The Prevention of Legionellosis in New Zealand

Guidelines for the Control of *Legionella* Bacteria

Te Kāwanatanga o Aotearoa
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Foreword

Legionellosis refers to the disease caused by any species of *Legionella* bacteria. The severity of the disease covers a wide spectrum, from mild 'flu-like symptoms (called Pontiac fever) to severe and potentially fatal pneumonia (called Legionnaires' disease). The first known case of legionellosis in New Zealand was diagnosed in 1979. It is now known that infection generally follows inhalation of aerosolised water or dust from a contaminated source containing the bacterium.

Legionella bacteria are widespread in the water and soil environments. They are found in various aquatic settings including lakes, rivers, ground water, and hot springs, and in engineered water systems within buildings and industrial processes. *Legionella* bacteria also naturally occur in rich organic soils and sludge, including compost, garden mulch, potting mix, and effluent from waste treatment plants.

Many different environmental sources have been linked to cases of legionellosis in New Zealand. Predominantly, these are warm water systems (where there is a lack of biocide control, or risk of stagnation, or the water is recirculated) or soil conditioners such as composts and potting mixes.

In common with controlling most public health issues, the adoption of preventive measures is the most effective strategy for managing the risk of legionellosis. This includes careful attention to regular maintenance and cleaning schedules of air conditioning and water systems in buildings, along with controlling the discharge from devices that generate or release water or dust aerosols into the atmosphere.

The purpose of these guidelines is to increase awareness about the hazards associated with *Legionella*, improve the management of potential sources of *Legionella*, and improve the reporting and investigation of cases of legionellosis.

The guidelines are intended to assist all those concerned with *Legionella* and health, including public health officers, local authorities, building owners, air conditioning engineers, employers and others dealing with the maintenance and monitoring of air and water handling systems in buildings.

They are also a general guide for managing the risk of other proven sources of *Legionella* such as garden soils, compost and potting mixes, as well as recreational water sources. Part 2 of the guidelines provides advice on the follow-up of cases of legionellosis.

Acknowledgements

These guidelines reference Standards published by Standards New Zealand, in particular provisions of Australian/New Zealand Standard (AS/NZS) 3666: Parts 1, 2, 3 and 4, *Air-handling and water systems of buildings – Microbial control,* with the permission of Standards New Zealand under Licence 000807, and compliance documents such as the *New Zealand Building Code* administered by the Ministry of Business, Innovation and Employment.

The latest versions of the Standards referred to in these guidelines may be purchased from:

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Contents

Introduction

Scope and application

This guidance document is divided into two parts.

- **Part 1: *Legionellosis, sources of Legionellae and control measures*** provides up-to-date information, advice, and guidance for minimising the risk of significant contamination in waters of cooling towers, cold and heated water distribution systems, and spa pools. The procedures described for the decontamination and cleaning of such systems are based on current internationally accepted practices.
- **Part 2: Guidelines *for the follow-up of cases of Legionellosis*** sets out the actions required following the identification of one or more cases of legionellosis.

Legionella bacteria often proliferate in warm water systems where the water is allowed to stagnate, or there is a lack of chemical disinfection, or excess nutrients due to accumulation of sediment, or corrosion in pipework or fittings, or the development of biofilms that support the growth of protozoa – the natural host of legionellae.

These guidelines are intended for building owners, managers and contractors of buildings that incorporate the systems and specific items of equipment or plant that are known to harbour *Legionella*.

These guidelines are also intended for use by public health officers when advising or following up identified legionellosis cases or undertaking a *Legionella* risk assessment.

The guidelines also recognise that *Legionella* bacteria have been isolated from sources other than water. These include composts, soil conditioners and mulches, soils for landscaping and garden use, and potting mixes, and provides several precautions that can be taken to minimise the risk of infection.

The application of principles and practices described in these guidelines should significantly reduce the risk of future outbreaks, clusters, and sporadic cases.

Part 1: Legionellosis, sources of *Legionellae*, and control measures

2 Legionellosis

2.1 Historical aspects

In 1976, 201 people staying at a hotel in Philadelphia, USA, suffered from a respiratory illness that became known as Legionnaires' disease. After a six-month investigation, researchers from the Centers for Disease Control in Atlanta, United States, isolated the causative agent – a previously unrecognised micro-organism, named *Legionella pneumophila* serogroup 1 (Lpsg1). Since then, many more *Legionella* species have been identified, and subdivision of some species into serogroups has occurred.

Since 1976, outbreaks of Legionnaires' disease have occurred worldwide, including New Zealand, but sporadic cases greatly outnumber cases related to outbreaks.

Surveillance for legionellosis began in New Zealand in 1979 using serologic and histological methods with the first case of legionellosis diagnosed in 1979 (Holst et al., 1980). The disease became notifiable in June 1980. Since 2010, surveillance has shown there are between 150 and 180 cases of legionellosis annually, with less than 2.0% of these associated with outbreaks.

2.2 *Legionella* species causing disease

The number of new *Legionella* species have continued to increase since the first recognised culture-isolation of *L. pneumophila* serogroup 1 (Lpsg1) from lung biopsy tissue in 1977 (McDade et al., 1977). Retrospective studies since have identified Lpsg1 as the cause of a legionellosis outbreak amongst recruits at a military base in the USA in 1947 (McDade et al., 1979).

To date 66 different species of *Legionella* with taxonomically valid names have been described, with a further five awaiting clarification of their taxonomic status. Of these, 29 different species are associated with human infection (Table 1). The predominant species responsible for cases of legionellosis in New Zealand are *L. pneumophila* and *L. longbeachae* (Graham et al., 2012*)*.

For the 21 years between 2000 and 2020, of the 2675 laboratory-identified clinical cases of legionellosis in New Zealand, 51% were attributed to *L. longbeachae*, 31.2% to *L. pneumophila* and 13.5% to other *Legionella* species.

Other *Legionella* species less frequently associated with disease in New Zealand are *L. bozemanae* (3.0%)*, L. dumoffii* (3.0%)*, L. gormanii* (1.3%)*,* and *L. micdadei* (3.2%). This is different to disease surveillance patterns seen in most other countries where *Legionella pneumophila* causes 90% of legionellosis, with Lpsg1 alone accounting for approximately

85% of cases (Doleans et al., 2004). Many of the rarer pathogenic species have not been seen in New Zealand and for some, their pathogenicity has been reported following a single human case.

Table 1: *Legionella* species and serogroups

Legionella species	Serogroups	Human pathogenicity *	Isolated in New Zealand
L. adelaidensis	1	Unknown	
L. anisa	1	Established	Yes
L. antarctica	1	No	
L. beliardensis	1	Unknown	
L. birminghamensis	1	Established	Yes
L. bononiensis	1	Unknown	
L. bozemanae	2	Established	Yes
L. brunensis	1	Unknown	
L. busanensis	1	Unknown	Yes
L. cardiaca	1	Established	
L. cherrii	1	Established	Yes
L. cincinnatiensis	1	Established	Yes
L. clemsonensis	1	Putative	
L. donaldsonii	1	Unknown	Yes
L. drancourtii	1	No	
L. dresdenensis	1	Unknown	
L. drozanskii	1	Unknown	
L. dumoffii	1	Established	Yes
L. erythra	2	Putative	Yes
L. fairfieldensis	1	Unknown	
L. fallonii	1	Unknown	Yes
L. feeleii	2	Established	Yes
L. geestiana	1	Unknown	Yes
L. genomospecies 1	1	Unknown	
L. gormanii	1	Established	Yes
L. gratiana	1	Unknown	Yes
L. gresilensis	1	Unknown	
L. hackeliae	2	Established	Yes
L. impletisoli	1	Unknown	
L. indianapolisensis	1	Putative	

Legionella species	Serogroups	Human pathogenicity *	Isolated in New Zealand
L. israelensis	1	Unknown	
L. jamestowniensis	1	Unknown	Yes
L. jeonii	1	Unknown	
L. jordanis	1	Established	Yes
L. lansingensis	1	Established	Yes
L. londiniensis	2	Putative	Yes
L. longbeachae	2	Established	Yes
L. lytica	1	Unknown	
L. maceachernii	1	Established	Yes
L. maioricensis	1	Unknown	
L. massiliensis	1	Unknown	
L. micdadei	1	Established	Yes
L. moravica	1	Unknown	
L. nagasakiensis	>1	Established	
L. nautarum	1	Unknown	Yes
L. norrlandica	1	Unknown	
L. oakridgensis	1	Established	Yes
L. parisiensis	1	Established	Yes
L. pneumophila	16	Established	Yes
L. polyplacis	1	Unknown	
L. qingyii	1	Unknown	
L. quateirensis	1	Unknown	Yes
L. quinlivanii	2	Unknown	Yes
L. rowbothamii	1	Unknown	
L. rubrilucens	1	Established	Yes
L. sainthelensi	2	Established	Yes
L. santicrucis	1	Unknown	Yes
L. saoudiensis	1	Unknown	
L. septentrionalis	1	Unknown	
L. shakespearei	1	Unknown	
L. spiritensis	2	Unknown	
L. steelei	1	Putative	Yes
L. steigerwaltii	1	Unknown	
L. taurinensis	1	Unknown	Yes

Legionella species	Serogroups	Human pathogenicity *	Isolated in New Zealand
L. thermalis	1	Unknown	
L. tusconensis	1	Established	
L. tunisiensis	1	Unknown	Yes
L. wadsworthii	1	Established	Yes
L. waltersii	1	Putative	Yes
L. worsleiensis	1	Unknown	
L. yabuuchiae	1	Unknown	

* Pathogenicity according to Bartlett *et al* 2022

Source: Deutsche Sammlung von Mikroorganismen und Zellkulturen (DSMZ) (2023) and NCTC (2023)

2.3 The disease and its symptoms

Legionellosis is the disease caused following the opportunistic infection by *legionellae* bacteria resulting from a combination of factors including contact with an infected environmental source and a predisposition to the disease.

A person's susceptibility to infection increases with advanced age (greater than 65 years), male sex, underlying chronic illness, cigarette smoking, presence of chronic diseases and immunodeficiency (Cunha et al., 2016). Infection is primarily caused by inhalation of aerosols of water or dust containing viable *Legionella* or the aspiration of *Legionella*-contaminated water. Person-to-person transmission is extremely rare with only one reported case (Correia et al., 2016).

Legionellosis can be viewed as a spectrum of disease ranging from a non-pneumonic, self-limiting, febrile illness of only 2–6 days duration (Pontiac fever), to a non-productive cough leading to pneumonia with high fever (Legionnaires' disease) that requires medical intervention and can progress to multi-organ failure and death. Pontiac fever has a relatively short incubation period, typically 24–48 hours, while for Legionnaires' disease the incubation period varies from 2–10 days (WHO, 2007).

Table 2 lists the most common symptoms of legionellosis. Pontiac fever cases make up a small proportion of all legionellosis cases in New Zealand possibly due to it being a milder and self-resolving illness and consequently goes untested and therefore unreported.

Table 2: Main characteristics of Legionnaires' disease and Pontiac fever

Characteristic	Legionnaires' disease	Pontiac fever
Incubation period	Usually 2–10 days, rarely up to 20 days	5 hours to 3 days (most commonly 24–48 hours)
Duration	Weeks	2–5 days
Case-fatality rate	Variable depending on susceptibility; in hospital patients, can reach 40–80%	No deaths reported
Attack rate	0.1–5% of the general population 0.4–14% in hospitals	Up to 95%
Symptoms	• Often non-specific • Loss of strength (asthenia) • High fever • Headache • Non-productive, dry cough • Sometimes blood-streaked expectoration • Chills • Muscle pain • Difficulty in breathing, chest pain • Diarrhoea (35–50% of cases) • Vomiting, nausea (10–30% of cases) • Central nervous system manifestations, such as confusion and delirium (50% of cases) • Renal failure • Hyponatraemia (serum sodium <131 mmol/litre) • Lactate dehydrogenase levels >700 units/mL • Failure to respond to beta-lactam antibiotics or aminoglycosides • Gram stain of respiratory specimens with numerous neutrophils and no visible organisms	• Influenza-like illness (moderate to severe influenza) • Loss of strength (asthenis), tiredness • High fever and chills • Muscle pain (myalgia) • Headache • Joint pain (arthralgia) • Diarrhoea • Nausea, vomiting (in a small proportion of cases) • Difficulty breathing (dyspnoea) and dry cough

Source: World Health Organization (2007)

2.4 The environmental habitats of legionellae

Bacteria of the genus *Legionella* are widely distributed natural inhabitants of waters and rich organic soils (WHO, 2018). They have been isolated from ground water and terrestrial waters (lakes, rivers, drains, and other bodies of water), as well as estuarine and marine waters and wastewater.

Legionellae are also abundant in organically rich matrices such as compost, garden soil, sewage sludge, and mulch derived from tree bark and other vegetative material. They are rarely 'free-living' bacteria and are most often associated with other micro-organisms in mixed population biofilms, or as intracellular parasites of fresh water and soil protozoa (Boamah et al., 2017; Declerck, 2010; Rowbotham, 1980). Certain free-living amoebae are part of the normal microflora of waters and damp soils and can support the intracellular multiplication of many different legionellae (Croze et al., 2021).

Legionellae have also been shown to replicate in the gut of soil and water nematodes (Brassinga et al., 2010; Rasch et al., 2016; Hemmerling et al., 2023). This may indicate that nematodes act as natural hosts for legionellae and promote their proliferation in environments where they are co-habitants. However, the full interaction between legionellae and their eukaryotic hosts (protists and nematodes) is still unclear.

Since legionellae can be considered part of the natural biome of water and soil, their presence in terrestrial and ground water sources is a given, although usually at levels where they are undetectable by usual laboratory methods. Because these water sources are used for both drinking water and industrial processes, this allows legionellae to eventually progress into engineered water systems where they can proliferate.

The sediment, scale, and sludge that accumulates or forms on the internal surfaces of water fixtures and storage vessels creates an ideal niche for both legionellae and their eukaryotic hosts to proliferate as biofilm-associated communities. The biofilm also protects the bacteria from adverse environmental conditions, including the biocidal action of water treatment chemicals and periods of drying.

Sediment, scale and sludge includes materials from corrosion products of the plumbing system, organic debris and silt carried or dissolved in the source water, precipitated salts, and complex macromolecules produced by the microflora present.

Under less-than-optimal growth conditions legionellae can remain viable (actively respiring) but become non-cultivable on laboratory media. This state is termed 'viable but non-culturable' (VBNC) and can be regarded as a survival strategy when the bacterium is under physiological stress due to starvation, or exposure to chemical disinfectants or heat (Kirschner, 2016). Legionellae in this state can be revived by protozoan hosts and human macrophages, again becoming cultivable on laboratory media (Dietersdorfer et al., 2018).

The ability of *Legionella pneumophila* and other legionellae to move between a viable and culturable state to a VBNC state under limiting environmental conditions may partially explain our inability to determine an infection source when attempting to detect them using standard culture methods (Ducret et al., 2014; Kirschner, 2016).

2.4.1 Water temperature and its effect on legionellae

In the laboratory, legionellae have been found to grow over a wide temperature range (20–46°C), with an optimal temperature range for replication of 32–44°C. Although reported to survive at temperatures between 0°C and 63°C, *Legionella pneumophila* cannot actively grow at either temperature extreme, with metabolic activity stopping at around 50°C. At 70°C the organism is killed almost instantaneously (Dennis et al, 1984; Kusnetsov et al., 1996; Schulze-Robbecke et al., 1987).

Investigations of the relationship between the chemical environment in plumbing systems and the growth of *Legionella* have shown that low concentrations of certain metals such as iron, zinc and potassium enhance proliferation of the species. Hence, the metal components and corrosion products of plumbing systems (e.g., galvanized iron) may play a role in the formation of biofilm which promotes growth of *Legionella* bacteria (Berry et al., 2006). The constituents of certain types of natural rubber compounds and hemp used in plumbing fittings can also support the multiplication of *Legionella* by promoting biofilm formation (Colbourne et al., 1984).

