doors and air intakes, or onto balconies and patios. Submerged lighting and pumps can provide a heat source that can promote the growth of *Legionella*.
- **Dental chairs:** Build-up of biofilm within the plumbing of dental chairs (including handpieces, ultrasonic scalers, air or water syringes, water storage devices [where used] and waterlines), and generation of water aerosols within the mouth and breathing zones during dental procedures can lead to infection of at-risk individuals.
- **Garden irrigation systems, water features and pressure sprayers:** These systems can produce fine aerosols and operate at elevated temperatures that can cause risks if the aerosols reach vulnerable people via air-conditioning intakes or open windows, doors, balconies or patios. Long hoses and surface plumbing, which can result in increased water temperatures in hot weather, may increase this risk.
- **Hydrotherapy pools:** These pools can maintain water at temperatures favourable for *Legionella* growth, but pose a lower risk than spas because the potential for aerosol generation is lower.
- **Ice machines and water coolers:** *Legionella* can survive freezing. A risk can arise if severely immunocompromised patients are given ice to suck on or chilled water to drink, which can lead to accidental aspiration of *Legionella*-contaminated water. Heat generated by a water chiller or ice machine's compressor may create optimal growth temperatures in water supplying the ice machine or chilled water dispenser. In addition, these devices often include activated carbon filtration on the inlet, which can remove residual disinfection from the water, increasing the opportunity for *Legionella* to colonise the device downstream of the carbon filter. It is recommended that activated carbon filtration is not used in ice machines and water coolers in health and aged care facilities.
- **Respiratory therapy equipment:** Inhalation of contaminated aerosols from items such as nebulisers and humidifiers can lead to infection of at-risk individuals.
- **Showers:** Showerheads may generate fine aerosols that can be inhaled. Both showerheads and shower hoses are known to support the growth of *Legionella* because water may remain in them for extended periods, particularly if they are not used frequently. The ability of these fittings to support the growth of *Legionella* and

generate fine aerosols that can transmit *Legionella* deep into the lungs can make showers a high risk for vulnerable people, particularly severely immunocompromised patients.

- **Spa pools:** These pools feature water temperatures that support *Legionella* growth and they generate aerosols. There is therefore a risk of aspiration or inhalation of *Legionella*-contaminated aerosols if cleaning or maintenance is inadequate, or where water quality (in particular residual disinfectant levels) is not adequately maintained.

#### **2.2.4 Risk assessment of patients or residents**

The second element of the risk assessment is to determine which patients or residents are most at risk of *Legionella* infection, where they are located in the facility and how they might be exposed.

In some facilities, there may be designated wards or rooms where vulnerable people reside, and these may be assessed as being of higher risk than other parts of the facility. In other facilities, wards or rooms may be occupied by different people of varying vulnerability; the risk assessment may therefore need to accommodate these differing uses.

## 3. Managing your risk

The management of *Legionella* risk in health and aged care facilities is an ongoing process that involves the establishment, implementation and maintenance of control measures. The control measures and their maintenance should be documented in the risk management plan, and should be regularly monitored and reviewed for their effectiveness in reducing the overall risk.

The system analysis and risk assessment will provide the understanding required to determine the extent of controls needed and allow you to scale an approach appropriate to your facility. The following describes a range of control measures to consider incorporating into a *Legionella* risk management plan.

### 3.1 Implementing controls

To prevent infection, health and aged care facilities should implement proactive strategies to reduce the risk of growth of *Legionella* within their water distribution systems and minimise exposure of vulnerable people. Since a number of control options are available, depending on the level of risk and the feasibility of implementing the controls, *Legionella* control programs are based on a ‘multi-barrier’ approach, which involves implementing a number of controls that collectively reduce the risk of *Legionella* infection.

If only single point controls are used (eg increased temperature), there is a risk that failure of that one control measure can create a *Legionella* infection risk. The multi-barrier approach is more likely to reduce the risk of infection because there is a series of back-up controls in place. A multi-barrier approach uses:

- controls associated with the quality of the incoming water (Section 3.1.1)
- plumbing controls, including design, commissioning and operational controls (Section 3.1.2)
- disinfection systems (Section 3.1.3)
- regular maintenance (Section 3.1.4)
- exposure controls for patients based on their risk status (Section 3.1.5).

For each control measure identified, it is necessary to determine:

- the objective of the control measure
- the location in the system where the measure is to be implemented and controlled
- the type and frequency of monitoring for the control measure
- the acceptable limits for the parameter being monitored
- the corrective action to be taken if the parameter fails to meet the acceptable limits
- the documentation procedure for the control measure.

### 3.1.1 Incoming water quality controls

Where significant hazards and risks have been identified with the incoming water supply (eg high turbidity, high temperature, inadequate residual disinfectant), you should discuss potential improvements that could be made to the supplied water with your water provider. In the case of low residual disinfection, discussions with the provider are warranted. However, it should be recognised that the residual may not be easily increased, and the supply network infrastructure may be very difficult to modify. Operational water quality infrastructure controls (see Section 3.1.2) such as on-site water treatment will likely be necessary if the drinking water provider is unable to resolve incoming water quality concerns.

### 3.1.2 Plumbing controls

The plumbing system within a health or an aged care facility presents a number of risks associated with the growth of *Legionella*, and a number of controls may be needed for these risks.

#### *Design controls*

Design controls are most effective when applied during building construction and involve avoiding the creation of hazard sources (described in Section 2.2.3). However, consideration should also be given to measures that reduce the risk of *Legionella* during design of renovations or newly installed systems within a facility. When decommissioning a section of a water distribution system, redundant pipework and attached systems should be isolated and drained without creating dead legs. Compliance with any relevant plumbing standards and codes is essential.

Section 2.2.3 provides details of the design risks for plumbing systems. Care should be taken in design to avoid or minimise these risks by undertaking a risk assessment of any proposed plumbing design. For example:

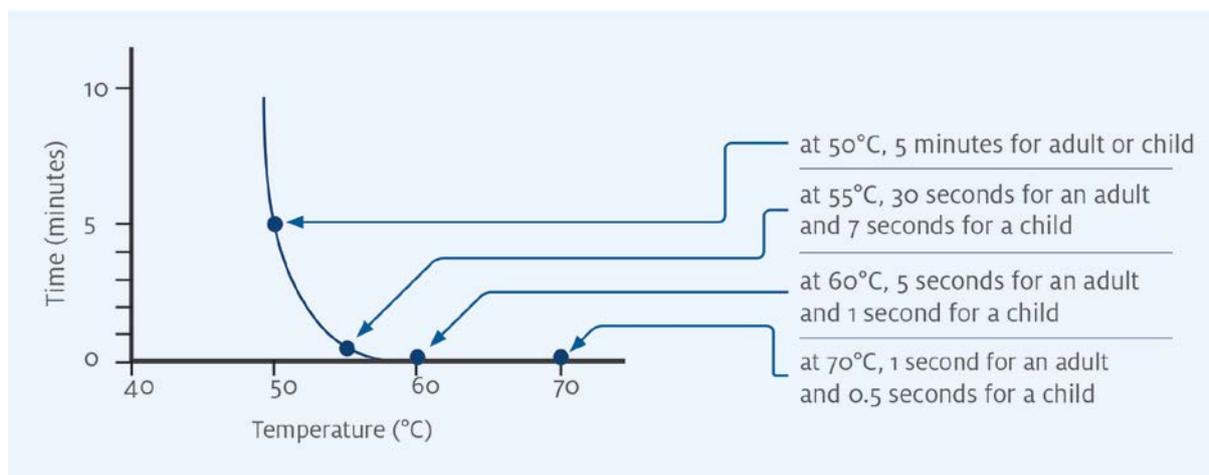
- dead legs and areas of low flow should be avoided
- pipework should be designed and installed in a way that ensures that temperature transfer between hot and cold pipes does not occur
- where possible, the use of materials known to support the growth of biofilm should be avoided and the materials selected should also be compatible with the concentrations of disinfection chemicals that may be used in the system (eg high concentrations of chlorine for short periods of time).
- hot water systems should be designed to maintain a storage temperature of  $\geq 60^{\circ}\text{C}$  and a return temperature of  $\geq 55^{\circ}\text{C}$  at all times, including times of peak demand on the system
- cold water storage should be designed to prevent local contamination and heating above  $20^{\circ}\text{C}$  during periods of extended hot weather
- cold water pipework should, as far as reasonably practical, be protected from the environmental heating of contained water above  $20^{\circ}\text{C}$ .

A key design consideration is achieving a balance between the need to maintain heated water temperatures at a minimum of  $60^{\circ}\text{C}$  to minimise the risk of *Legionella* growth and the need

to dispense heated water at approximately 45°C for sanitary purposes to prevent scalding. Figure 2 shows the time required for a full-thickness burn at various temperatures. To prevent scalding, heated water systems should have accessible and serviceable TMVs installed at or near outlets to dispense heated water for sanitary purposes at a suitable temperature. New tapware designs that allow for integrated microfiltration, remote electronic flush control, and TMV and snap-lock disconnection must also be serviceable.

The provision of convenient and safe access for monitoring, maintenance and water treatment should be considered at the design stage. The correct implementation of specified design controls should be confirmed postconstruction.

Figure 2 Time required for full-thickness burns at varying temperatures



Source: SA Health (2013)

### **Commissioning controls**

Since there are hazards relating to the commissioning of new equipment or entire new facilities, it is strongly recommended that the water quality is checked via *Legionella* testing before the handover or operation of a facility. Effective commissioning is a critical point for *Legionella* risk in the life of a building. If detectable levels of *Legionella* are present in a new water distribution system at the time of handover, *Legionella* concerns will likely remain for the life of the system.

Section 18 of AS/NZS 3500.1 describes the requirements for commissioning a drinking water service, and must be strictly followed to minimise the potential for *Legionella* colonisation. Pre-commissioning chlorination should be undertaken for all new water tanks and plumbing infrastructure installed in health and aged care facilities, regardless of pipe diameter or water supply (eg not limited to storage tanks and water services that are DN 80 or larger, as specified in Appendix J of AS/NZS 3500.1).

Contractors undertaking commissioning works must be suitably trained and experienced, and should be asked to confirm that pre-commissioning chlorination and subsequent *Legionella* testing will take place. Samples for *Legionella* testing must not be collected for at least 3 full days after the pre-commissioning chlorination is completed. Contractors should provide

evidence that this has taken place and has been effective by providing the results of testing showing that *Legionella* has not been detected.

Pre-commissioning chlorination and subsequent *Legionella* testing should be conducted:

- when a plumbing system is newly constructed
- after modification of a plumbing system
- after a portion of a plumbing system is decommissioned, but remains connected for future capacity requirements (this is not recommended)
- when recommissioning a stagnant system.

The *Legionella* risk management plan should be reviewed during the commissioning phase to consider risk factors such as:

- when a building is expected to only be partially occupied, which may result in low flow or stagnation
- when ongoing construction within or adjacent to a building may affect water quality.

If *Legionella* is detected via water testing (eg positive *Legionella* culture), the water system should be chlorinated again in accordance with the procedures outlined in Appendix J of AS/NZS 3500.1. *Legionella* testing should also be conducted weekly for 4 weeks after occupancy to confirm the microbial stability of the system.

### Operational infrastructure controls

The *Legionella* risk management team should consider implementing the following operational infrastructure controls during daily operation of a facility to ensure that the risk of *Legionella* growth is minimised. Controls are based on managing water system risks or health risks.

These controls may include:

- for water system risks
  - installing on-site disinfection systems that increase the level of free residual chlorine or other disinfectant circulating in the water system
  - maintenance and monitoring to ensure that water system risks are managed on an ongoing basis
  - weekly flushing of unused outlets
  - installing point-of-entry filtration (eg installed at the water supply inlet to the facility). This is unlikely to have any significant impact if biofilms and *Legionella* already exist within the system. However, it may improve the efficacy of on-site residual disinfection by reducing turbidity if this is a problem in the incoming water.
- for health risks
  - in higher-risk areas such as those where immunocompromised patients are present, removing aerosol-generating items (eg showers, misting devices, tap aerators) to reduce the likelihood of infection

- using point-of-use microfiltration to prevent the discharge of *Legionella* when it is detected in a specific section of a water distribution system
- modifying care practices, such as substituting sponge bathing for showering.

### 3.1.3 Disinfection systems

No single method of disinfection will work for all sites and in all circumstances. This is because there are many differences between sites, including differences in:

- incoming water quality and chemistry
- design and maintenance of the system
- number of outlets
- compatibility of system materials or attached equipment using water from the system with some disinfectants
- the number of staff available for maintenance
- system usage patterns
- vulnerability of patients or residents.

Different facilities will need different solutions. It is up to the *Legionella* risk management team and the staff overseeing the water system to identify which method is most appropriate, based on manufacturers' validation data, independent published reports, independent expert advice and their own knowledge and experience. Because of the variability in systems and the changing nature of systems over time, this may involve trial and error, or even require different solutions for different parts of the system.

Both systemic and localised treatments are available.

Systemic treatments, which treat all of the water in all or part of the system, include:

- heat disinfection – also known as pasteurisation or thermal shock disinfection (usually limited to all or part of some heated water systems, not an entire water distribution system)
- chlorination
- chlorine dioxide
- copper–silver ionisation.

An overview of systemic treatments is presented in Table 1.