In general, the ability of legionellae to proliferate in defined ecosystem is dependent on the interrelationship between temperature, pH, the chemical composition of the water, nutrient levels, the makeup of the microbiome, and the presence of sediments. Controlling these factors allows for the proliferation of legionellae in water systems to be controlled. However, temperature alone cannot be used to eliminate *Legionella* from contaminated water systems (Cervero-Aragó et al., 2019; Molina et al., 2022).

Table 3 provides a summary of the temperature effect on *Legionella pneumophila* growth under laboratory conditions.

Table 3: The effect of water temperature on *Legionella pneumophila* growth

Temperature	Effect on *Legionella*	Cell cultivability	Cell viability on media *
Above 70°C	Disinfection temperatures	Instant death	Resuscitable in amoebae
66°C	Disinfection temperature	*Legionella* will die in 2 minutes	VBNC, Resuscitable in amoebae
60°C	No active growth	*Legionella* will die in 32 minutes	VBNC, Resuscitable in amoebae
55°C	No active growth	*Legionella* will die in 5–6 hours	Mixed population: VC & VBNC

Temperature	Effect on *Legionella*	Cell cultivability	Cell viability on media *
50 to 55°C	No active growth	Slow decline in viable cells	Mixed population: VC & VBNC
47 to 50°C	No active growth	*Legionella* can survive but do not multiply	Viable
45 to 47°C	Slow growth	*Legionella* multiply slowly	Viable
35 to 45°C	Optimum growth range	Rapid increase in viable cell counts	Viable
20 to 35°C	Active growth range	Viable cell count determined by nutrient level	Viable
Below 20°C	No active growth	*Legionella* can survive but is dormant	Mixed population: VC & VBNC

* VC: Viable and culturable; VBNC: Viable but non-culturable
Source: Cervero-Aragó et al., 2019.

2.5 Exposure sources

The primary sources responsible for legionellosis cases in New Zealand are warm water or composted organic material. It is proposed that every legionellosis case has been exposed to a contaminated environmental source where legionellae have been able to proliferate to a level where any eventual aerosolisation of the material harbouring the legionellae increases the likelihood of contact with a susceptible person.

Legionella from both terrestrial and ground water sources can enter and colonise engineered water systems, and have been isolated from air conditioning cooling towers, decorative fountains, ultrasonic nebulisers, room humidifiers, hot whirlpools[1] and spa baths, hot water from taps and showers, medical devices containing water (eg, respiratory care devices, such as CPAP machines) (Butler and Breiman, 1998), water coolers (Schousboe and Brieseman, 2007) and ultrasonic mist machinery in grocery stores (Stout and Yu 1997).

Sanitary hot water services in large buildings, such as hotels and hospitals, have been shown to be a common source of infection. Lpsg1 has previously been found in the cold-water storage tanks that receive water directly from Christchurch Hospital's 90-metre deep artesian well (Schousboe et al., 2005). A Portuguese study found that over 100 groundwater samples collected from six different boreholes located in two geographical

[1] Studies have demonstrated respirable (5 micrometre and smaller) aerosols above whirlpool spas (Baron and Willeke 1986, Mangione et al., 1985). These respirable aerosols are apparently generated largely by jet droplet and film collapse mechanisms (Baron and Willeke 1986).

areas over a seven-year period had low numbers of *Legionella* isolates detected (Costa et al., 2005).

Infections by *L. pneumophila* strains are commonly associated with exposure to a contaminated water source – either a domestic drinking water supply (usually unchlorinated), or recreational water (eg, a spa or swimming pool, a stream, estuarine or geothermal water).

A domestic water supply can be either reticulated from a territorial authority or from a private source, such as roof-collected rainwater stored in a tank, or a ground water (well or bore) supply, or a terrestrial supply such as a stream or lake. Any water can potentially be a source, with the risk potential increasing as water temperature increases from 20 to 50°C and with biocide concentration decreasing to ineffectual levels.

In situations where the *Legionella*-contaminated water source is aerosolised, such as from cooling towers, humidifiers, spa pools, water sprayers or vehicle washes, the potential for outbreaks is amplified because of the increased numbers of people potentially exposed to the contaminated aerosols.

In 2006 there was a reported outbreak of Legionnaires' disease in Beachlands, Manukau, Auckland associated with contaminated roof-collected rainwater storage tanks. It was concluded that aerosols from a nearby marina water blaster contaminated with the same strain of Lpsg1 were a likely source by spreading it onto nearby rooftops and rainwater tanks. It was also apparent from a contaminated property at Beachlands that a filter on the cold-water line to the kitchen tap was acting as an amplifier – with higher *Legionella* counts downstream than upstream (Simmons et al., 2008).

Regarding marine environments, legionellae have long been shown to be tolerant to salt water (Ortiz-Roque and Hazen, 1987; Heller et.al., 1998). *L. pneumophila* was present in amoebae that can grow in salt water which could lead to the growth and persistence of this pathogen in this environment (Gast et al., 2011). A sea water spa pool contaminated with Lpsg1 was shown to be the source of a legionellosis case (Linsak et. al., 2021).

Legionella longbeachae has long been associated with composts and potting mixes, so infections caused by *L. longbeachae* are common amongst gardeners (Steele et al, 1990a). The mechanism of infection from this material is not fully understood but is likely to be caused by the inhalation of aerosolised dust particles containing legionellae that are created when handling the material. Another potential source for creating aerosols is the wind since gardening activities are usually undertaken outside. Handling compost in poorly ventilated environments such as potting sheds or enclosed greenhouses has also been linked to exposure to *Legionella* (Cramp et al., 2010).

The potential for human exposure to *Legionella* in compost and other soil conditioners is not limited to *L. longbeachae* with many *Legionella* species having been cultured from

composted material. These include but are not limited to *L. pneumophila* strains as well as *L. bozemanae*, *L. dumoffii*, *L. feeleii*, *L. gormanii*, *L. jordanis*, *L. micdadei*, and *L. sainthelensi* (Graham et al., 2023a). Cases of sporadic legionellosis due to *L. pneumophila* following exposure to potting mix and topsoil have been reported (Loh and Soni, 2020). There have been both definitive and presumptive cases of *L. pneumophila* and *L. bozemanae* infections following compost use by home gardeners in New Zealand.

Table 4 summarises the different environmental matrices identified as the source of clinically proven legionellosis cases in New Zealand between 2000 and 2022. The environmental source for each case is categorised as either ‘definitive’, ‘probable’, or ‘suspected’ based on the degree of matching between the clinical and environmental samples.

A definitive source was determined with a molecular match using sequence-based typing (Gaia et al., 2005) and/or mip gene sequence analysis (Ratcliff, 2013) between the clinical isolate and the environmental isolate. A probable source is where there is a species match between the case and their environmental source, but identification was made using incongruent methods. A suspected source is where there is a likely source identified, but no environmental sampling is undertaken.

Table 4: Confirmed and potential sources of legionellosis in New Zealand

Source	Exposure event/source	Definitive source	Probable source	Suspected source
Soil	Compost, potting mix use	L. bozemanae, L. longbeachae, L. pneumophila	L. bozemanae, L. longbeachae, L. micdadei, L. pneumophila	L. bozemanae, L. dumoffii, L. hackeliae, L. jordanis, L. micdadei, L. longbeachae, L. pneumophila
	Bark mulch, leaf litter	L. longbeachae	L. longbeachae	L. bozemanae, L. dumoffii, L. micdadei, L. longbeachae, L. pneumophila, L. sainthelensi
	Gardening activities and house/section maintenance		L. longbeachae	L. bozemanae, L. dumoffii, L. micdadei, L. longbeachae, L. pneumophila, L. sainthelensi
	Soil (including excavation/ construction activity)			L. dumoffii, L. longbeachae
	Animal manure, biosolids		L. dumoffii, L. longbeachae	L. dumoffii, L. longbeachae, L. micdadei
Recreational water	Spa pool use	L. pneumophila	L. pneumophila	L. bozemanae, L. pneumophila
	Swimming pool use		L. pneumophila	L. pneumophila

Source	Exposure event/source	Definitive source	Probable source	Suspected source
	Near spa pool but did not use	L. pneumophila	L. pneumophila	
	Geothermal pool/spring		L. pneumophila	L. pneumophila L. micdadei, L. sainthelensi
Non-potable water systems	Water blaster		L. pneumophila	L. longbeachae, L. pneumophila
	Irrigation systems			L. feeleii L. pneumophila
	Fountains and ornamental water features			L. dumoffii, L. feeleii, L. pneumophila
	Storm water/effluent water system		L. longbeachae	L. dumoffii, L. longbeachae, L. pneumophila
Industrial process water	Cooling tower	L. pneumophila	L. dumoffii, L. jordanis L. longbeachae, L. pneumophila, L. sainthelensi	L. anisa, L. dumoffii, L. pneumophila, L. sainthelensi
	Recycled vehicle wash			L. pneumophila
	Metal cutting fluid			L. pneumophila
	Plastic moulding apparatus			L. pneumophila

Source	Exposure event/source	Definitive source	Probable source	Suspected source
Treated drinking water systems	Home water system	L. pneumophila	L. pneumophila	L. anisa, L. pneumophila
	Residential care home water system	L. pneumophila	L. pneumophila	
	Hotel hot water system	L. pneumophila	L. pneumophila	
	Hospital hot water system	L. pneumophila	L. pneumophila	
	Drinking water fountain		L. pneumophila	L. pneumophila
	Surgical heater-cooler unit	L. pneumophila	L. pneumophila	
	CPAP device		L. pneumophila	L. pneumophila
	Humidifier		L. pneumophila	L. pneumophila
Non-treated drinking water	Home water system (ground water)	L. pneumophila	L. pneumophila	
	Home water system (roof-collected rainwater)	L. pneumophila	L. bozemanae, L. pneumophila	L. pneumophila, L. sainthelensi
	Reservoir in vessel or caravan	L. pneumophila	L. pneumophila	L. pneumophila

Source: ESR EML (unpublished data); Graham et al., 2023a.

2.6 Mode of transmission

The route of human infection is through the inhalation of dust or water aerosols containing *Legionella*. Aerosols of five or less microns (micrometre, or one-millionth of a metre) in diameter can reach the alveoli of the lower respiratory tract. Upon transmission, the bacteria invade and replicate mainly within alveolar macrophages by the same mechanism used to invade amoeba (Winn and Myerowitz, 1981).

Aerosol generating systems that have been linked to disease transmission include cooling towers and air scrubbers where *Legionella* can grow intracellularly in protozoa within biofilms. Aquatic biofilms are ecological niches in which *Legionella* survives and proliferates. Cooling towers and evaporative condensers of air conditioning systems produce aerosols that may be either inhaled directly or passed through an air intake system for a building and then inhaled.

Transmission via cooling towers has been most often documented when cases have been relatively close (less than 500 m) from contaminated sources (Breiman 1993). Bhopal et al (1991) have suggested that cooling tower aerosols are responsible for a portion of sporadically occurring cases of legionellosis in Scotland. Studies have shown that in densely populated urban areas drifting aerosols from contaminated cooling towers have infected other such systems in close proximity (i.e., within 500 metres) (Castellani et al.,1997).

A study in France showed that the transmission of *Legionella* bacteria from a cooling tower appears to have extended over a distance of at least 6 km from the source (Nguyen et al., 2006). A spatial study that was carried out by the Ministry of Health, New Zealand in 2005, showed clusters of cases located in the southwest region of Christchurch, where a number of cooling towers were also concentrated. However, the report noted that the analysis did not specifically identify any single tower as the putative source of the outbreak (Ministry of Health, 2005).

There is also evidence that showers can produce aerosols containing *Legionella*. For example, *L. pneumophila* has been isolated from air samples collected in a shower room (Dennis et al., 1984). Kool et al (1998) described taking air samples in a hospital and finding *L. pneumophila* serogroup 6 in the room after the showers had been turned on.

In Victoria in 2008, seven cases of Legionnaires' disease were linked to a warm water system at a self-service car wash facility. Water was being stored at ~45°C before being supplied to a high-pressure hose that generated a fine mist. Lpsg1 was detected at 80 cfu/mL in samples collected from the outlet and at ~39,000 cfu/mL from the storage tank (Department of Health, 2010). Another study has provided essential evidence for car wash facilities using hand-held hoses as a *Legionella* infection source (Euser et al., 2013).

There is evidence that aspirational legionellosis is another transmission mode, although considered less common. For example, when drinking contaminated water (with the subsequent inhalation or aspiration of aerosols while drinking) has been suggested as a possible source of legionellosis (Stout and Yu 1997).

Two outbreaks of legionellosis in separate nursing homes were linked to contaminated drinking water where the findings suggested that the most likely mode of infection was aspiration due to swallowing (Loeb et al., 1999). Aspiration of contaminated water in association with nasogastric tube feeding has been described as a mechanism (Venezia et al., 1994). The occurrence of Legionnaires' disease in neonates following the use of home birthing pools contaminated with *Legionella* is another example of aspirational transmission (Collins et al., 2015).

Vehicle windscreen washer fluid has also been identified as a potential source of legionellosis with epidemiological studies showing that professional drivers may be at increased risk of acquiring Legionnaires' disease (Wallensten et al., 2010; Politi et al., 2022). One study published in 2010 suggested that car windscreen washing sprays without added wash detergent may have been a possible mode of transmission via inhalation.

2.7 Laboratory diagnosis

The diagnosis of legionellosis depends on specialised laboratory tests (see Table 5) (WHO, 2007). Routine laboratory tests will not identify the *Legionella* bacteria. The clinical symptoms of legionellosis are not specific to differentiate it from other causes of community-acquired pneumonia and may not contribute to establishing an accurate diagnosis.

Testing for legionellosis should be routinely carried out on any patient admitted to hospital with severe pneumonia, whether or not they present with clinical features suggesting legionellosis. This is primarily because pneumonic illness due to a *Legionella* infection does not produce any characteristic symptom that typifies Legionnaires' disease.

Patients with pneumonia that do not respond to therapy with beta-lactam antibiotics or in combination with aminoglycosides, or present with other underlying severe chronic pulmonary disease, or are immunocompromised, should also be tested for Legionnaires' disease.

Several different methodologies are currently available for the clinical diagnosis of legionellosis. These include *Legionella* culture, detection of *Legionella*-specific antibodies in serum, *Legionella* urinary antigen detection, and the detection of *Legionella* nucleic acid by nucleic acid amplification tests (Mercante & Winchell, 2015; WHO, 2007).

The sensitivity of diagnostic tests for legionellosis ranges widely with no one test having a sensitivity greater than 90% (see Table 5). Each diagnostic test has its own advantages and limitations, but no single test fulfils all the requirements of clinicians, microbiologists, and epidemiologists. For this reason, and to improve the positive rate, the examination of different specimen types with different tests in parallel is strongly recommended.

The occurrence of false-positive *Legionella* testing results, particularly for serological and nucleic acid amplification tests (NAAT), demonstrates the value of routine confirmatory testing procedures. All clinical samples giving positive test results should be sent to the Legionella Reference Laboratory (ESR Kenepuru Science Centre) for confirmatory testing and further characterisation for epidemiological and surveillance purposes.

Table 5: Comparison of methods for laboratory diagnosis of Legionellosis

Method	Sensitivity (%)	Specificity (%)	Comments
NAAT (PCR/LAMP)			
Lower respiratory tract specimen Urine serum	80-90 30-50	95-99 95-99	• Rapid (2–8 hours). • Diagnostic validity of positive results without confirmation by other methods remains unclear. • Potential to detects all *Legionella* spp. • Clinical utility of urine as a specimen type considered doubtful.
Culture isolation			
Sputum BAL or transtracheal aspirate Lung biopsy Blood	5-70 30-80 70-90 10-30	100 100 100 100	• ‘Gold standard’ method. • Requires supplemental tests to speciate. • Requires 3–5 days, sometimes (rarely) up to 14 days. • Highest specificity test. • Requires specialist media. • Reliant of good sample collection.
Urinary antigen			
EIA ICT (Lpsg1) ICT (*L.longbeachae*)	75-90 50-90 59.1	80-85 65-99 82.2	• Very rapid (15 minutes–3 hours), frequently earliest positive finding, may remain positive for several weeks/months. • Most assays only detect Lpsg1; limited data for other serogroups or species.