Localised treatments only treat water passing one or more points within the system. Such treatments may be usefully applied to the incoming cold water supply to prevent *Legionella* entering the system, particularly for systems that have a history of contamination. Alternatively, localised treatments can be used as point-of-use treatments to disinfect parts of a water distribution system in higher-risk areas. These methods have either little or no residual effect, and are commonly employed at or near the point of use. Localised treatments include:

- UV light
- ozonation
- point-of-use microfiltration.

An overview of localised treatments is presented in Table 2.

The most effective treatments have proven to be a combination of systemic disinfection of entire water systems and local disinfection or filtration of specific portions of systems where people at greater risk of *Legionella* infection may be present.

Any parts of the system where penetration of the disinfectant is prevented (such as dead legs) will reduce the effectiveness of a disinfection method. This means that selection of a particular method of disinfection must consider the system as a whole.

All disinfection systems will require regular monitoring, inspection and maintenance to ensure effective operation, varying in frequency with the type of treatment, equipment and associated risks. Facilities with disinfection systems should document procedures and recording requirements for:

- routine inspection, maintenance, calibration and, when necessary, repair of dosing equipment
- confirmation of adequate water chemistry throughout the system relevant to the disinfection method used
- monitoring and maintenance of consumable items.

All staff and contractors who operate, monitor or maintain disinfection systems should be suitably trained and experienced.

Table 1 Overview of systemic treatments

Technology	Description	Strengths	Weaknesses
Heat disinfection (pasteurisation or thermal shock disinfection)	Periodic heating of the calorifier or water heater to a temperature sufficient to achieve 70°C at all outlets and then flushing heated water through all heated ring mains, heated water pipework and heated water outlets to control <i>Legionella</i>	<ul style="list-style-type: none"> <li>• Relatively simple (theoretically but generally not in practice)</li> <li>• Does not require addition of chemicals</li> </ul>	<ul style="list-style-type: none"> <li>• Scalding hazards from the super-heated water</li> <li>• Requires considerable hours of labour</li> <li>• Results in a high volume of wastewater</li> <li>• Uses a large amount of energy to heat water</li> <li>• Many facilities do not have sufficient hot water capacity to offer this method</li> <li>• Has poor long-term control</li> <li>• May unintentionally lead to significant heat transfer to cold water</li> <li>• Cannot be used to disinfect cold water pipework</li> </ul>
Chlorination	Sodium hypochlorite, chlorine gas or chloramines added to the water to control <i>Legionella</i>	<ul style="list-style-type: none"> <li>• Relatively easy to implement and monitor</li> <li>• Relatively cost effective depending on dosing equipment required and volume of chlorine needed</li> <li>• Easily installed in existing systems, without major modifications</li> <li>• Residual effect for downstream decontamination</li> </ul>	<ul style="list-style-type: none"> <li>• Potential corrosion of pipework and other plumbing infrastructure</li> <li>• pH must be maintained at <math>\leq 7.6</math> to be effective</li> <li>• Free residual chlorine and chloramines decay rapidly at hot water temperatures (<math>\geq 60^{\circ}\text{C}</math>)</li> <li>• Different concentrations are required for residual disinfection and superchlorination</li> <li>• Generation of undesirable disinfection byproducts such as trihalomethanes</li> <li>• May be incompatible with reverse osmosis membranes</li> <li>• Removed by activated carbon filtration and UV light</li> </ul>

Technology	Description	Strengths	Weaknesses
Chlorine dioxide	Highly water soluble gas or stabilised liquid added into water to control <i>Legionella</i>	<ul style="list-style-type: none"> <li>• Less corrosive than chlorine</li> <li>• More effective than chlorine but less effective than ozone</li> <li>• Residual effect for downstream decontamination</li> <li>• Inactivation efficiency not pH dependent at pH 5–10</li> </ul>	<ul style="list-style-type: none"> <li>• Produces chlorite and chlorate as byproducts, which must be monitored (along with chlorine dioxide) and prevented from exceeding health guideline concentrations</li> <li>• Unsuitable for use in water with high oxidant demand</li> <li>• Removed by activated carbon filtration and UV light</li> </ul>
<b>Copper–silver ionisation</b>	Copper and silver ions released into the water to control <i>Legionella</i>	<ul style="list-style-type: none"> <li>• Does not corrode piping or plumbing fixtures</li> <li>• Remains effective at all water temperatures</li> <li>• Easily installed in existing systems without major modifications</li> <li>• Residual effect for downstream decontamination</li> </ul>	<ul style="list-style-type: none"> <li>• Difficult to optimise the correct dosing for each system if the unit is not installed appropriately</li> <li>• Water hardness and pH can affect the efficiency of the system</li> <li>• Monitoring levels of silver and copper in the system is difficult</li> <li>• Not commonly used in Australia or New Zealand, therefore minimal local experience is available</li> </ul>

Table 2 Overview of localised treatments

Technology	Description	Strengths	Weaknesses
Ultraviolet (UV) light	UV light with a wavelength of 250–265 nanometres controls <i>Legionella</i>	<ul style="list-style-type: none"> <li>• Useful for small areas that may need additional or special attention, such as a high-risk unit</li> <li>• Relatively easy to install</li> <li>• No adverse effect on water or plumbing</li> <li>• Leaves no taste or chemicals in the water</li> <li>• Has no disinfection byproducts</li> </ul>	<ul style="list-style-type: none"> <li>• Limited application (point-of-use or supplementary disinfection tool)</li> <li>• Affected by turbidity and particulates, which ‘shade’ bacteria from the UV, rendering it less effective</li> <li>• No residual effect</li> <li>• Performance depends on the system being designed to be suitable for the flows</li> <li>• No effect on biofilm</li> </ul>
Ozonation	Gas generated on site and added immediately to water to control <i>Legionella</i>	<ul style="list-style-type: none"> <li>• Effective over a wide pH and temperature range compared with chlorine</li> <li>• Very strong oxidiser</li> <li>• Effective at low concentration</li> </ul>	<ul style="list-style-type: none"> <li>• No residual effects</li> <li>• High concentrations may damage piping, fittings and seals</li> <li>• Minimal impact on biofilm-bound <i>Legionella</i></li> <li>• Unstable, so must be produced on site and used immediately</li> <li>• Can produce harmful by-products in drinking water</li> </ul>
Point-of-use microfiltration	Membrane filter installed at or near outlet with pore size of $\leq 0.2 \mu\text{m}$ , which prevents most bacteria from passing through while allowing normal water flow	<ul style="list-style-type: none"> <li>• May assist where other methods are unable to control <i>Legionella</i> or in areas where disinfectant residuals are to be avoided (eg dialysis)</li> <li>• Can be a useful supplement to another form of disinfection for high-risk areas</li> <li>• Can allow continued use of <i>Legionella</i>-contaminated systems in high-risk areas while investigations are undertaken and engineering solutions sought</li> <li>• Has no disinfectant by products</li> <li>• Plumbing modifications may be required</li> </ul>	<ul style="list-style-type: none"> <li>• Must be periodically replaced or sterilised</li> <li>• Relatively high maintenance burden</li> </ul>

### 3.1.4 Regular maintenance

Your water systems will need regular maintenance to ensure that the risk of *Legionella* colonisation remains low and that the control measures are in place and are working. Maintenance should be undertaken in conjunction with a system of water quality monitoring (Section 3.2).

Generally, the supplier of disinfection equipment will be responsible for maintenance of that equipment. Users need to satisfy themselves of the availability of ongoing maintenance arrangements and support, particularly in rural locations and outside normal working hours.

A common cause of *Legionella* growth within water distribution systems is the presence of hidden dead legs and/or cold water with temperatures above 20°C and/or hot water with temperatures below 60°C. Therefore, when hot or warm taps are no longer required within a facility, they and associated pipework should be removed and cut back to the recirculating loop or main distribution point without creating a dead leg.

All unused outlets should be flushed every 7 days at full flow. Where outlets have the facility to mix warm and cold water, both warm and cold sections must be flushed. The period of flushing must be sufficient to remove all stagnant water leading to the outlet and for the operating temperature to be reached at the outlet.

Typical maintenance regimes are based on the system analysis and risk assessment. They include:

- monitoring the condition of any water storages, tanks and vessels (eg for sediment build-up, turbidity, disinfectant residual, pH) and cleaning, repairing or replacing them when necessary
- ensuring that thermostats and other temperature devices are working effectively
- maintaining appropriate temperatures in water storages and throughout the water distribution system
- maintaining and calibrating disinfection units
- monitoring levels of disinfectant chemicals to ensure that adequate levels of disinfection are being maintained
- calibrating probes and monitoring equipment
- cleaning system components such as TMVs, outlets or showerheads/shower hoses to prevent or remove biofilms, scale or other environments that may contribute to the growth of *Legionella*
- periodically repairing and/or replacing shower hoses and heads, taps and other outlets
- weekly flushing of unused outlets (as discussed above)
- replacing filters in accordance with manufacturers or suppliers instructions.

### 3.1.5 Exposure controls

Although water and plumbing controls are important to avoid or reduce the growth of *Legionella*, exposure controls are also needed to ensure that the patients, staff and visitors of

health care and aged care facilities are not at risk from aerosols that potentially contain *Legionella*.

Exposure controls will vary, but can include:

- removing aerators from taps
- avoiding mist-generating devices
- switching to showers that reduce the amount of aerosol generation.

The general principle is to reduce the chance of contaminated aerosols being generated, dispersed and inhaled by those groups most susceptible to *Legionella* infection. Many exposure control measures are labour intensive and, as such, their use is often limited to areas of greatest risk in a facility.

Exposure control options include:

- providing sterile water for drinking (eg boiled and cooled, sterile bottled or dispensed via point-of-use microfiltration) in areas where high-risk patients are not bathed, such as intensive care units and high-dependency units
- avoiding use of ice machines and water chillers for high-risk patients where aspiration may be a risk (eg patients with swallowing problems)
- using sponge bathing in place of showers
- using point-of-use microfiltration to exclude *Legionella* from basins or showers (see Section 3.1.3)
- managing aerosol dispersion (eg exhaust ventilation systems in shower enclosures).

### 3.2 Monitoring

Sampling and analysis of water in a facility's water distribution system is vital to:

- ensure that the risk control measures instituted are effective – this is sometimes referred to as **operational monitoring**
- determine the presence and extent of *Legionella* colonisation, both generally and following the implementation of control or remediation measures – this is known as **verification monitoring**.

Monitoring is part of an effective *Legionella* risk management strategy. Monitoring provides the ability to assess the effectiveness of maintenance and controls, and detect the presence of *Legionella* before cases of Legionnaires' disease occur.

There is no single formula for determining the ideal monitoring approach for all facilities. Where internal expertise is not available, external expert advice may be sought to ensure that any monitoring reflects actual conditions as far as is practical, and is cost-effective. This document provides an overview of key monitoring elements and methods, so that facilities that are not in a position to determine their own monitoring approach are better able to evaluate the appropriateness of an approach proposed by another party. Sample collection,

transportation and analysis should be undertaken or overseen by suitably trained and experienced people.

The locations and frequency of monitoring should be based on factors such as:

- the system analysis and assessment of the risk that the cold, warm and hot water systems and their components might cause residents, patients, visitors or workers to contract Legionnaires' disease
- the size and complexity of the system (eg more extensive pipework and more outlets will require more samples, to ensure that the samples are representative of the system)
- the extent to which the risks are managed and monitored by other means (eg multi-barrier proactive approaches, including temperature and disinfection, and the results of monitoring of these parameters)
- the implications of an outbreak of Legionnaires' disease on the organisation, residents or patients, staff and the public
- compliance with state/territory or local guidance, requirements or regulations.

Once a monitoring approach has been developed, the process should be regularly reviewed by the *Legionella* risk management team and results should be recorded as directed by the *Legionella* risk management plan. Operational monitoring points should be clearly described and marked on a map or diagram of the facility, which is included in the *Legionella* risk management plan.

### 3.2.1 Types of monitoring

#### *Operational monitoring*

Operational monitoring involves the measurement, usually on site in real time, of specific parameters at specific locations within a water distribution system. The results of operational monitoring provide an immediate indication that the water quality within the system is within the required specifications (eg appropriate temperature, adequate disinfectant residual). Because the monitoring is performed in real time, operational monitoring results can trigger immediate corrective actions. The frequency of operational monitoring should be sufficient to quickly reveal any deviation from acceptable limits and relative to risk presented by such deviations (eg cold water temperature may only need to be monitored during the warmer months; hot water leaving boilers, storage or calorifiers may require continuous monitoring, with an automatic alarm triggered if the temperature drops below 60°C).

Monitoring of temperature, pH, turbidity and disinfectant residual are commonly used to confirm that *Legionella* controls are effective. Temperature testing is relatively simple. Monitoring of disinfectant levels is dependent on the type of disinfectant used. The capacity to easily and effectively monitor disinfectant levels should be a consideration in the selection of a disinfectant. Monitoring of water stagnation (ie the amount of time water sits in the pipe network) is essential to implement an effective weekly flushing program for unused outlets. This can be done from recorded room occupancy and frequency of use of outlets.

Details of the operational monitoring for the facility should be documented in the risk management plan and should include:

- the parameters being tested
- testing locations
- frequency of monitoring
- operational limit(s)
- the corrective action to be taken and communication requirements and responsibilities if the parameter is not within the specified operational limit
- the records to be kept for each monitoring activity and corrective action.

It can be useful to take samples from a location close to the entry point for incoming water so that any deterioration in water quality within the facility's water network can be assessed.