Method	Sensitivity (%)	Specificity (%)	Comments
			• Recent assay able to detect both *L. pneumophila* and *L. longbeachae.*
Serology (by IFA or EIA)			
Paired sera Single serum	60-80 (unknown)*	95-99 50-70	• Valid test requires parallel testing of paired sera taken at least 14 days apart. • May require follow-up testing to demonstrate seroconversion. • Seroconversion may take >3 weeks. • Specificity decreased by serum antibody cross-reactions.
Direct Fluorescent Antigen testing			
Sputum or BAL Lung biopsy	25-75 60-80	80 80	• Very rapid (2–4 hours). • Limited sensitivity. • Experience needed, technically difficult. • Not recommended for diagnostic testing due to poor performance.
Mass spectrometry			
MALDI-TOF-MS	<90	Not applicable	• Requires prior culture isolation. • Cannot be used for primary diagnosis. • Limited speciation and unable to reliably subtype *L. pneumophila.*
Metagenomics Next-generation sequencing			
Respiratory, blood or joint aspirate sample	Limited data	Limited data	• High cost. • Still regarded experimental.

BAL = bronchoalveolar lavage; EIA = enzyme immunoassay; ICT = Immunochromatographic test; IFA: Indirect immunofluorescent antibody; LAMP: Loop-mediated isothermal amplification; Lpsg1 = *Legionella pneumophila* serogroup 1; NAAT = nucleic acid amplification test; PCR = polymerase chain reaction. * Diagnostically unreliable.

Source: adapted from Bai et al., 2023; Reller et al., 2003; World Health Organization, 2007.

Serology

Most cases of legionellosis in New Zealand prior to 2016 were diagnosed serologically using indirect fluorescent antibody (IFA) testing methods to detect a rise in *Legionella*-specific antibodies in serum. Compared to culture, serology testing has a higher sensitivity, and faster turnaround, but lower specificity primarily due to antibody cross-reaction. As a diagnostic test, serological testing does not have an impact on patient management because seroconversion occurs relatively late (often two to six weeks after the symptom onset, but occasionally longer and sometimes not at all) in the course of the infection.

Test sensitivity is increased by using methods that detect both IgG and IgM antibody isotypes, since some studies have shown the immune response is primarily IgM. At best, serological testing is retrospective and serves as confirmation of suspected cases and can be useful when the window for collecting samples suitable for molecular or culture diagnoses has passed. Serologic testing is also useful in epidemiological and outbreak investigations when testing for exposure in a defined at-risk population (Thornley et al., 2017).

When relying on serological methods, antigens to all *Legionella* strains known to cause disease in New Zealand should be used when screening serum from suspected cases, as frequently this is the only clinical specimen taken. For effective surveillance, all potential causative agents should be screened for, otherwise a result bias is created as well as false-negative results.

Culture

Legionella culture isolation from clinical specimens is still considered the ‘gold standard’ method, even with its poor positive rate. *Legionella* does not colonise humans and cannot be isolated from healthy people. Routine culture from lower respiratory tract specimens should be encouraged as this enables genetic matching with available environmental samples.

The availability of culture isolates is imperative for source identification during outbreak or cluster investigations (WHO, 2007). However, its relatively low sensitivity and its reliance on the availability of a lower respiratory tract sample make it inadequate as the sole diagnostic test (WHO, 2007). Approximately only half of patients with legionellosis can produce an adequate sputum sample for testing, resulting in more invasive collection methods being employed to collect tracheal aspirate, bronchoalveolar lavage, or induced sputum samples.

Molecular detection

The most useful method for the diagnosis of legionellosis in New Zealand is molecular detection by nucleic acid amplification tests (NAAT) from lower respiratory tract samples

(Priest et al., 2019). Since 2016 this has become the method of choice due to its superior sensitivity and the ability to detect all legionellae.

The molecular detection of *Legionella* using PCR or other DNA amplification platforms is agnostic in the sense that it will amplify the nucleic acid from any *Legionella* strain present in the sample with equal efficacy when using primer and probe sets that target housekeeping or virulence genes present in all legionellae. Assays with specificities that do not include all *Legionella* species will present biased test findings. The collection and processing of appropriate clinical samples from symptomatic patients also influences test findings and lower respiratory tract samples have a greater positive predictive value than those collected from the upper respiratory tract for both culture and NAAT.

Legionella NAAT enables specific amplification of minute amounts of *Legionella* DNA and can provide results within a short timeframe. Unlike the UAT, it has the potential to detect infections caused by any *Legionella* species. Although data on performance characteristics for this test method are limited, NAAT on lower respiratory samples is now regarded as a valid diagnostic method (Avni et al., 2016). Since the issue of false-positive results is difficult to address, any suspected case giving a positive result by *Legionella* NAAT should be interpreted with caution. *Legionella* NAAT is now routinely available at an increasing number of specialised laboratories, including ESR.

Legionella Urinary Antigen Test

The Legionella urinary antigen test (UAT) is useful for the diagnosis of legionellosis as it does not rely on the collection of a respiratory tract sample. The UAT can give a positive result many days before serologic or culture methods.

The UAT detects a heat stable lipopolysaccharide component of the *Legionella* cell wall that is excreted in the urine. The sensitivity of the UAT is positively correlated with disease severity and the length of time since the onset of symptoms. Sensitivity is increased without loss of specificity by concentration of the urine. However, all UATs are limited in that they can only detect either a single *Legionella* serogroup, or a very narrow range of species or serogroups.

Most commercially available tests are available either as immunochromatographic tests (ICT) or as enzyme immunoassays so can be easily performed in any standard diagnostic laboratory without requiring specialist equipment. Traditionally these have only detected antigens from Lpsg1 (Reller et al., 2003). Recently the test range has been expanded by one kit manufacturer to include the detection and differentiation of both Lpsg1 and *L. longbeachae* (Podmore and Schousboe, 2020).

Several different ICT UATs for the detection of Lpsg1 in urine are commercially available. Each have differing performance characteristics, some of which should not be used as a

sole diagnostic assay for determining a current Lpsg1 infection, due to poor sensitivity and specificity (Kawasaki et al., 2022).

A positive *Legionella* result using a test designed to detect Lpsg1, although evidence of a *Legionella* infection, cannot be used as empirical evidence of infection by Lpsg1. This is because the test sometimes detects or cross-reacts with other serogroups of *L. pneumophila* and occasionally with non-*L. pneumophila* species (Reller et al., 2003). Supplemental testing using either culture or molecular testing to increase the positive predictive value of testing should be carried out especially if the UAT result is negative and there is a high suspicion of legionellosis.

There have also been reports of intermittent antigen excretion and the failure of patients with Lpsg1 infection to excrete antigen in their urine. Where a Lpsg1-specific UAT is used as the sole diagnostic test, cases of legionellosis caused by other strains will be missed. So, a negative urinary antigen result does not rule out a *Legionella* infection.

Persistent shedding of the antigen has also been reported in some patients, with the antigen still being detected up to a year after the onset of symptoms. This is usually seen in severely immunocompromised patients. Nevertheless, the UAT is of utility where the patient may not be able to provide an adequate respiratory tract sample, since a non-productive cough is a common sequalae with legionellosis cases.

In recent times, whole-genome sequencing has emerged as a major tool to support epidemiologic investigation (suspected clusters and outbreaks) of Legionnaires' disease and for characterisation of new strains, but still requires the culture isolation of the bacterium (Graham et al., 2023b).

Historically, direct fluorescent antibody (DFA) testing served as a rapid diagnostic method, although it always suffered from a low PPV and poor diagnostic accuracy. The DFA test has now been superseded by more accurate tests, especially NAAT and the UAT, and should not be considered as a clinically useful test.

2.8 Legionellosis in New Zealand

The first case of Legionnaires' disease in New Zealand was reported in 1979. Legionellosis became a notifiable disease in June 1980. Most New Zealand cases appear to be sporadic with the first reported outbreak occurring in 1990. Since then, a total of 27 recorded outbreaks have been identified. *L. pneumophila* and *L. longbeachae* have been identified as the causes of these outbreaks.

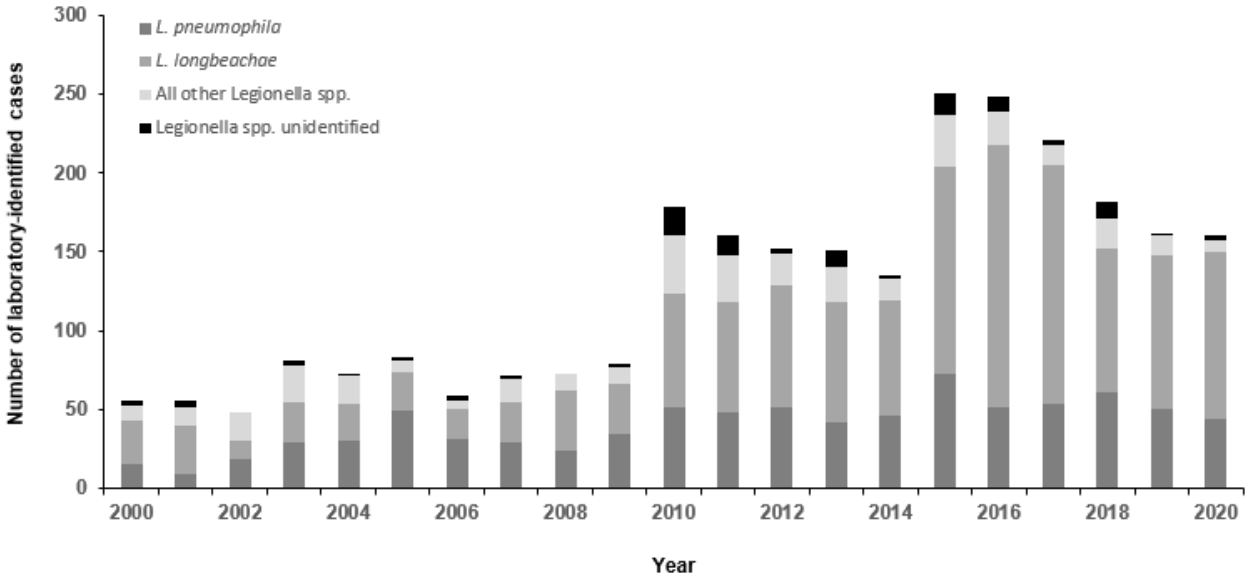
The largest outbreak to date occurred in 2005, involving 18 cases and causing two deaths. The source was thought to have been one or more cooling towers that returned a positive result after spatial analysis identified geographical clusters of cases (White et al., 2012). It is possible, however, that common source outbreaks have happened without being

recognised. The first suspected outbreak of Pontiac fever in New Zealand occurred in March 1998 (Maas et al., 2000). In 2007, the first documented outbreak of Pontiac fever due to *L. longbeachae* serogroup 2 in potting mix was reported (Cramp et al., 2010).

Between 2000 and 2020, of the 2,675 legionellosis cases fitting the case definition, 1,942 fitted the criteria for confirmation of a case and 733 as probable (Graham et al., 2023b).

In New Zealand, unlike many other countries, *L. pneumophila* is not the most *prominent Legionella* species causing infection (see Figure 1). Each year approximately 80-90% of all reported legionellosis cases can be attributed to either *L. pneumophila* or *L. longbeachae* species, although these figures fluctuate from year to year. The remaining 10-20% of cases are attributed to other *Legionella* species: these commonly consist of *L. bozemanae*, *L. dumoffii, L. feeleii*, *L. gormanii*, *L. jordanis*, *L. micdadei,* and *L. sainthelensi*.

Figure 1: Clinical laboratory-proven *Legionella* cases, 2000–2020



Source: Graham et al., 2023b

2.9 Legionellosis and the role of agencies in New Zealand

This section outlines the role of different enforcement agencies and building owners (including contractors) in the control and prevention of *Legionella*.

2.9.1 Ministry of Business, Innovation and Employment

The Ministry of Business, Innovation and Employment (MBIE) is responsible for administering the Building Act 2004. Under this Act, buildings must be safe, not endanger health and must have features that contribute to the health, physical independence and

well-being of people who use them. The Building Act sets the framework to ensure this. For buildings with wet cooling systems provisions include:

- building warrant of fitness regime
- offence provisions
- territorial authorities setting policies on dangerous and insanitary buildings.

The New Zealand Building Code Handbook contains model compliance schedules that include mechanical ventilation and air conditioning[2] systems. This involves complying with the AS/NZS 3666.1 *Air-handling and water systems of buildings – Microbial control*, which specifies the design, maintenance, and inspection regimes for cooling towers.

2.9.2 WorkSafe New Zealand

WorkSafe is New Zealand's primary workplace health and safety regulator and is responsible for administering the Health and Safety at Work Act 2015.

The role of WorkSafe is to assess a workplace's ability to understand and manage hazards which may arise in their day-to-day work. WorkSafe works with businesses to promote compliance with health and safety legislation, establish health and safety controls around work processes, and educate on managing hazards.

If a workplace is identified as being a possible source of *Legionella* bacteria, then WorkSafe is the lead agency, working with the local office of the National Public Health Service and other agencies such as territorial authorities to investigate specific risks in the workplace which may have contributed to the growth of the bacteria.

In serious cases, action may be taken under the Health and Safety at Work Act 2015 to improve the health and safety of the workplace, prohibit dangerous activities or to prosecute.

In the event of a wider outbreak of legionellosis, the relevant local office of the National Public Health Service would lead the response, with support from the national office and other organisations as needed.

2.9.3 Health NZ and the National Public Health Service

Legionellosis is a notifiable disease under the Health Act 1956. Health professionals and all medical laboratories (since December 2007) are required to inform their local Medical Officer of Health in the National Public Health Service of any case of legionellosis either suspected on clinical grounds or established on both clinical grounds and positive laboratory tests.

[2] Mechanical ventilation and air conditioning is a system specified under the Specified Systems, Change of Use, Earthquake Prone Buildings) Regulations 2005.

The local office of the National Public Health Service will investigate each notified case using a standard risk assessment questionnaire aimed at identifying all potential exposure sources for the case. When there is more than one case in an area, public health officers will look for common exposure events, such as places visited with cooling towers or spa pools, or exposure or use of the same reticulated water system.

Health NZ liaises with the Medical Officer of Health regarding any public health response and ESR regarding the laboratory testing and results.

Public health officers will usually take environmental samples to test for *Legionella* bacteria from potential sources and may make recommendations if there are any health risks identified. Health NZ will assist public health officers by providing technical advice, if necessary.

In the event of a cluster of cases, the public health response involves using the characteristics of notified cases (place, time, personal attributes such as age, ethnicity and gender – this is known as descriptive epidemiology) to establish a hypothesis as to the source of the cluster. Environmental sampling is essential in supporting or refuting the hypothesis, which in turn guides the appropriate response. Environmental sampling is used after any remedial action has been undertaken at sources found to harbour legionellae to assess the effectiveness of the remedial action.

The NPHS may issue a media release and have direct communication with other members of the community who may have been exposed to a common source. This is to encourage prompt identification of suspected cases and to understand the extent of any cluster or potential outbreak.

2.9.4 Territorial authorities (district, unitary and city councils)

Councils are required to follow the regulations made under the Building Act 2004 to ensure buildings are safe and healthy. They administer and enforce the building warrant of fitness regime under the Building Act 2004. This identifies mechanical systems and features present in a building (such as sprinkler systems, lifts, and cooling towers), the performance standards for those systems, and how they will be monitored and maintained to ensure they continue to function safely and effectively (MBIE New Zealand Building Code Handbook, 2014).

Compliance schedules made under Section 22 of the Building Act 2004 specify inspection, maintenance and reporting procedures for mechanical ventilation and air conditioning systems, to ensure compliance with the New Zealand Building Code. For a building to comply with the Building Code, the territorial authority (or other building consent authority) will issue a ‘compliance schedule’ itemising all specified systems in the building, as found in the Building (Specified Systems, Change of Use, Earthquake Prone Buildings) Regulations 2005. Mechanical ventilation and air conditioning systems are specified under these regulations.

The compliance schedule sets out the inspection, testing and maintenance requirements for the specified systems. The building owner must maintain those systems in accordance with the compliance schedule, issuing each year a building warrant of fitness to the territorial authority confirming that this has been done. However, there is no requirement to record this information in a readily accessible system such as an electronic database.

While it's not mandatory, the provision by Territorial Authorities of a register of both commercial and industrial cooling towers would prevent delays obtaining locations of all cooling towers when attempting to identify potential sources while investigating outbreaks and cluster events (see text box below: '*Learning from past events'*).

Learning from past events

Central register of wet cooling towers and evaporative condensers

In the 2005 Christchurch *Legionella* outbreak there were significant delays (weeks) in accessing the records showing the location of cooling towers for that city.

When the Medical Officer of Health approached the Christchurch City Council in 2005 and asked for a list of cooling towers in Christchurch, the council conducted a search of the compliance schedules on the file which contained mechanical ventilation or air conditioning systems and produced a list of cooling towers that were within the building warrant of fitness system. This took considerable time as cooling towers were not identified as a separate specified system at that time.

An additional issue arose with industrial cooling towers that were not under the compliance schedule regime. As a result, council staff had to consult people who provided services to treat towers or might have had the local knowledge of where industrial cooling towers were located. This was a slow and inaccurate method to identify all industrial cooling towers. Furthermore, the resulting delay in identifying the location of the cooling towers for immediate shock treatment increased the likelihood of more individuals contracting the disease.

In response to the 2012 cluster of legionellosis cases that highlighted the absence of a single register of buildings containing cooling towers, the Auckland Council passed the Property Maintenance and Nuisance Bylaw 2015 (as empowered by the Local Government Act 2002). This bylaw requires owners to register their industrial wet cooling tower systems annually, monitor *Legionella* bacteria levels, regularly clean and maintain their cooling towers, and send test results to the Council (Stephens, 2020).

Although the introduction of a bylaw is an important step, without national mandatory registration of all cooling towers and mandatory testing, outbreaks of this nature will continue to be challenging to investigate and cooling towers a risk to public health.

2.9.5 Standards New Zealand

Standards New Zealand is a business unit within the Ministry of Business, Innovation and Employment (MBIE). It is responsible for managing the development and distribution of a variety of Standards across a range of sectors nationally. Standards are documents that define materials, methods, processes, practices, or outcomes and can be used to set requirements, provide better practice, and deliver guidance. Many New Zealand Standards are developed in partnership with Standards Australia.

Relevant standards for the control and prevention of *Legionella* in cooling systems include the Australian/New Zealand Standard (AS/NZS) 3666: Parts 1, 2, 3 and 4, *Air-handling and water systems of buildings – Microbial control*. It sets out evaporative cooling tower design and installation, water management practices and standards, equipment maintenance and sampling of evaporative cooling water for chemical and bacteriological testing. It also sets out disinfection and follow-up sampling procedures to follow in the event of *Legionella* positive test results.

To improve the control of *Legionella* bacteria, Legionnaires' disease and general microbial control performance requirements at large installations, the Australian Standard AS 5059 entitled "*Power station cooling tower water systems - Management of Legionnaires' disease health risk*" was developed. This is primarily for use by power station designers, constructors, owners, operators, and regulatory authorities. This Standard sets out an advanced risk management methodology that includes all procedures set out in **AS/NZS 3666 Part 3**.

Other Standards related to the prevention of legionellosis involve methods of detecting legionellae in different matrices. These include the following:

- **AS/NZS 3896:2008** Waters – Examination for *Legionella* spp. including *Legionella pneumophila*
- **AS/NZS 5024(Int):2005** Potting mixes, composts and other matrices – Examination for legionellae
- **ISO 11731:2017** Water quality – Enumeration of ***Legionella***
- **ISO/TS 12869:2019** Water quality – Detection and quantification of ***Legionella*** spp. and/or *Legionella* pneumophila by concentration and genic amplification by quantitative polymerase chain reaction (qPCR).

The recommended method for the detection of *Legionella* species detailed in AS 3896:2017. This updates the previous version AS/NZS 3896:2008. It is recommended that AS 3896:2017 is more appropriate for use by cooling tower operators as it is more up to date and the method has been optimised for the isolation of legionellae from waters with potentially elevated levels of interfering micro-organisms.

2.9.6 Building owners/operators and employers

Building owners subject to a compliance schedule for their specified systems must demonstrate through robust records that the requirements for maintenance and testing for *Legionella* can be evidenced. Owners that comply with the compliance schedules are required to carry out monthly testing for the presence of total bacteria and *Legionella* bacteria provided they have an automatic dosing system. This is a requirement for the building's annual warrant of fitness and must be made legally available for audit in the agreed format.

Building owners are responsible for ensuring their buildings are properly maintained to comply with the building warrant of fitness. A building warrant of fitness is a statement supplied by the building owner to the council confirming that safety systems have been maintained and checked in accordance with requirements issued by the territorial authority.

Building owners must provide their building warrant of fitness to the council on an annual basis along with copies of inspection forms and any recommendations made by the inspecting 'IQP' (an independent qualified person) approved by the territorial authority (MBIE New Zealand Building Code Handbook, 2014).

If building owners do not comply with a notice from the territorial authority to comply with their building warrant of fitness, they could be fined up to $200,000 and in the case of a continuing offence, a further fine not exceeding $20,000 for day or part day during which the offence is continued (MBIE New Zealand Building Code Handbook, 2014).

In circumstances relating to industrial cooling towers, or cooling towers for industrial process that are not part of a building as defined in section 8 of the Building Act 2004, testing for *Legionella* in these cooling towers is required to be carried out by employers to ensure a safe working environment under the Health and Safety at Work Act (HSWA) 2015. This can be achieved by seeking a copy of a monthly water quality report in accordance with AS/NZS 3666.3 or requiring the building to report by exception.

Operators of any cooling system (including industrial, commercial, domestic, and small transportable cooling systems) other than refrigerated room air-conditioners and ductless split systems (heat pump systems), need to satisfy themselves that the cooling equipment remains safe and free of *Legionella* bacteria. It is highly recommended that all cooling water systems undergo monthly sampling and reporting of water quality in accordance with AS/NZS 3666.3. Owners and operators of industrial cooling towers who choose voluntarily to comply with AS/NZS 3666.3 will be seen to *eliminate risks to health and safety, so far as is reasonably practicable* (Section 30, HSWA) in the workplace.

3 Cooling Tower Systems

The basic function of a cooling tower is to remove heat to the atmosphere using circulating fluids. They rely on the passage of cooler air over a heated fluid to lower the temperature of the fluid. Air movement is one key principle in cooling tower design and is achieved either by natural or mechanical means. Air movement in a natural draught tower is created by the chimney affect with moist warm air rising because it is less dense and moves up and out of the tower drawing in cooler drier air in at the bottom. Air movement in mechanical draught cooling towers is achieved by power-driven fans within the tower.

To date, natural draught large-scale towers, such as those used at thermal power stations, have not been implicated in outbreaks of Legionnaires' disease, and these guidelines are not applicable to towers of this type. However, it is recommended that organisations responsible for the operation of these towers develop and maintain proper control of water quality since *Legionella* bacteria have been isolated from them.

3.1 Types of cooling towers

Cooling towers are an efficient and relatively inexpensive means of removing excess heat from building heating, ventilation, and air conditioning (HVAC) systems. Cooling towers are commonly part of the HVAC system in most large commercial, industrial (including refrigeration plants) and hospital buildings. Cooling towers are also used for removing excess heat directly from industrial processes, such as in food processing plants and plastics moulding and metal working factories. There are two main types of mechanical cooling towers.

- Dry (closed-circuit) cooling towers, where there is no direct contact between ambient air and the process fluid being cooled.
- Wet (open-circuit) cooling towers, where the process water is in direct contact with ambient air.

Both types of cooling towers can release aerosolised water to the atmosphere, and both require the same maintenance programmes to prevent the growth and proliferation of *Legionella* bacteria. However, some closed-circuit cooling towers can operate in cool temperatures in a "dry" mode that does not use water or generate aerosols because the tower rely on airflow to cool the process fluid.

Materials used in cooling tower construction should be corrosion resistant and non-porous, with easy-to-clean surfaces. Internal surfaces should be smooth, and edges and corners rounded to facilitate cleaning. The tower's design should provide easy access to internal surfaces of the tower, including the fill. Towers should be designed so that components, particularly drift eliminators and fill, can be easily cleaned, preferably *in situ*. There should

be large access panels to allow easy removal of components when required. Basins and sumps should be sloped to outlets with provision for rapid draining and filling.

In keeping with AS/NZS 3666.1, the following factors should be considered in the location of wet cooling systems that includes evaporative condensers and cooling towers.

- Locate as far as possible from building fresh air intakes, including windows that can be opened.
- Avoid locating close to dusty roads or car parks, or kitchen exhaust fans,[3] or other sources of organic matter which could assist in the growth of *Legionella*.
- Consider the direction of prevailing winds and ensure exhaust is discharged away from outdoor public areas, pedestrian zones.
- Consider future construction, including nearby sites, and the effects of reversal or air flow through some towers when the tower fan is idle. Relocation of cooling towers or air intakes should be considered in some circumstances, particularly if they are situated close to each other.
- Consider exposure to environmental contamination, such as soil or dust from demolition or construction sites, or soil or dust laden air in rural setting. This will increase cleaning the required frequency to reduce the level of solids in the system, and in turn, reduce bacterial growth.
- Tower design must consider the effect of direct sunlight. This must be minimized in the wetted areas of the cooling tower to prevent algae growth. *Legionella* and other bacteria feed on algal metabolic waste. Louvres may be necessary on inlets and outlets to exclude direct light.

3.2 Cooling tower design configuration

Cooling towers are categorised according to a number of different characteristics based on air flow dynamics and the placement and use of mechanical fans. A typical layout of an air-conditioning system using a cooling tower is illustrated in Figure 2. The cooling tower water gains heat from refrigerant circulating through the condenser, and in the process of being distributed over the tower fill, loses heat to the rising air through evaporative cooling and convective and conductive heat exchange. The mode of air flow is either forced or induced draught.

To date, large scale towers with natural draughts, such as those used in power generation, have not been implicated in outbreaks of Legionnaires' disease, and these guidelines are not applicable to towers of this type. However, it is recommended that organisations

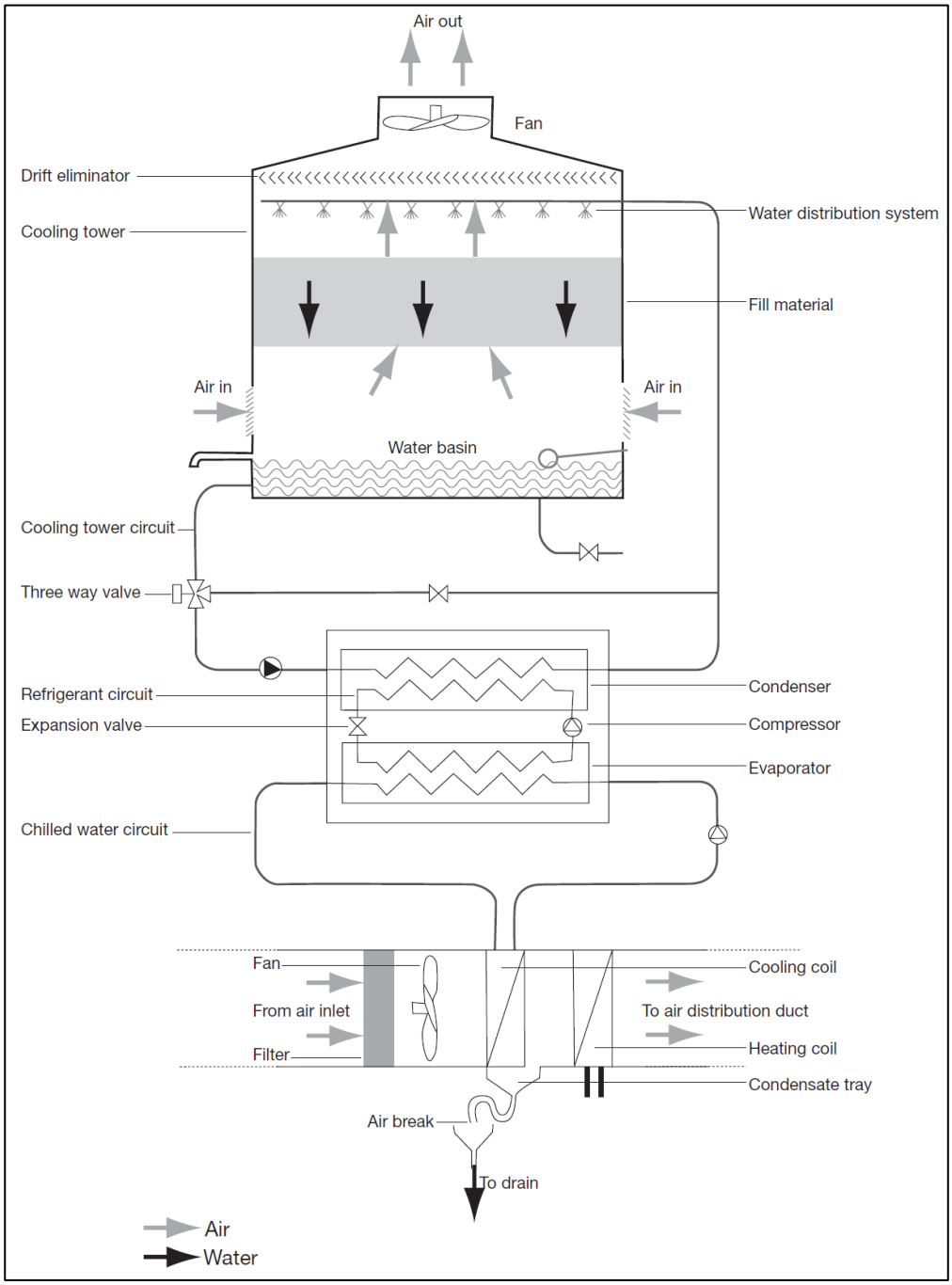
[3] AS/NZS 3666.1: 2011 states '*The effluent of kitchen exhaust systems may hinder the control of microbial growth in cooling towers. Kitchen exhaust should be discharged at a distance of not less than 8 m from any cooling tower intake or discharge opening*'. Reproduced with the permission of Standards New Zealand under Licence 000807.

responsible for the operation of these towers develop and maintain proper control of water quality since *Legionella* bacteria have been isolated from them.

The direction of air flow though the tower is either ‘crossflow’ where airflow and water flow are at right angles to each other, or ‘counterflow’ where airflow and water flow are in opposite directions. The more common types of cooling tower systems are illustrated below in Section 3.2.1 and 3.2.2.

Wet cooling towers use water as the heat sink. The water is pumped from the basin at the bottom of the tower to the top where it falls through a structure and flows over the heat exchanger material (fill) within the tower before accumulating in the water basin before being recirculated. The fill is designed to create an extensive wet surface area through which air passes resulting in a high heat transfer rate. There are several different types and configurations of cooling tower available, each of which has common operational features: the use of a water basin, the use of fans, the use of fill and the use of drift eliminators.

Figure 2: Schematic layout of an air conditioning system using a closed-loop cooling tower.