All measurement and sampling procedures, and corrective actions require a written procedure that provides the details of how to conduct and record the activity. An example of operational monitoring linked to elements of the system and the risks identified is provided in Table 3.

Table 3 Examples of water system risks, operational monitoring and controls for *Legionella* management in a health or aged care facility

Water system risk	Operational monitoring point(s)	Critical limit/ verification	Frequency of monitoring	Example control measures
Elevated turbidity in incoming water	At point of entry to facility	Turbidity >1 NTU (nephelometric turbidity unit)	Online, weekly or event based	<ul style="list-style-type: none"> <li>Request water provider to reduce turbidity of incoming water (eg through proactive pipe cleaning)</li> <li>Once water provider controls source of elevated turbidity, flush facility plumbing to waste, via scour if possible</li> <li>Filter and/or disinfect at point of entry</li> </ul>
Low disinfectant residual in incoming water (does not prevent <i>Legionella</i> growth)	At point of entry to facility	Free residual chlorine or total chlorine in chloraminated water supplies <0.5 mg/L	Online or weekly	<ul style="list-style-type: none"> <li>Enquire if water provider can increase disinfectant residual of incoming water</li> <li>Filter and/or disinfect at point of entry</li> </ul>
Stagnation of water in plumbing system	Monitor and record use of water in rooms/facilities	Outlet unused for 7 days	Same day every week	<ul style="list-style-type: none"> <li>Flush unused outlets</li> <li>Remove dead legs</li> </ul>
Water temperature (supports <i>Legionella</i> growth)	At selected representative hot and cold water outlets and storage vessels	Water temperature >20°C or <60°C	Monthly or more frequently if heater is undersized or during extended periods of hot weather Online continuous monitoring of hot storage and return water temperatures	<ul style="list-style-type: none"> <li>Increase temperature of calorifiers/storage</li> <li>Ensure that hot water pipes do not raise temperature of cold water pipes (eg via appropriate lagging)</li> </ul>
Low disinfectant residual within plumbing (does not prevent <i>Legionella</i> growth)	At cold outlets furthest from water supply point-of-entry to facility At warm water outlets furthest from water heater	Free residual chlorine <0.5 mg/L Free residual chlorine <0.2 mg/L	Weekly	<ul style="list-style-type: none"> <li>Boost disinfectant residual at point of entry to facility</li> <li>Increase flushing to prevent loss of residual within facility</li> <li>Test again to verify effectiveness of controls</li> </ul>

### **Verification monitoring**

Verification monitoring involves taking samples that are tested for specific parameters, usually at an analytical laboratory accredited for the analytical method being used. As a result, analytical results of samples taken as part of verification monitoring are often obtained more than 24 hours after the sample is taken (up to 10 days in the case of *Legionella* culture testing). Verification monitoring is used to confirm the quality of the water supply and determine whether the existing control measures are effective. Corrective actions can be undertaken as a result of adverse results; however, the corrective actions need to take into consideration the time lag between sampling and reporting of results.

The typical parameters that are analysed as part of verification monitoring are *Legionella* concentrations in water samples or presence when taking swabs of showerheads, outlets, spa jets, etc. Measuring the concentration of total bacteria (usually expressed as total bacterial count – TBC, heterotrophic colony count – HCC, or heterotrophic plate count – HPC) in water samples at the point of entry of water to the facility and at several distal outlets throughout the facility may be useful to indicate problem areas of microbial regrowth occurring within the facility water distribution system. However, TBC is not an indicator of health risk and the results should be interpreted accordingly.

A number of microbial tests are available for *Legionella*, as summarised in Table 4. Facilities should contact their local public health authority and accredited water testing laboratory for advice on the recommended testing method and sample size for their jurisdiction, and to obtain suitable sampling bottles (incorporating an appropriate disinfectant neutraliser). In addition to those methods listed, a commercial ‘fast one-hour’ *Legionella* field testing kit is commercially available, but it has not been recommended by public health authorities in Australia or New Zealand to date. Any technique used for *Legionella* testing of water should be fully validated and ideally accredited by the National Association of Testing Authorities (Australia) or International Accreditation New Zealand.

Verification monitoring is typically undertaken less frequently than operational monitoring. It is not usually urgent to receive verification sampling results, so culture currently remains the recommended method for *Legionella* verification monitoring. Verification monitoring should also include parameters usually included in operational monitoring (eg free residual chlorine and temperature), as this can assist in the interpretation of elevated TBCs or *Legionella* detections.

Details of verification monitoring for the facility should be documented in the risk management plan and should include:

- the parameters being tested
- testing locations
- frequency of monitoring
- operational limit(s)
- the corrective action to be taken and communication requirements and responsibilities if the parameter is not within the specified operational limit
- the records to be kept for each monitoring activity and corrective action.

All measurement and sampling procedures, and corrective actions require a written procedure that provides the details of how to conduct and record the activity and, where applicable, where and how samples must be sent for analysis.

Analysis for culturable *Legionella* is generally reported by Australian laboratories in terms of the numbers of colony forming units (CFU) of *Legionella pneumophila* serogroup 1 (SG1), *Legionella pneumophila* SG 2-14, *Legionella* species (not pneumophila), and total *Legionella* per millilitre or litre of water tested (CFU/mL or CFU/L). Although the relative numbers of these have implications for the risk of infection (*Legionella pneumophila* SG1 is generally the most virulent form), all *Legionella* detections should be treated the same in terms of the corrective actions applied.

It is important to be aware that failure to detect *Legionella* by culture does not guarantee the absence of *Legionella*, as *Legionella* is difficult to grow on culture media and viable but nonculturable (VBNC) *Legionella* may be present.

Table 4 *Legionella* testing options

Technology	Description	Strengths	Weaknesses
Culture methods	Involves growing <i>Legionella</i> on selective media and provides confirmation of total <i>Legionella</i> The culture method used and the sample size collected will determine the lower limit of detection	<ul style="list-style-type: none"> <li>The established methods for testing water for <i>Legionella</i> in Australia and New Zealand (AS/NZS 3896, ISO 11731 and ISO 11731.2)</li> <li>Cost-effective</li> <li>Well-understood methods</li> <li>Provides environmental isolate for comparison with patient isolate (if available)</li> </ul>	<ul style="list-style-type: none"> <li>Time consuming (up to 10 days – average 5–7 days)</li> <li>May underestimate level of <i>Legionella</i> because of difficulty in growing the organism on culture media and the possible presence of viable but nonculturable (VBNC) <i>Legionella</i></li> <li>Does not allow subspecies determination (although it is the initial step in determining subspecies)</li> <li>Reliability dependent on skill and experience of laboratory technician</li> </ul>
Immuno- agglutination (serotyping)	Involves an antibody–antigen- based reaction that tests <i>Legionella</i> colonies against antibodies specific for <i>Legionella pneumophila</i> serogroups	<ul style="list-style-type: none"> <li>Confirmed detections are identified as <i>Legionella</i> spp., <i>Legionella pneumophila</i> serogroup 1 or serogroup 2-14</li> </ul>	<ul style="list-style-type: none"> <li>Requires previous growth, typically through culture method</li> </ul>
Quantitative polymerase chain reaction (QPCR)	Involves amplifying a <i>Legionella</i> - specific DNA molecule to detect and quantify <i>Legionella</i>	<ul style="list-style-type: none"> <li>Specific and more sensitive than culture of <i>Legionella</i></li> <li>Rapid reporting (&lt;1 day)</li> </ul>	<ul style="list-style-type: none"> <li>Difficult to equate to standard culture methods (eg CFU/mL)</li> <li>Does not distinguish between live and dead bacteria</li> <li>Does not allow subspecies determination (eg <i>L. pneumophila</i> SG1 vs SG2-14)</li> </ul>
Rapid DNA assay	A method that couples standard <i>Legionella</i> culture methods with DNA technology to allow more rapid detection	<ul style="list-style-type: none"> <li>Equivalent in accuracy to culture method (AS/NZS 3896)</li> <li>Results available at least 3–4 days faster than culture method</li> </ul>	<ul style="list-style-type: none"> <li>Limited availability</li> </ul>