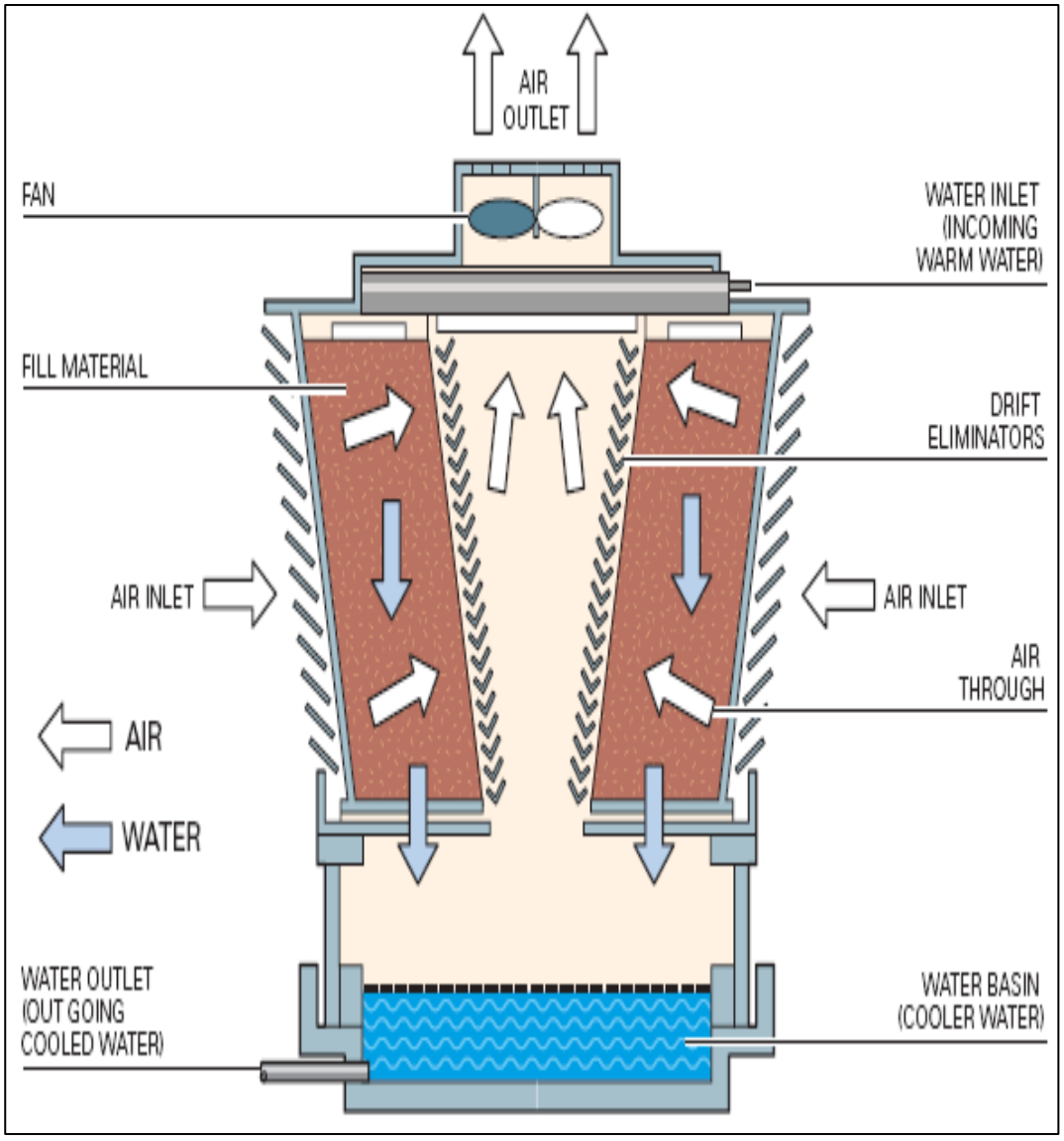
Source: Department of Health (2021)

3.2.1 Induced draught cooling tower

These cooling towers use mechanical fans located at the air discharge point (top) of the cooling tower to draw air through the tower fill fan. The warm moist air is removed at high velocity to reduce unwanted recirculation.

Figure 3 shows a crossflow configuration where air enters the tower through inlet louvres located above the basin perimeter and is drawn horizontally through the fill at right angles to the water flow. The placement of the louvres prevents direct sunlight on the fill material.

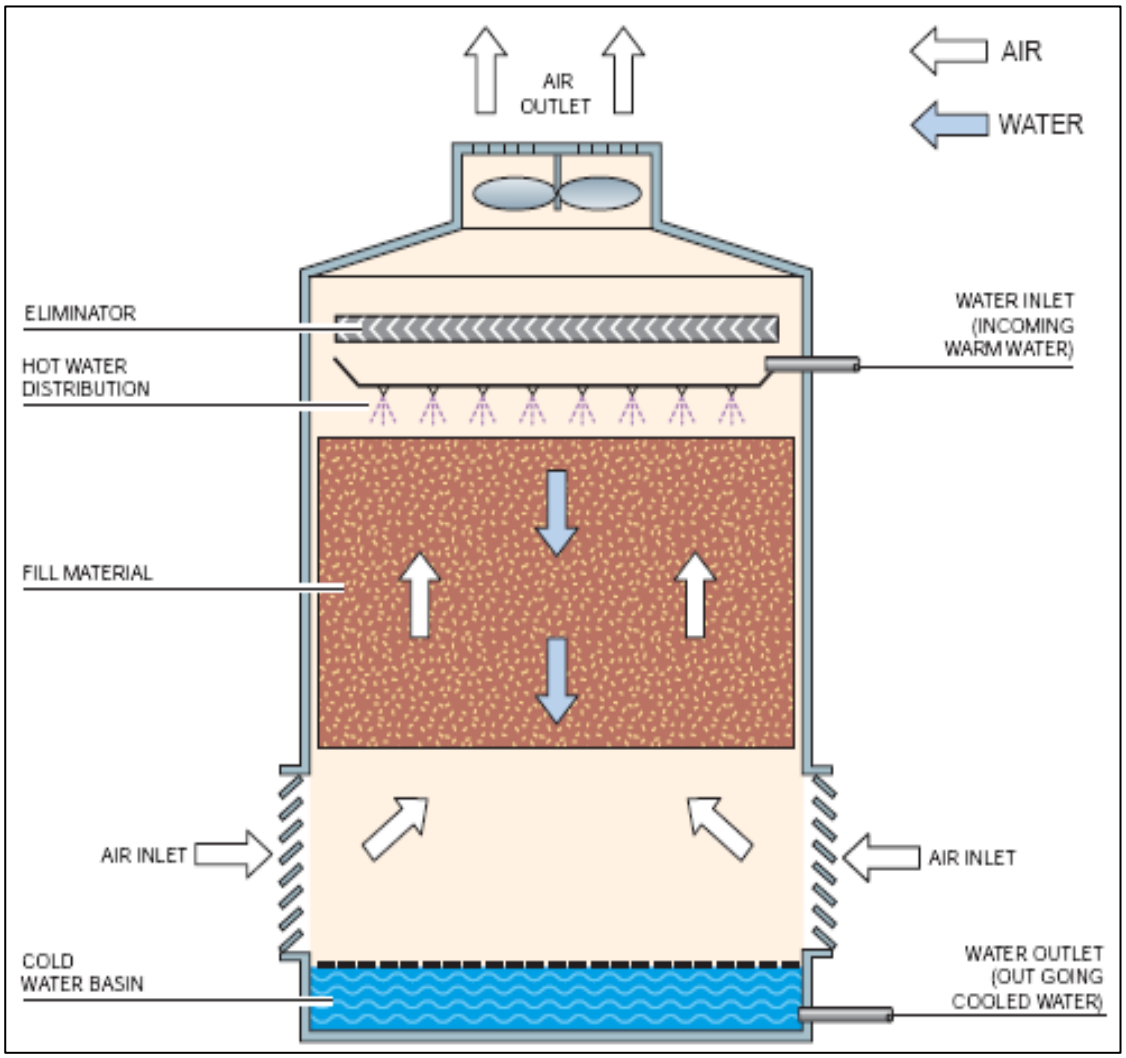
Figure 3: Induced draught crossflow (open-loop) cooling tower



Source: Department of Health (2021)

Figure 4 shows an induced draught tower with the drift eliminator located immediately adjacent to the air exhaust. Air is drawn vertically through the tower through inlet louvers that prevent direct sunlight on the water basin. This is a counterflow configuration.

Figure 4: Induced draught counterflow cooling tower

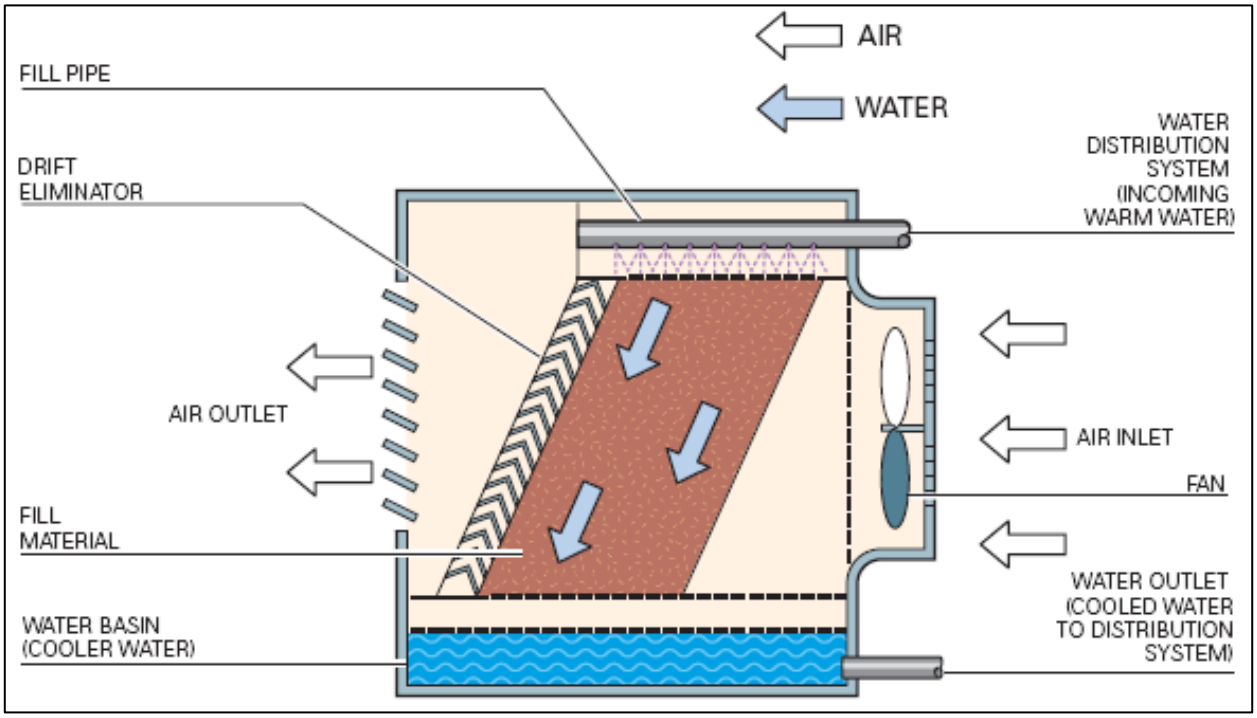


Source: Department of Health, (2021)

3.2.2 Forced draught cooling tower

These cooling towers are similar to induced draught towers, but use mechanical fans located at the air intake just above the basin. Air is forced vertically through the tower fill in the opposite direction to the water flow (see Figure 5).

Figure 5: Forced draught crossflow cooling tower



Source: Department of Health, (2021)

3.3 Evaporative condensers and fluid coolers

These units are similar in principle and operation to cooling towers. Evaporator condensers are primarily used in large cooling systems or systems where the outdoor temperature is high. Water is distributed directly over a bank of pipes which contain circulating refrigerant or other process fluids, but there is no fill as in cooling towers. There are two main types of evaporative condensers: forced draught and induced draught (see Figure 6), depending on the location of fan.

Figure 6: Evaporative condenser, induced draught (closed-circuit)

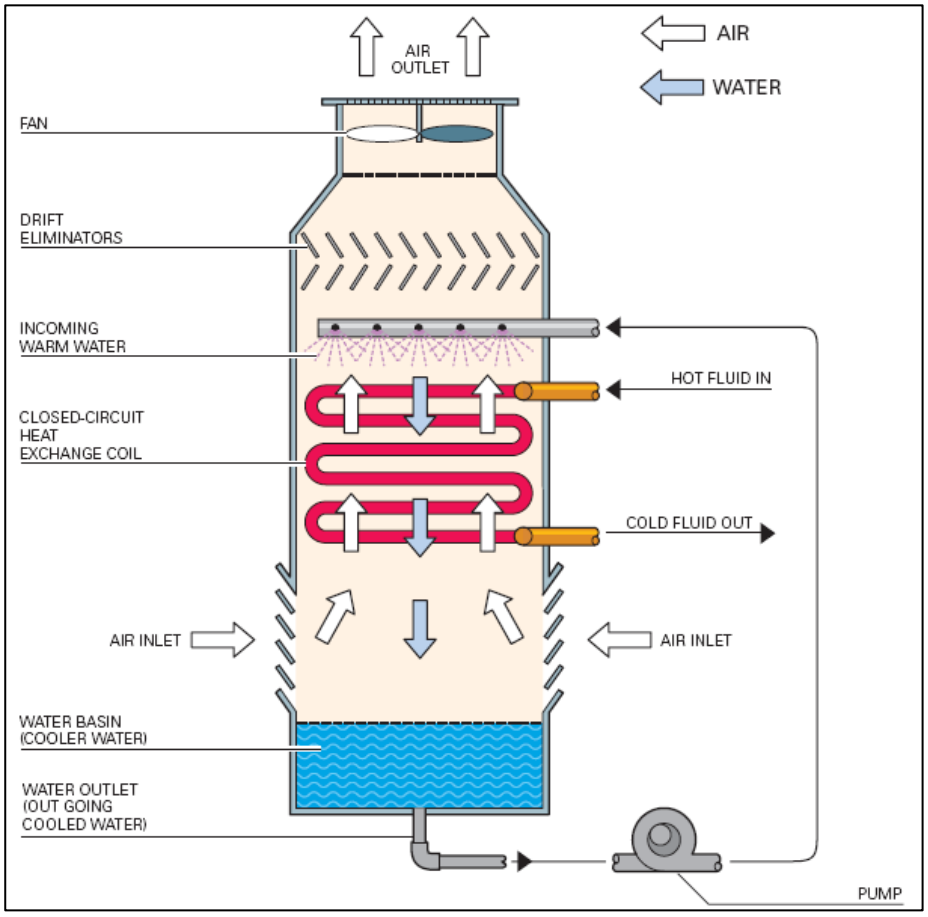


Diagram shows cut away of an evaporative condenser.
There is no fill and cooling water is sprayed over bare pipes containing the fluid requiring to be cooled.

Source: Department of Health, (2021)

3.4 Drift eliminators

In the operation of all cooling towers, water is lost through evaporation, bleed-off and drift. Drift is the portion of the circulating water entrained in the cooling tower exhaust as very small droplets (aerosols). These droplets are produced within the tower by water impacting on the tower fill and by the water distribution system. Without drift eliminators, the air flow will carry the smaller droplets through and out of the tower.

To minimise drift loss ie, droplets or drift leaving the cooling tower, eliminators must be located before the tower exhaust. It is important to restrict the amount of drift emanating from the tower as it contains dissolved minerals, chemicals, and micro-organisms, including bacteria. The risk from drift lies in the transport of bacteria and chemicals to nearby environs. AS/NZS 3666 Part 1 establishes a performance standard for drift eliminators, requiring the drift loss of a cooling water system to be no more than 0.002% of the water circulating rate.