### 3.2.2 Sampling locations

Verification sampling should be done at locations where a water system risk or health risk is identified, based on the system analysis. Such locations include points of the system that are

infrequently used, or where patients or residents are at a higher risk of acquiring Legionnaires' disease.

Sampling of water in the system at the point of the most likely exposure (eg showers) and at the most distal point from the water supply is required to verify the effectiveness of controls throughout the system. As with operational monitoring, it can also be useful to take samples from a location closest to the entry point for incoming water so that any deterioration in water quality within the facility's water network can be assessed.

### **3.2.3 Number of samples and frequency of sampling**

In general, the number of samples collected and the frequency of sampling should reflect the number of people using the system, the complexity of the system, the level of risk within the facility and any local regulatory requirements. The sampling program should cover each individual plumbing system (eg at a building, department or ward level), because plumbing systems may vary in age, performance and condition throughout a facility. It is rare that a plumbing system is so simple or regular that a fixed number of samples can be recommended per facility or per number of beds. For example, the number and length of pipes per ward, and usage may vary after each TMV.

It is recommended that sufficient sampling is undertaken to establish a baseline understanding of the water distribution system, including each unique plumbing or water system (eg warm, cold or hot system) in the facility. This may be following commissioning of the system or at commencement of the sampling regime. If significant changes occur in either the water distribution system or the control measures applied, sampling should be undertaken to confirm that the system remains free from *Legionella*. Areas of high clinical risk and the outlet furthest from the point of entry of water to the system should be emphasised.

An example of verification monitoring linked to elements of the system and the risks identified is provided in Table 5.

Table 5 Examples of verification monitoring and controls for *Legionella* management in a health or aged care facility

Verification monitoring	Sampling locations	Critical limit/ verification	Frequency of monitoring	Example control measures
Verification monitoring shows microbial growth within water distribution system, possibly indicating that the <i>Legionella</i> controls have failed or are inadequate	At the point of entry of water to the facility and at various distal outlets throughout the facility	As per risk management plan – significant regrowth within system indicated by total bacterial count culture results	As per risk management plan	<ul style="list-style-type: none"> <li>Investigate system and review control measures as relevant to the results</li> </ul>
Verification monitoring shows <i>Legionella</i> presence in plumbing system	Water samples and swabs collected from appropriate outlets within the facility as per the risk management plan	<i>Legionella</i> detected by culture	As per risk management plan and following any suspected case of Legionnaires' disease	<ul style="list-style-type: none"> <li>Control exposure of patients and staff</li> <li>Boost disinfectant residual at point of entry to facility</li> <li>Increase flushing to prevent loss of residual within facility</li> <li>Test again to verify effectiveness of controls</li> <li>Install microfiltration at affected outlets</li> <li>If these measures are ineffective or not possible, consider sanitation options such as heat disinfection or hyperchlorination</li> </ul>

### 3.2.4 Documentation

It is important that the details of the sampling program and results are documented. The documentation should identify:

- sampling frequency
- sampling locations
- sampling methods
- who will take the samples
- which accredited laboratory will perform the analysis
- what additional analyses are appropriate (eg microbial species determination, turbidity, corrosion products, water temperature at regular and additional locations)
- what should be recorded in relation to sampling, including where, how and by who.

Sampling results should be regularly reviewed spatially and temporally to identify trends, changes in system performance and potential persistent, recurring and emerging problems. This information is particularly useful for disease investigations, should a case of *Legionella* infection be identified or suspected.

## 4. Responding to detections or cases

If *Legionella* is detected in a water sample, the facility should immediately investigate whether the control measures are adequate, and the system control measures should be assessed and checked to identify whether any failures have occurred. If faults are detected, they should be rectified before further sampling to verify the efficacy of the intervention. If verification identifies further positive results, the full system should be reassessed.

Where *Legionella* is detected in a water sample from a facility water distribution system, exposure of vulnerable people should be immediately controlled, in accordance with Section 3.1.5. Once exposure has been controlled, you should determine possible risk locations and the potential extent of colonisation of the system through increased water monitoring. Where *Legionella* colonisation has been found, apply appropriate control measures (eg disinfection) to the affected sections or components of the water distribution system, or the entire water distribution system, depending on the extent of identified or potential colonisation.

If one outlet in a facility produces a positive *Legionella* test result, compare with other results across the water distribution system to determine whether the system is locally contaminated or there is wider contamination throughout the system. If other samples taken at the same time are positive for *Legionella*, it would lend support to the possibility of systemic contamination. Repeated detections over time (including following the implementation of corrective measures) may indicate the presence of biofilm and/or stagnation protecting *Legionella* from disinfection and allowing it to re-establish to detectable levels following disinfection. It is recommended that the entire warm water system (not the entire water distribution system) is disinfected following any detection of *Legionella* in water collected from a warm water system because the contamination is likely to be systemic.

### 4.1 Control measures

If *Legionella* is detected in a facility's water distribution system, or a case of Legionnaires' disease is shown or suspected to be linked to colonisation of a facility water distribution system, one or more of the following control measures or an alternative suitable decontamination procedure should be undertaken as a matter of priority:

- **Heat disinfection:** This involves flushing all outlets systematically with water  $\geq 70^{\circ}\text{C}$  for a minimum of 5 minutes, or  $\geq 60^{\circ}\text{C}$  for a minimum of 10 minutes if  $70^{\circ}\text{C}$  cannot be achieved or maintained, with stringent controls employed to prevent scalding (eg actively informing all residents and staff, and preventing use of taps other than by suitably trained and experienced staff). This method is only effective for a short time (ie weeks), so it should only be considered to provide a temporary remedy while the source of the contamination and possible measures to address it are investigated. Many facilities do not have sufficient hot water storage capacity or the logistical or human resource capability to undertake efficient heat disinfection, and therefore the option to employ this method is limited. Also, this method can only be used to disinfect heated water systems.

- **Chlorination and hyperchlorination:** Maintenance of a free residual chlorine concentration of  $\geq 0.5$  mg/L at all cold water outlets and  $\geq 0.2$  mg/L at all heated water outlets can help suppress proliferation of *Legionella* in a water distribution system, but, when colonisation has become established, a higher concentration dose is required.

The use of chlorine to control *Legionella* in these circumstances requires a sufficiently high concentration dose of chlorine for a sufficient amount of time to control *Legionella*. Maintaining a free residual chlorine concentration of  $\geq 2$  mg/L throughout the entire water distribution system while flushing each outlet systematically for a minimum of 5 minutes may reduce levels of free *Legionella* in subsequent water samples from the system to below the limit of detection. However, chlorine is a poor penetrator of biofilms, so ongoing residual disinfection may be necessary to control *Legionella* long term in an extensively colonised system.

Chlorine dosing of water distribution systems is complicated, and the method used to achieve the desired free residual chlorine throughout the system without causing system damage will depend on the design of the system and the available infrastructure and expertise. It will usually be necessary to engage a suitably trained and experienced contractor to successfully undertake a hyperchlorination. The efficacy of chlorine decreases considerably as the pH of the water increases. Therefore, it may be necessary to add acid in a controlled fashion to maintain the pH at  $\leq 7.6$  during hyperchlorination. To hyperchlorinate water from a chloraminated supply, 'breakpoint chlorination' needs to be reached before the desired free residual chlorine concentration can be achieved. Therefore, there are additional complexities to consider when hyperchlorinating a water distribution system on a chloraminated water supply.

In some circumstances, it may be appropriate to chemically clean the system before hyperchlorination to reduce biofilm and sediment in the system, and improve the efficacy of hyperchlorination. Before undertaking a chemical clean, comprehensive procedures will be required to ensure that no hazardous exposures occur, and thorough investigations will be necessary to ensure that it will cause no damage to system components and connected equipment.

- **Cleaning of fittings or replacement with new or cleaned fitting:** This involves removal and disassembly of the components, and inspection and cleaning of individual components in accordance with the manufacturer's recommendations. This will generally consist of a physical clean followed by an appropriate heat or chemical disinfection. In Australia, TMVs should also be maintained in accordance with Australian Standard AS 4032.3.
- **Implementation of appropriate exposure controls** (see Section 3.1.5): This can provide protection to patients and residents while other control measures are being investigated and implemented.

Where any of these activities are proposed, it is essential that:

- the work is done by people with the skills and knowledge to undertake the work safely and effectively
- the methods selected are based on a sound understanding of the impact on, and compatibility with, the water distribution system infrastructure and any attached systems (eg systems associated with renal dialysis)
- all building occupants are advised that the water supply will be unavailable, and actively prevented from using the system while decontamination takes place
- all confirmatory steps to ensure water is safe for use are taken before occupants can again use the system
- each process step and the results of confirmatory testing are documented, as specified in the *Legionella* risk management plan.

Once appropriate control measures have been implemented or undertaken, normal operation of the system and facility can usually recommence immediately. However, exposure controls should be continued in high-risk areas and for high-risk patients and residents until further sample results indicate that the control measures have been successful. Samples should be collected for testing not less than 3 days and not more than 7 days following completion of appropriate control measures.

#### **4.2 Response to a suspected case of Legionnaires' disease**

Where a health or aged care facility-acquired Legionnaires' disease case is suspected or confirmed, you should promptly conduct sampling, swabbing and testing to determine the extent of potential *Legionella* colonisation within the water distribution system, before commencing appropriate precautionary control measures (eg chemical or heat disinfection) as a matter of priority.

Clinical staff and carers should be advised to consider or raise the possibility of *Legionella* infection should residents of the facility present with pneumonia or respiratory infection. The *Legionella* risk management plan should also include procedures for heightened patient surveillance in response to specified triggers such as *Legionella* detection, and suspected or confirmed cases.

The relevant local public health authority should be contacted promptly for advice on an appropriate response to a suspected case of Legionnaires' disease, to ensure that the response is proportionate to the risk, can be undertaken appropriately and meets any regulatory requirements. Legionnaires' disease is notifiable in all the states and territories of Australia and in New Zealand. Medical practitioners and laboratories must notify the relevant health department or authority as soon as practicable upon suspecting or confirming a diagnosis of Legionnaires' disease.

#### **4.3 What to do if the problem persists**

International experience has shown that it is difficult to eradicate *Legionella* from most systems once they have been colonised. Some facilities may have to aim for keeping

*Legionella* numbers as low as possible through stringently employed controls to reduce the risk of infection. A heightened patient surveillance system for cases of Legionnaires' disease will also be needed.

In complex and/or older facilities, biofilms may be well established and difficult to control. Additionally, documentation of the plumbing systems may be poor, and dead legs may be prolific. Some techniques to approach *Legionella* risk management in these settings are:

- conducting an advanced assessment of your plumbing system through the engagement of suitably trained and experienced experts
- adjusting occupancy or use of the facility to reduce the risk of infection
- contacting your local public health authority for advice on measures to address the risks.

Sponge bathing rather than showering, using alternative drinking water supplies, installing on-site water treatment and implementing point-of-use microfiltration are some options that should be considered in facilities with ongoing *Legionella* detection from their water distribution system.

## 5. Reviewing your *Legionella* risk management plan

A *Legionella* risk management plan should be a living document that is reviewed regularly by the *Legionella* risk management team, especially following incidents or cases, to assess the effectiveness of the response. A full review of the plan should be conducted annually or more frequently, based on the risk assessment, after a detection of *Legionella* in the water distribution system or a case of Legionnaires' disease, or after significant system modifications or change of use. The frequency of, and triggers for, plan reviews should be documented in the plan.

## 6. Summary

This document has been developed to assist health and aged care facilities to understand the risk posed by *Legionella*, and develop a *Legionella* risk management plan to reduce the risk in a way that is appropriate to their circumstances.

To determine water system risks and health risks, and measures to manage them, the key steps of the process are to:

- 1 establish a risk management team consisting of suitably trained and experienced people
- 2 undertake a system analysis
- 3 undertake a risk assessment based on the system analysis
- 4 identify, document and implement control measures in the form of a *Legionella* risk management plan, based on the risk assessment
- 5 verify the effectiveness of control measures through a monitoring program
- 6 develop procedures to respond to *Legionella* cases or detections.
- 7 review the *Legionella* risk management plan regularly and in response to defined and documented triggers.

The size and complexity of the *Legionella* risk management plan will largely depend on the size of the facility, the complexity of the water distribution system and the vulnerability of the people occupying the facility.