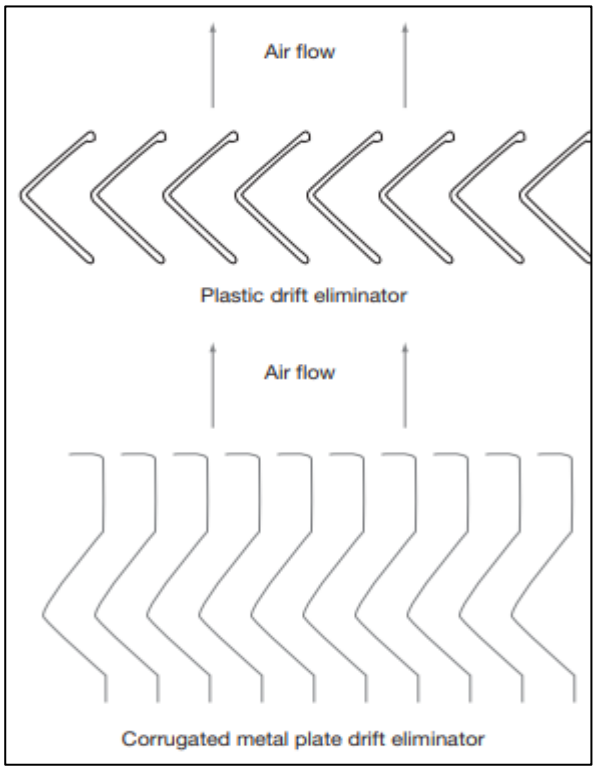
The eliminator and fill material should be able to withstand the pressure of a water jet. Eliminators should preferably be able to be cleaned in-situ to avoid incorrect fitting when being replaced after removal for cleaning. Incorrect alignment of eliminators may result in unacceptable levels of drift.

The performance of drift eliminators cannot be measured *in situ*, so should be of proven performance before being fitted (tested in accordance with AS/NZS 4180: 1994 - *Drift loss from cooling towers - Laboratory measurement*). Drift eliminators must be fitted and installed in compliance with AS/ NZS 3666 Part 1. Part of the monthly physical inspection of the cooling tower should include the condition and correct placement of the drift eliminators.

Drift eliminators are usually constructed from plastic, metal or wood. Modern drift eliminators are generally constructed of materials such as UV stabilised propylene which can be retrofitted into older systems. Figure 7 shows that they are oriented in zig zag passageways to enable air to move through while trapping water droplets.

Note: the use of wooden drift eliminators is discouraged as these are difficult to sanitise and encourage the growth of persistent microbial biofilms. Wooden drift eliminators should be replaced with plastic or metal ones.

Figure 7: Types of drift eliminators



Source: Adapted from New South Wales Department of Health (2004)

3.5 Cooling tower fill material

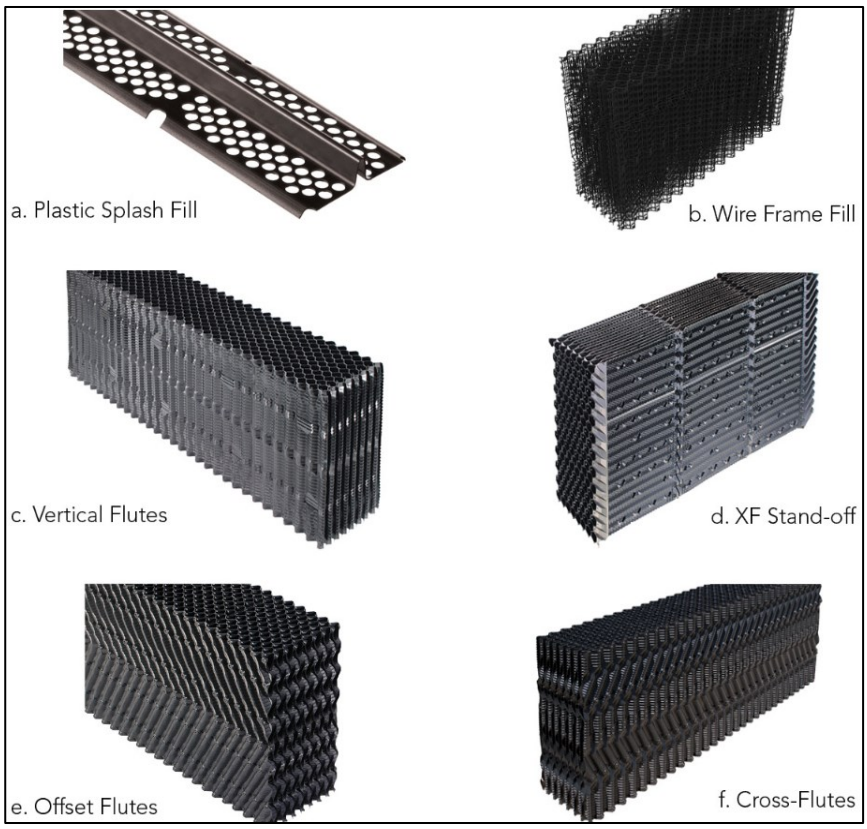
The underlying principle for all cooling towers is to enhance water contact with air to allow hot water to cool rapidly on exposure to air at ambient temperature. Maximising the thermal efficiency of cooling towers is achieved by maximising the available surface area over which to create the water-air interface. The fill selection plays a critical role in achieving this.

There are two common types of fill media:

- Splash fill (common in crossflow towers): consists of layers of horizontal bars or slats that falling water hits spreading into small droplets. This increases the water surface area exposed to air which accelerates the cooling and evaporation rates of the water.
- Film fill (more common in newer towers): consists of corrugated sheets of material, often fluted, and combined into blocks. This increases the circulation water surface area exposed to the airflow, thereby increasing heat rejection, and reducing air resistance.

Figure 8 illustrates a variety of fill designs ranging from modern splash fill to very high efficiency film fill material. The choice of fill depends on the fouling tendencies of the cooling water. The fill media must be protected from fouling, scaling, and corrosion.

Figure 8: Types of fill media



Source: Brentwood Industries

4 Operation and maintenance of cooling towers

4.1 Water treatment

To optimise the heat transfer efficiency and maximise the effective life of the cooling tower and associated equipment, it is standard practice to chemically treat the circulating water.

Corrosion inhibitors are used to minimise the corrosion of metal surfaces, which may result in serious maintenance problems and premature failure of plant and equipment.

Surfactants, biocides, and other chemicals are used to control fouling through scale, silt, and microbial growths in order to maintain efficient heat transfer at metal surfaces. This

ensures free flow of water throughout the system and prevents the proliferation of certain micro-organisms which are responsible for surface corrosion and degradation.

These basic reasons for treating cooling tower water have not changed. However, with the discovery of *Legionella*, there is now an ongoing re-evaluation of biocides used in these water systems. It is now recommended practice to incorporate biocides, preferably broad-spectrum types, which reduce the total microbial load.

In the dynamic environment of a cooling tower system, the performance of chemicals is different from that in a controlled laboratory trial. Cooling tower water is subjected to temperature changes and varying flow velocities at different locations within the system. Many other parameters, including pH, conductivity, total dissolved solids, suspended matter, and the biological mass within the system can vary with time, so must be monitored routinely to ascertain the overall performance of the tower.

Biocides must come into contact with the micro-organisms to ensure adequate control. Particulate matter, scale, debris, slimes, and the presence of other micro-organisms such as protozoa have the potential to shield *Legionella* from biocides, and this may result in their persistence and proliferation when biocide levels fall. For corrosion inhibitors to be effective, they must contact the metal surfaces to be protective, which requires that the system be free of fouling. Chemicals may be absorbed by contaminants in a dirty system, further reducing the effectiveness of any treatment programme.

Most cooling tower fans are thermostatically controlled, resulting in variations in air flow rates and accompanying airborne debris. Thermostatically controlled water pumps and valves can be responsible for a wide range of waterflows through the system, including no flow during periods of low-heat rejection. Many air conditioning systems associated with office buildings are shut down at night and during weekends, resulting in stagnant conditions during these periods.

For any water treatment programme to be effective, it is important that the water and all wet surfaces of the cooling tower system are maintained in a high state of cleanliness.

The aim of combining physical cleanliness of the internal surfaces of a cooling tower system with the use of an appropriate water treatment programme, is to maximise heat transfer, minimise corrosion, and control microbial populations, including *Legionella*. As expected with any preventive maintenance programme, the cost will be offset by increased plant efficiency and increased operational life of the equipment.

If there is no on-site expertise, it is essential that specialists in the treatment of cooling tower water systems be brought in to provide and monitor appropriate water treatment.

4.2 Bleed-off

Water supplied to a cooling tower contains a wide and varying range of dissolved substances and the amount is dependent on the source water. During the normal operation of a cooling tower, evaporation occurs, resulting in an increase in the total dissolved solids in the cooling water over time.

Increasing levels of certain substances increase the potential for corrosion of metal surfaces. Eventually the water will become saturated, and materials will start to deposit within the system. Because the solubility of certain compounds decreases with increasing temperature, deposits can occur at those heat transfer surfaces operating at the highest temperature. These inorganic materials cannot be removed by oxidising biocides such as chlorine and ozone.

To overcome these problems, a small percentage of the total water volume is regularly discharged to waste (bleed-off) and replaced with fresh water. This has the effect of limiting the concentration of total dissolved solids and is usually controlled in association with conductivity or chloride ion analysis of the water. Excessive bleed-off should be avoided as this will result in a loss of water treatment chemicals, which will reduce the effectiveness of the water treatment programme.

Bleed-off can be carried out by a continuous controlled flow to waste or by intermittent discharge. Intermittent bleed-off can be achieved by manual operation of drain valves or by automatic systems operating on a time frequency or controlled by a conductivity chloride meter. Back-washing of filters with cooling water is also a form of intermittent bleed-off.

Bleed-off also provides limited control of suspended matter in the cooling water. As the quantity of bleed-off in a cooling tower decreases, the cycles of concentration increase, the amount of make-up water needed decreases, and the quantity of treatment chemicals decreases. A bleed-off lockout timer should be used to prevent bleed-off for a set period following biocide dosage to prevent wastage of expensive biocide chemicals.

4.3 Biocides

4.3.1 Ideal biocide

The ideal biocide is effective against a wide spectrum of bacteria, algae, protozoa, and fungi. It should have a long activity time, no mammalian toxicity, and be environmentally acceptable in tower drift and water discharge. It must be quick acting and effective at a low concentration over the pH range encountered in cooling tower water, be compatible with other chemicals used, and not cause deterioration of materials with which it comes into contact. Biocides should be capable of penetrating foam, sludge, slime, and scale within the system without foaming.

Ideally, biocides should be low in cost, safe and easy to transport, handle and apply, and their effectiveness should not be reduced by contaminants within the cooling tower system or by substances present in the make-up water. The biocide level should be able to be measured on-site over the range normally used in the water treatment programme.

Since the ideal biocide does not exist, the appropriate treatment for a particular tower is compromise. If biocides are to be cost-effective in cooling water systems, they should possess a range of properties.

4.3.2 Types of biocide

Biocides used in cooling tower water are usually divided into two main groups: oxidising and non-oxidising compounds. Both oxidising and non-oxidising biocides have a role to play, and it is often recommended that they be rotated or used in combination. Scale and corrosion inhibitors must be compatible with the biocides used for microbial control.

4.3.2.1 Oxidising biocides

Commonly used oxidising antimicrobials for cooling water include chlorine, bromine, stabilised bromine, combinations of bromine and chlorine, chlorine dioxide, halogenated hydantoins, peroxy compounds such as hydrogen peroxide and peracetic acid and ozone (WHO, 2007). Oxidising antimicrobials are often effective when fed continuously using metering systems with small pumps and many towers are successfully treated with continuous dosing with chlorine or bromine (WHO, 2007).

One of the difficulties associated with oxidising biocides is the lack of penetration ability to control the biological growth within a biofilm, and it is necessary to incorporate a dispersant to assist in the disinfection of cooling tower systems.

Halogenated biocides

Chlorine in the form of ‘free chlorine’ is formed when chlorine gas, sodium hypochlorite or certain other chlorine-releasing compounds are added to water. Bromine in the form of hypobromous acid (‘free bromine’) has similar properties to free chlorine but its action is not as sensitive to pH variations. Also, certain bromine-ammonia by-products are more efficient biocides in contrast to the weaker effects of chlorine-ammonia compounds. A bromine-release compound bromo-chloro-dimethyl hydantoin (BCDMH) has shown acceptable control of *Legionella* spp. in field situations.

Other halogenated oxidising biocides have the potential for use in cooling tower systems but have been used to a very limited extent. One example is chlorine dioxide. The technical difficulties associated with its production and control on-site are factors which restrict its use.

Hydrogen peroxide

Hydrogen peroxide is a versatile and powerful oxidizer but a relatively weaker disinfectant when compared to chlorine. For microbial disinfection of cooling towers hydrogen peroxide is usually stored at 50% solution and is injected into the water body and maintained at levels between 10-20 ppm. It is also used in combination with ozone (peroxone) or ultraviolet light for enhanced microbial disinfection.

Hydrogen peroxide works extremely well at exfoliating organic biofouling on surfaces through mechanical means, eg, effervescing “scrubbing bubbles”. It can also be used occasionally at higher concentrations for maintenance cleaning purposes on fouled heat exchangers, cooling water loops and process water loops.

Hydrogen peroxide can be used as a dechlorinator, so is incompatible with systems using halogenated biocides.

Ozone

Ozone is a powerful oxidising biocide which has been used overseas as an alternative for the chemical biocides in cooling tower water treatment. Ozone reacts with organic material, including micro-organisms within the cooling tower water. The oxidative products formed further react with other micro-organisms, biofilm and scale. As ozone gas is an unstable chemical, it must be produced on-site by means of an ozone generator and used immediately in water treatment. Care must be exercised to maintain the generators in accordance with the manufacturer’s recommendations to ensure peak efficiency.

Ozone has had variable success in cooling tower water treatment, with some reports of accelerated corrosion. In addition, ozone maintains very poor residual properties compared to halogenated biocides.

4.3.2.2 Non-oxidising biocides

The most common type of biocidal treatment of cooling tower water is by non-oxidising biocides. As an example, non-oxidising chlorinated phenolic thioether has shown acceptable control of *Legionella* spp. in field situations when used correctly. Other broad-spectrum non-oxidising biocides are the quaternary ammonium derivatives and isothiazolinones. Isothiazolones and quaternary ammonium compounds have a high toxicity rating for aquatic flora and fauna so should not be used.

4.3.3 Comparison of biocide types

The use of chlorine as a biocide for potable water and in swimming pools is well known, and bromine is now widely used in spa pools.

The advantages of these biocides are rapid kill of bacteria and easy measurement of the free chlorine or bromine residual on-site by means of a simple, robust and reliable test kit.

Automatic electronic control systems, which can give accurate pH and low chlorine or bromine residual control in re-circulating water systems, have been available for many years. With either chlorine or bromine, this precise method of control should be used to overcome potential corrosion problems associated with high levels of oxidising biocide and low pH. Maintaining an active residual between 0.5-1.0 mg/L [0.5-1.0 parts per million (ppm)] of free chlorine with appropriate pH and water quality in conjunction with maintaining good cleanliness of the system will usually result in good microbiological control.

A portion of any oxidising biocide added to a wet cooling system is consumed in reacting with organic and inorganic materials present in the make-up water. It is necessary to overcome this chlorine or bromine 'demand' of the system to provide a free biocide residual.

An increase or decrease in water pH reduces the effectiveness of halogenated biocides, chlorine much more so than bromine. Preferably, chlorine should be used in water where the pH is controlled between 6.8 and 7.8 and bromine in water where the pH is controlled between 7.4 and 9.0. Outside these narrow pH ranges the biocidal effect drops significantly.

Non-oxidising biocides usually have a much lower kill rate than oxidising biocides but because they are less reactive, they may persist longer in the system (an advantage over oxidising biocides). Non-oxidising biocides are usually dosed at higher concentrations (15–20 ppm) than oxidising biocides (0.5-1.0 ppm) and may require longer contact times at these concentrations (4–10 hours) (WHO, 2007).

The major deficiency of the majority of non-oxidising biocides is the lack of a simple on-site test to determine their concentration in water. Consequently, initial biocidal concentration is determined by calculation based on the estimated water volume of the system and the weight of biocide added. A calculated figure may be determined for a limited period of time based on dilution with make-up water, bleed-off rates, drift loss, and other losses, if they can be quantified. However, it is almost impossible to directly determine the loss of biocide by absorption and breakdown under the varying conditions within the system.