## Abbreviations and definitions

### *activated carbon filtration*

A method of water filtering that uses a bed of activated carbon to remove chlorine, volatile organic compounds, taste and odour from water by chemical absorption.

### *biofilm*

Microbial populations that adhere to and grow on the inside of pipes and other surfaces.

### *breakpoint chlorination*

The process of maintaining sufficient free chlorine in water to chemically convert chloramines and ammonia-nitrogen compounds to inert nitrogen gas.

### *CFU*

Colony forming unit. A unit used to estimate the number of viable bacteria in a sample.

### *chloramines*

Compounds formed by the reaction of hypochlorous acid or aqueous chlorine with ammonia. Chloramines are an alternative to chlorination that are weaker disinfectants but much longer lived within water distribution systems.

### *chlorination*

Use of chlorine as a means of disinfection. This can include continuous residual disinfection or hyperchlorination.

### *chlorine*

The main drinking water disinfectant used worldwide. Generally dosed as either liquid sodium hypochlorite or chlorine gas. Requires pH to be maintained at  $\leq 7.6$ .

### *chlorine dioxide*

A reactive gas that is a more effective disinfectant than chlorine. Usually generated and dosed on site but also available as a stabilised liquid.

### *dead legs*

Sections of a water distribution system that do not allow the flow of water.

### *drinking water*

Water intended primarily for human consumption as supplied from the tap. Drinking water is also used for other purposes such as bathing and showering.

### *facility*

All of the buildings sharing plumbing connections under the control of the facility manager, even when not used for clinical purposes.

### *free residual chlorine*

The concentration of residual chlorine in water that is present as dissolved gas ( $\text{Cl}_2$ ), hypochlorous acid ( $\text{HOCl}$ ) and/or hypochlorite ions ( $\text{OCl}^-$ ).

### ***hot water***

Heated water  $\geq 60$  °C.

### ***hot water system***

A heated water system that delivers heated water through the majority of the system at  $\geq 60$  °C. May include TMVs close to sanitary outlets.

### ***hyperchlorination***

Elevating the free residual chlorine concentration to obtain a specified level throughout the water system and holding it there for a sufficient time to control *Legionella*.

### ***point-of-entry filtration***

Filtration installed at the point of entry of water to a facility (eg directly after the water meter) to reduce turbidity and organic material to improve efficacy of some disinfection methods and minimise the build-up of sediment within a water distribution system.

### ***point-of-use microfiltration***

Membrane filter installed at or near an outlet with a pore size  $\leq 0.2$   $\mu\text{m}$  that prevents most bacteria passing through while allowing normal water flow.

### ***suitably trained and experienced***

A person who has the appropriate knowledge and competencies needed to fulfil the roles and responsibilities assigned to them. These qualities and competencies could be gained through training or experience or a combination of both.

### ***TBC***

Total bacterial count. A measure of the total bacteria that can be cultured from a water sample in a general-purpose growth medium. It does not include other microbes (such as viruses or most fungi) or many other viable but nonculturable (VBNC) bacteria. Also known as total plate count (TPC), heterotrophic colony count (HCC) and heterotrophic plate count (HPC).

### ***TMV***

Thermostatic mixing valve. A valve that automatically blends hot water with cold water to deliver warm water for sanitary purposes to prevent scalding

### ***total chlorine***

The sum of free residual and combined chlorine (chloramines).

### ***turbidity***

A measure of the light-scattering property of water caused by the presence of fine suspended matter such as clay, silt, plankton and other microbes.

### ***UV light***

Ultraviolet light

### ***viable but nonculturable (VBNC) Legionella***

*Legionella* cells that have entered a nonreplicative viable but nonculturable state following exposure to various stresses.

***warm water***

Heated water distributed and/or delivered at approximately 45 °C for sanitary purposes to prevent scalding.

***warm water system***

A heated water system that distributes warm water throughout the majority or all of the system.

***water distribution system***

The entirety of infrastructure used for distributing and delivering water within a facility from the point(s) where water enters the facility to its points of use, including all plumbing, pipework, storage tanks, heaters, vessels, pumps, valves, outlets and connected systems.

## Appendix 1 Risk assessment tables

Adapted from the Australian Drinking Water Guidelines (2011).

Table A1.1 Qualitative measures of likelihood

Level	Descriptor	Example description
A	Almost certain	Is expected to occur in most circumstances
B	Likely	Will probably occur in most circumstances
C	Possible	Might occur or should occur at some time
D	Unlikely	Could occur at some time
E	Rare	May occur only in exceptional circumstances

Table A1.2 Qualitative measures of consequence or impact on facility

Level	Descriptor	Example description
1	Insignificant	Insignificant impact, little disruption to normal operation, low increase in normal operating costs (eg temporary low free residual chlorine concentration that can be resolved via flushing)
2	Minor	Minor impact for part of facility, some manageable disruption to normal operation, some increase in operating costs (eg several rooms or one wing with infrequent use, requiring routine flushing to maintain free residual chlorine concentrations)
3	Moderate	Major impact for part of facility, significant but manageable modification to normal operation, increase in operating costs, increased monitoring (eg localised <i>Legionella</i> colonisation, requiring investigation and implementation of controls)
4	Major	Major impact for most of facility, systems significantly compromised, abnormal (if any) operation, high level of monitoring required (eg extensive <i>Legionella</i> colonisation, requiring investigation and implementation of controls)
5	Catastrophic	Major impact for whole of facility, complete failure of systems (eg extensive <i>Legionella</i> colonisation with one or more confirmed cases of health or aged care facility-acquired Legionnaires' disease)

Table A1.3 Qualitative risk analysis matrix – level of risk

Likelihood	Consequences				
	1 Insignificant	2 Minor	3 Moderate	4 Major	5 Catastrophic
<b>A (almost certain)</b>	Moderate	High	Very high	Very high	Very high
<b>B (likely)</b>	Moderate	High	High	Very high	Very high
<b>C (possible)</b>	Low	Moderate	High	Very high	Very high
<b>D (unlikely)</b>	Low	Low	Moderate	High	Very high
<b>E (rare)</b>	Low	Low	Moderate	High	High

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*This is not an exhaustive list of relevant publications.*

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## **Standards**

*AS 4032.3 Water supply – Valves for the control of heated water supply temperatures – Requirements for field testing, maintenance or replacement of thermostatic mixing valves, tempering valves and end of line temperature control devices*

*AS/NZS 3500 Set (Parts 0-5):2013 Plumbing and drainage Set*

*AS/NZS 3896 Waters – Examination for Legionella spp. including Legionella pneumophila*

*ISO 11731 Water quality – Detection and enumeration of Legionella*

*ISO 11731.2 Water quality – Detection and enumeration of Legionella – Part 2: Direct membrane filtration method for waters with low bacterial counts*