4.4 Application of chemicals

4.4.1 Dosing points

Certain water treatment chemicals may have the potential to react with each other at the concentrations in which they are supplied. This should be established before use and if problems are likely with the proposed chemicals, separate dosing points should be used to ensure dilution of one potentially reactive chemical prior to adding a second.

Water treatment chemicals should be added to turbulent zones within the water system to assist with rapid dilution and mixing.

4.4.2 Methods of dosing

A number of dosing systems are available for adding chemicals to cooling tower water.

Manual dosing is usually carried out on a regular basis (eg, weekly) by broadcasting a diluted form of the biocide across the surface of the water in the tower basin. Another method is to add the chemical to a turbulent zone of the water system over a period of a few minutes. Safety is important when using this method, which should be used in conjunction with suitable automatic dosing equipment as required in AS/NZS 3666.1.

Metering systems are available which inject chemical solutions into the circulating water through a small pump. The metering devices may be controlled in a variety of ways, including:

- electrically linking the metering pump with the circulating water pump
- incorporating a timing device to produce pulse dosing of chemicals. Bleed-off should also be electronically delayed allowing biocides to circulate at maximum concentration before bleed-off
- electronically linking a make-up water flow meter with a metering pump to inject chemicals in proportion to the volume of make-up water.

Automatic metering systems are the preferred method of dosing for most chemicals. It should be noted that AS/NZS 3666.1 (section 4.1.3) and AS/NZS 3666.3 (section 2.4) stipulate that all water-cooling systems must have automatic dosing systems and should not be manually dosed. Drip-feed systems are not recommended.

4.4.3 Dosing frequency

Biocides, corrosion inhibitors, scale and sludge dispersants should always be maintained at appropriate levels for optimum performance. Controlled dosing of the necessary chemicals by metering pump is the best way to achieve optimum concentrations.

Maintenance of a low concentration of biocide is used for microbiological control. It is common practice to alternate biocides periodically or use a combination of two different biocides to provide better control against a range of micro-organisms.

Slug or shock dosing (single high-concentration injection of chemical) is not a recommended method for the addition of oxidising biocides, although this is acceptable for non-oxidizing biocides. However, metered automatic dosing linked to either blow-down or make-up is the most appropriate method of applying biocides to a wet cooling system. Frequency of dosing should be related to heterotrophic plate counts (HPC) (see section 4.9.1 and 4.9.4) and general cleanliness of the tower.

4.4.4 Discharge from cooling towers

The discharge of cooling tower wastewater poses the following contamination risks.

- Sediment can cause turbidity problems in waterways and water bodies.
- Most biocides and anti-corrosion chemicals are toxic to humans, as well as to plants and animals in aquatic environments.
- Biocide and anti-corrosion chemical residues discharged to sewer may be toxic to the microbes used for sewage treatment.
- Heavy metals (additives or sourced from pipework) are toxic and can accumulate in aquatic organisms.

Currently within New Zealand there is no comprehensive or integrated statutory framework covering the management of liquid waste such as industrial cooling tower wastewater. The current management of industrial cooling tower wastewater in New Zealand is subject to a number of statutes including the Resource Management Act 1991 (RMA) and Local Government Act 2002 (LGA).

The type, quality and quantity of industrial liquid waste such as cooling tower wastewater that may be released to a sewer, natural waterway or disposed of by some other means may be covered by legislation such as local trade waste bylaws pursuant to the LGA.

Alternatively, the discharge of cooling tower wastewater to a natural waterway either with or without treatment, may be captured under the requirements of 15(1)(d) of the RMA 1991 which provides for the regulation of the discharge of contaminants from industrial or trade processes. Under section 15 of the RMA no person may discharge cooling tower wastewater (captured under the definition of ‘contaminant’) unless the discharge is expressly allowed by a national environmental standard or a rule in a regional plan.

4.5 Ultraviolet light

Ultraviolet (UV) light is often used to control bacterial levels in water systems and is preferably used in conjunction with filtration to enhance water clarity and improve penetration of the radiation into the water body. UV radiation in the spectral range of 200-300 nm (UV-C) is considered to provide better disinfection because this is the range that is readily absorbed by nucleic acids and proteins.

Traditionally UV disinfection systems have been operated using either low pressure or medium pressure mercury vapour lamps. Low pressure lamps allow for greater photoreactivation repair of *Legionella* after UV treatment compared to medium pressure lamps. This is most likely due to their narrow emission wavelength around 254 nm, whereas medium pressure lamps have a wider spectral range of around 200 – 600 nm.

Recently, UV light-emitting diode (LED) lamps have become available, but their utility in the treatment of cooling tower waters has not been fully evaluated. Mercury UV lamp systems require lamp replacement after about 300 days of continuous operation (this is significantly reduced with increased on-off switching cycles), whereas UV-LED lamps last up to 1,500 days without being affected by the frequency of on-off switching cycles. Sensing devices may be located within the lamp mounting to measure UV intensity. The sensors will indicate loss of effectiveness and the need for maintenance such as lamp cleaning or replacement. For best results, it is essential to keep the UV units and the circulating water clean.

UV light as a biocide has several limitations in a cooling tower environment. These limitations include:

- UV radiation has no effect on the pH, odour, or chemical composition of the water. However, the colour, turbidity and chemical composition of the water can interfere with UV transmission, so it is advisable to determine the UV absorbance of the water to be treated before installing UV equipment. Bacteria may be protected by turbidity, clumping and the presence of slimes; therefore, appropriate water filtration (eg, sand filtration) is recommended to be used in conjunction with UV light.
- The UV damage can be significantly reversed in *Legionella* and other bacteria by enzyme repair mechanisms such as those which operate in the dark (dark repair) and on subsequent exposure to bright light, including sunlight (photoreactivation).
- Disinfection occurs only in water passing through the unit and, as no residual is produced, there is no anti-microbial action in other parts of the system.
- UV light has no effect on biofilm formation outside the immediate area of treatment.

Due to these limitations, UV disinfection should not be used as the primary means of water treatment in cooling towers.

4.6 Proprietary devices

A number of different non-chemical devices for the conditioning of water in swimming pools, steam generators, potable water supplies and other water applications have been developed at various times over several decades. They often claim to control scale, bacteria, algae and other contaminants. These devices rely on an effect produced by permanent magnets, electromagnets and electrostatic fields.

There is a lack of conclusive scientific evidence to demonstrate that these devices have any significant effect on water quality and the survival and growth of *Legionella* in controlled laboratory or field trials. Therefore, they are not recommended for use in cooling towers for the control of bacteria (Duda et el., 2011).

4.7 Filtration

Cleanliness of a system is of paramount importance in the control of microbes in cooling tower water. One of the simplest methods available to control particulate matter in water is filtration. A full-flow filtration plant that will remove fine particles is impracticable in most systems because of space and weight restrictions, and such filtration units would have excessive installation and operating costs. However, side-stream filtration, incorporating an independent water pump and pipe work, is effective for all cooling towers.

The side-stream operation ensures that a proportion of the cooling tower water is continuously filtered, and the use of a sand filter of the domestic swimming pool type, with manual or automatic back-wash facility, should be considered. This system can circulate biocide-treated water through the tower basin when the cooling tower system is idle and will provide a measure of microbial control within the basin water. Sand filters can remove suspended debris from the circulating water and have the capacity to filter out larger micro-organisms, such as protozoa, which may protect *Legionella* from the effect of biocides. If filters are installed, they should be included in the routine inspection and maintenance programme.

Other methods of filtration with different retention capabilities are available. Coarse filters have the potential for full-flow filtration but allow a high percentage of suspended matter to pass through. Fine filters such as cartridge or membrane filters can produce water of very high quality, but they may rapidly become fouled.

For larger systems, cyclonic separators are a good alternative because they require less maintenance than conventional methods of filtration. Poorly maintained or infrequently back-washed filters can become reservoirs for contamination rather than enhancing disinfection.

4.8 Maintenance

Well-maintained systems are less likely to be colonised with *Legionella* bacteria than systems that are poorly maintained. Continued vigilance in terms of preventive maintenance and a good water treatment programme are required to minimise the risk of *Legionella*.

AS/NZS 3666.2 recommends a maintenance programme for cooling towers that aims to ensure optimum thermal performance through a combined strategy of mechanical maintenance and total tower cleanliness. These maintenance procedures provide for regular water treatment, inspections and cleaning, and should be put into practice immediately upon the cooling tower being put into service. Detailed records must be kept of all maintenance procedures undertaken and all biological and chemical testing carried out on cooling towers.

Cooling towers should also be cleaned and disinfected before commissioning in accordance with the routine cleaning and disinfection procedure.

4.8.1 Operation

Staff or contractors responsible for operating the relevant equipment should have clear instructions. These should describe the operating characteristics, including commissioning data, and installation drawings, together with any modification of the total air conditioning system, schematic wiring and automatic control diagrams, and manufacturer's recommendations for servicing.

All operating staff must be trained to perform the required monitoring and maintenance tasks as described in section 2.6 of AS/NZS 3666.2. Authorisation of regular plant servicing and data collection by the building owner or nominated representative is essential. Details of all regular, planned maintenance should be recorded in a manual for performance trend identification and for prompt attention to faults reported by operational staff or building occupants.

4.8.2 Routine inspections

The Building Act 2004 requires all buildings that contain a mechanical ventilation system (which can incorporate air conditioning cooling towers) have a compliance schedule and must undergo routine inspections and maintenance on a monthly basis. The New Zealand Building Code Handbook contains a model compliance schedule for mechanical ventilation systems.

In carrying out monthly visual inspections the tower should first be examined under normal working conditions, with appropriate safety equipment being worn to prevent the inhalation of aerosols. A number of items can be examined externally, including signs of microbial growths, algae, water leaks, splashing and blockages, or restrictions at air inlets. If chemical dosing equipment is installed, it should be examined for correct operation and for adequate stock of chemicals.

Internally, water flow through the tower should be viewed for normal unrestricted flow, and drift eliminators examined internally or externally for damage and excessive drift.

With the fan, water pump and any dosing and filtering equipment switched off, the internal structure of the tower should be examined to check the condition of plant and equipment. For example, note should be made of any deterioration of materials (timber, metal, etc) particularly the fill, drift eliminator, basin, and water distribution system.

Internal surfaces should be examined for signs of corrosion, scale, microbial growths and general fouling, and the water checked for clarity.

More detailed inspections should be undertaken when the plant is completely shut down during the annual inspection. This provides an opportunity for examination of the interior of

pumps, sections of pipework and heat exchange equipment. A water treatment specialist should assess the relevance of any signs of corrosion, biofilms, or deposits.

4.8.3 Water treatment programme

A water treatment programme is necessary for cooling tower systems to control for corrosion, the build-up of scale, microbial growth, and biological fouling.

Records of the water treatment programme in accordance with section 2.6 of AS/NZS 3666.2 should be kept and co-ordinated with all other relevant activities such as draining and cleaning procedures. The programme should be regularly reviewed to assess its effectiveness.

Organisations supplying chemicals for particular applications should be able to provide scientific justification for their use and to advise on any necessary safety precautions, including material safety data sheets (MSDS).

On each inspection, the water treatment specialist should provide a detailed report, including advice necessary to ensure that proper water treatment chemistry is maintained, together with general assessment of the tower condition.

4.9 Water testing for cooling towers

4.9.1 Microbial testing

Regular testing for both *Legionella* and heterotrophic bacteria must be undertaken on all cooling towers in a laboratory deemed competent to do such work, ie, an IANZ-accredited laboratory with ISO17025 accreditation. As noted in Section SS 9 Table 1: *Mechanical Ventilation, Air Conditioning Systems and Cooling Towers*[4] the Compliance Schedule Handbook (MBIE, 2014), the presence of *Legionella* bacteria in cooling tower waters must be monitored monthly using the standard method AS/NZS 3896:2008 *Waters-Examination for Legionella spp. including Legionella pneumophila*. Alternatively, either AS 3896:2017 or the ISO 11731:2017 can also be used for monthly testing with a lower level of detection of 10 cfu/mL.

Any test giving a positive *Legionella* result requires immediate remedial action to be carried out under the requirements of AS/NZS 3666.3 to ensure the *Legionella* control strategies are being met. *Legionella* tests with results greater than or equal to 1,000 cfu/mL should be notified within 48 hours to the local Medical Officer of Health within the local office of the National Public Health Service where the cooling tower is located.

[4] Refer to **https://icc.govt.nz/wp-content/uploads/2014/10/SBCG-SS9-Mechanical-Ventilation.pdf**

Territorial authorities can amend compliance schedules under the provision contained in the Building Act 2004 (Section 107). For example, territorial authorities could require all compliance schedules to include the current testing requirements for *Legionella* contained in the New Zealand Building Code Handbook (MBIE, 2014).

Cooling towers outside of the building warrant of fitness, such as those associated with an industrial manufacturing process, are covered under the Health and Safety at Work Act 2015 and as a minimum are expected to comply with AS/NZS 3666 Parts 1, 2, 3 and/or 4.

The presence of heterotrophic bacteria must be monitored monthly using the standard method AS/NZS 4276.3.2 *Water microbiology Method 3.2: Heterotrophic colony count methods – Plate count of water containing biocides*. An acceptable alternative method is AS/NZS 4276.3.1 *Water microbiology – Heterotrophic colony count methods – Pour plate method using yeast extract agar*.

Regular microbiological testing (ie, monthly) of cooling tower water is undertaken to assess the efficacy of the biocidal treatment and general cleanliness of the system, along with ascertaining the presence of *Legionella* bacteria. If either *Legionella* bacteria is detected or the acceptable HPC bacteria level is exceeded, then immediate remedial action is required, and the frequency of testing should be increased to weekly until control has been re-established.

When weekly dip slides are used for monitoring the heterotrophic bacteria level, the incubation temperature for these is 30°C for a minimum of 48 hours. Counts must remain below 10^4 to be acceptable. Although dip slides are convenient and inexpensive, their accuracy is limited. They are useful in detecting trends in bacterial levels and verifying that a water treatment programme is being implemented.

When there is an increase in the dip slide result, the HPC test should be carried out to quantify the microbiological load and the appropriate remedial action undertaken. Many variables affect the dip slide results, and a two-log difference between counts obtained by the agar plate and dip slide methods is not an uncommon finding. Monthly testing by the agar plate method is a more accurate assessment of HPC and is a useful check on the weekly dip slide results.

It should be noted that none of the above HPC methods will detect *Legionella* spp. because the media used will not support the growth of *Legionella*.

4.9.2 Chemical and physical testing

A number of tests on samples of cooling tower water can be carried out on-site. Most of the on-site analyses are for parameters related to control of corrosion, scale and particulate matter and include measurement of temperature, pH, conductivity, chloride, and alkalinity.

Monitoring of active biocidal residual is generally restricted to halogenated biocides such as chlorine and bromine.

When a decision has been made to carry out tests for suspended solids and total dissolved solids for example, water samples should be transported to a water testing laboratory for analysis. Turbidity may be determined either on-site with a portable turbidity meter or in the laboratory. The concentration of non-oxidising biocides can be determined in a well-equipped laboratory, although the methods used are usually time consuming and expensive.

4.9.3 Collecting water samples

For routine water analysis, care must be taken that samples are representative of the bulk of water circulating through the cooling tower system. This requires careful selection of sampling sites. If there are open basins, samples should be taken below the surface of the water.

When samples are obtained from taps, it is preferable to select those which connect directly into pipes containing the circulating water. If none are available, consideration should be given to installing sampling taps at appropriate locations. Sample taps should be clean, with no leaks and external fittings such as hoses, which may be responsible for sample contamination. In all cases of sampling from taps, water should be run to waste to ensure the removal of stagnant water from the tap and associated fittings before taking a sample. Ensure that water samples are taken well away from the inlet make-up water and the metering point of any chemicals.

In special circumstances, samples may be taken from locations which are not representative of the bulk of the tower water. For example, information on water quality in locations of very low flow may be required to assess microbial levels and the potential for localised corrosion. In some instances, it may be of interest to include sediment in the sample to be analysed.

Advice regarding the type of sample container to be used and the method of taking samples should be obtained from the laboratory where the samples are to be processed. This is particularly important for microbiological analyses when sterile containers are used for sample collection.

It is essential that the samples are:

- collected as described in AS/NZS 3666.3 Part 3 *'Performance-based maintenance of cooling water systems*'
- stored as described in AS/NZS 2031: 2001 *Selection of containers and preservation of water samples for microbiological analysis*
- transported as described in AS/NZS 3896: 2008 *Waters – Examination for Legionella spp. including Legionella pneumophila,* for *Legionella* samples.

Rapid-acting oxidising biocides must be neutralised, otherwise the biocide will continue to kill micro-organisms while the sample is being transported and the results of bacteriological analysis will not be representative of the water quality of the cooling tower at the time of sampling.

The sample container should be pre-sterilised and contain sodium thiosulphate to neutralise any chlorine or bromine which may be in the water. It is desirable to determine the level of residual disinfection at the sampling point at the time of collection.

The volume of the sample is usually determined by the analysing laboratory. A minimum of 100 mL is recommended by AS/NZS 3896. At least 2 cm of space must be left above the water to enable sample mixing to dissolve the neutraliser.

Samples must be clearly identified and be transported to the laboratory in containers that are securely sealed to avoid leakage and cross contamination. Water and biofilm swab samples must be packed into a container that protects the samples from exposure to light and temperature fluctuation.

Timing of sampling for bacteriological analysis is important, particularly when slug dosing of biocides is undertaken. It is recommended that sampling be undertaken just before slug dosing. This will demonstrate the worst-case scenario in the dosing cycle and may indicate the need for corrective action in the water treatment or cleaning programme.

In accordance with AS/NZS 3666.3, avoid sampling for at least 72 hours after online disinfection or system decontamination or cleaning. This is to allow conditions to stabilise before sampling. Where practicable, before sampling, the water should be circulated throughout the system for at least 30 minutes. Ideally, sampling should occur while the system is in operation.

The sample should be collected directly from the water basin or a sampling point located in the cooling water return line to the cooling tower. Take the sample for *Legionella* (or other microbiological examination) before any sample required for chemical analysis to help prevent contamination of the sampling point.

4.9.4 Relevance of heterotrophic plate count

Heterotrophic plate count (HPC) (also known as heterotrophic colony count, total colony count, total viable count and total heterotrophic count) is used as a general indicator of water quality in cooling tower systems. The test estimates the total bacterial load in the sample of water. It is reported as the number of colony-forming units per millilitre (cfu/mL).

Heterotrophic plate count is useful in assessing the effectiveness of biocidal treatment of cooling tower water and general cleanliness of the system. AS/NZS 3666.3 specifies an HPC of less than 10^5 cfu/mL as a level showing microbiological growth in general is in control. If the HPC result is greater than or equal to 10^5 cfu/mL in any water sample

collected from the cooling tower, the appropriate control strategy should be immediately initiated in accordance with Table 6 (see below), which is adapted from Table 3.2 from AS/NZS 3666.3.

Table 6: Control strategies for heterotrophic micro-organisms in cooling tower water

Test result (cfu/mL)	Required control strategy
< 100,000	**(1) Maintain monthly monitoring** Maintain water treatment programme.
³ 100,000 < 5,000,000	**(2) Investigate problem** Review water treatment programme. Take necessary remedial action (including immediate online disinfection) and undertake control strategy (3). **(3) Retest water within three to seven days of plant operation** a. If the test result is < 100,000 cfu/mL, repeat control strategy (1). b. If the test result is > 100,000 cfu/mL but < 5,000,000 cfu/mL, undertake control strategy (2). c. If the test result is ³ 5,000,000 cfu/mL, undertake control strategy (4).
³ 5,000,000	**(4) Investigate problem** Review water treatment programme. Take necessary remedial action including immediate disinfection as described in these guidelines and undertake control strategy (5). **(5) Retest water within three to seven days of plant operation** a. If the test result on retesting is < 100,000 cfu/mL, repeat control strategy (1). b. If the test result on retesting is ³ 100,000 cfu/mL but < 5,000,000 cfu/mL, repeat control strategy (4). c. If the test result on retesting is ³ 5,000,000 cfu/mL, investigate the problem, review the water treatment programme, and carry out immediate decontamination and repeat control strategy (5).

Source: Adapted from AS/NZS 3666.3 with the permission of Standards New Zealand under Licence 000807.

HPC does not indicate *Legionella* levels, but a rise in HPC indicates that conditions have generally become more favourable to bacteria. More favourable conditions for the bacteria detected by the HPC test may indicate that conditions are also favourable for *Legionella* to flourish. A reduction in HPC may indicate harsher conditions that may be inhibitory to *Legionella* also. However, in some situations, low HPC could indicate a favourable environment, without competition, for *Legionella* to multiply.

When slug dosing is undertaken, the lowest HPC can be expected soon after application of the biocide, and the highest count just before the next addition. Because biocide is lost through various routes, including bleed-off, there may be periods between successive dosings when the biocide concentration is ineffective. When this occurs, microbial numbers can increase. The bacterial quality of the make-up water may also influence the HPC.

The trends in HPC are, therefore, the most useful indicator of microbial conditions. Careful logging and storage of HPC results are essential to gauge the effectiveness of any changes to the system or its operation.

The monitoring of HPC should be regarded as an integral part of a thorough maintenance programme which includes frequent inspections, routine cleaning and disinfection, assessment of all water testing results, and periodic review of all aspects of the water treatment programme.

4.9.5 *Legionella* testing of cooling tower waters

Legionella should not be detected in any wet cooling system at any time. Since this is realistically unavoidable, whenever *Legionella* bacteria are detected the appropriate remediation steps are required to ensure conditions do not exist that allow their proliferation.

Examination of water samples for the presence of *Legionella* bacteria collected from wet cooling systems is undertaken using methodology detailed in standard AS 3896:2017, or the alternative AS/NZS 3896:2008. The lower limit of detection using these standard methods is 10 cfu/mL, so lower levels of legionellae will be missed. Monthly monitoring of cooling tower waters for the presence of legionellae is required while the cooling tower system is in operation. Standard AS/NZS 3666: Part 3, Section 3.2 and Appendices B and C outline the control strategies to be initiated if *Legionella* is detected. The required control strategy is dependent on the level of contamination, with more comprehensive action required with increased or persistent levels of contamination (refer to Table 7).

Appropriate disinfection and decontamination processes for cooling towers are detailed in Sections 4.10 and 4.11 respectively. These are based on the disinfection and decontamination processes outlined in AS/NZS 3666.3

There is no proven link between HPC levels and the presence of *Legionella* in cooling tower water. For example, it is possible to have very low HPC levels and still detect *Legionella* at significant levels. Because *Legionella* will not be detected by the HPC test, it is necessary to test specifically for *Legionella* monthly. This requires a specialist laboratory using test media specifically designed for the growth of *Legionella* and trained personnel and safety equipment in accordance with Appendix A of AS/NZS 3666.2 – '*Guidelines for the use of personal protective equipment during inspection and maintenance of air-handling and water systems*'.

Legionella test results require careful interpretation because the concentration of bacteria present is not directly proportional to the risk of acquiring infection. Available data suggest that most outbreaks associated with cooling towers occur when the *Legionella* concentration reaches 100 cfu/mL (10^5 cfu/L or greater), although lower levels may be associated with sporadic cases. AS/NZS 3666.3 recommends immediate decontamination of cooling waters when levels of *Legionella* exceed 1000 cfu/mL.

However, best practice dictates that wherever and whenever *Legionella* is detectable in a cooling tower water sample using test methods detailed in AS/NZS 3896:2008 or AS 3896:2017, then immediate remediation of the tower is required. For any positive result the first response should be disinfecting the tower, investigating any cause for the contamination, and retesting within three to seven days since the minimum period between routine tests for *Legionella* is one month and in that time the *Legionella* count in the tower can become well above any 'presumed acceptable' level.

Table 7: Control strategies for *Legionella* bacteria in cooling tower water

Test result (cfu/mL)	Required control strategy
Not detected (<10)	**(1)** Maintain monthly monitoring Maintain water treatment programme.
Detected as <1,000	**(2)** Investigate problem Review water treatment programme. Take necessary remedial action detailed in **Section 4.10** and undertake control strategy **(3)**. **(3)** Retest water within three to seven days of plant operation a. If not detected, retest water every 3 to 7 days until two consecutive samples return results of 'Not detected' and repeat control strategy **(1)**. b. If detected at <100 cfu/mL, undertake control strategy **(2)**. c. If detected at ≥100 cfu/mL, investigate problem, and review water treatment programme, and immediately undertake on-line decontamination in accordance with **Section 4.11** d. If detected at ≥1000 cfu/mL undertake control strategy **(4)**.
Detected as [3] 1,000	**(4)** Investigate problem Review water treatment programme. Take necessary remedial action detailed in **Section 4.11** and undertake control strategy **(5)**. **(5)** Retest water within three to seven days of plant operation a. If not detected, retest water every 3 to 7 days until two consecutive samples return results of 'Not detected' and repeat control strategy **(1)**. b. If detected at <100 cfu/mL, undertake control strategy **(2)**. c. If detected between 100 and 999 cfu/mL, investigate problem, review the water treatment programme, and immediately undertake remedial action detailed in **Section 4.11** and undertake control strategy **(3)**. d. If detected at ≥1000 cfu/mL immediately repeat control strategies **(4)** and **(5)**.

Source: Adapted from AS/NZS 3666.3 with the permission of Standards New Zealand under Licence 000807.

4.10 Routine cleaning and disinfection

Regular physical cleaning, the judicious use of chemicals, and appropriate bleed-off are effective procedures for maintaining a clean system. Chemicals should be added to the water at a rate sufficient only to maintain predetermined chemical concentrations and an HPC below the acceptable level. The bleed-off rate should be based on total dissolved solids, chloride or another appropriate parameter of the circulating water, and should be checked during regular maintenance inspections.

There are difficulties in prescribing a routine cleaning and disinfection frequency, as the operating conditions of cooling towers vary. As a guide, AS/NZS 3666.2 recommends the frequency of cleaning '*shall not exceed six months'*. More frequent cleaning may be required. When a cooling tower has been shut down for a prolonged period (for example longer than one month), the routine cleaning and disinfection procedure should be carried out just before restarting the equipment.

Storage tanks for drinking water which supply cold make-up water to the tower should be cleaned of rust, sludge and sediment whenever the tower is cleaned and disinfected. As an added precaution, these storage tanks can be disinfected by filling with water and chlorinating at 5 mg/L (5 ppm) free chlorine while maintaining the pH between 7.0 and 7.6. After one hour this disinfected water can then be added to the cooling tower as part of the routine cleaning and disinfection procedure shown below.

Relevant performance data determining the frequency of cleaning must be based on HPC levels and tower cleanliness.

A recommended procedure for routine cleaning and disinfection is as follows.

1. Implement occupational safety and health procedures as described in Section 10 'Occupational safety and health'.
2. Cease any chemical treatment and isolate all electrical equipment except the water circulating pump.
3. Add a low-foaming, chlorine-compatible bio-dispersant or low-foaming, bromine-compatible bio-dispersant to the re-circulating water before disinfection.
4. Disinfect the system by dosing the water with a biocide, either:
   - a chlorine-based compound (with detergent properties) equivalent to at least 10 mg/L of free chlorine for at least one hour, while maintaining the pH of the water between 7.0 and 7.5
   - a bromine-based compound (with detergent properties), equivalent to at least 20 mg/L of free bromine for at least one hour, while maintaining the pH of the water between 7.0 and 8.5.

5. Drain the entire water circuit, including the make-up tank.
6. Manually clean the cooling tower, sump, fill, drift eliminator, make-up tank and water recirculation circuit. Accessible areas of the cooling towers and its fill must be adequately washed. If the cleaning method involves high-pressure water spraying, close all nearby windows, blank off all air inlets, and tent the working area. The working areas must be isolated to avoid nuisance to the neighbourhood.
7. Refill with clean water, rechlorinate and recirculate for at least six hours, maintaining a minimum level of free residual chlorine at 5 mg/L (ppm) at pH of between 7.0 and 7.6.
8. Drain cooling tower system to waste in a manner approved by the territorial authority. Refill with water and dose with the appropriate start-up level of treatment chemicals.
9. Recommission the system and record all actions in appropriate written record. Refer to Appendix A for a sample service log sheet.

Source: Adapted from Office of Industrial Relations, Australia, 2018

4.11 Decontamination of cooling towers

Decontamination is required as specified under AS/NZS 3666.3 (although sampling is considered to be a relevant monitoring activity by AS/NZS 3666.2) when *Legionella* is detected at levels at or above 1,000 cfu/mL on initial testing, and at or above 100 cfu/mL on any re-testing. Decontamination must also be undertaken when recommended by a Medical Officer of Health.

Water samples should be taken prior to the addition of biocide and tests commenced immediately. It is prudent to immediately decontaminate any suspected system identified in source tracing rather than waiting for the results of the bacteriological tests. Storage tanks supplying cold make-up water to the tower should be decontaminated as described in section 6.12, ‘Sampling and Decontamination of hot, warm and cold water systems’.

Cooling towers should be decontaminated in accordance with the following procedure.

1. Implement occupational safety and health procedures, including the use of personal protective equipment (PPE) to workers who perform the disinfection[5], as detailed in section 10 'Occupational safety and health'.
2. Cease any chemical treatment. Isolate all electrical equipment, such as cooling tower fans, except the water circulating pump.
3. Add a low-foaming, chlorine-compatible bio-dispersant or low-foaming, bromine-compatible bio-dispersant to the re-circulating water.
4. Dose the circulating cooling water system with a biocide, either:
   - a chlorine-based compound, equivalent to at least 10 mg/L of free chlorine for at least one hour, while maintaining the pH of the water between 7.0 and 7.6
   - a bromine-based compound (with detergent properties), equivalent to at least 20 mg/L of free bromine for at least one hour, while maintaining the pH of the water between 7.0 and 8.5
   - add the disinfectant slowly, over five to 10 minutes, to a turbulent zone of the tower basin to promote its rapid dispersion. Use an anti-foaming agent if excessive foaming occurs
   - circulate the system for one hour, measure the pH and free chlorine or bromine levels regularly (for example, every 15 minutes). Adjust as required and record levels and actions in appropriate written record
   - ensure that the water is circulated through all parts of the system, including the standby condenser pump and any chillers that may currently be offline.
5. Switch off the water reticulating pump and drain the cooling tower to waste in a manner approved by the territorial authority. A wet vacuum cleaner can make it easier to remove waste material from a basin floor.
6. Refill the tower with clean water and switch on the re-circulating pump.
7. Repeat step 4 then switch off the reticulating pump. Drain cooling tower system to waste in a manner approved by the territorial authority.
8. Thoroughly clean the basin, fill, drift eliminator, fan and water distribution system. If the eliminators are moved, ensure they are correctly re-installed after cleaning. Suitable precautions should be taken to minimise the release of aerosols during cleaning.

[5] PPE '*should include full-length protective clothing, boots, impervious gloves, goggles, and a full or half-face respirator that combines a high efficiency particulate air filter of at least a P2 class (for filtering of aerosols) and a chemical cartridge filter of type B Aus or B1 (for filtering of disinfection chemicals) [for more information see Australian/New Zealand Standard 1715 – Selection, Use and Maintenance of Respiratory Protective Devices]. The person wearing the respirator should be clean shaven to maximise the seal between the respirator and face, and should be fit tested for the respirator and trained to fit check the respirator prior to each use'* (Office of Industrial Relations, 2018)

9. Refill the tower with clean water and switch on the reticulating pump.
10. Repeat step 4 then switch off the reticulating pump. Drain cooling tower system to waste in a manner approved by the territorial authority.
11. Refill with clean water, recirculate and take water samples for testing.
12. Recommission the system when *Legionella* and HPC levels are detected within acceptable range.
13. Enter details of all action in an appropriate written record (e.g., maintenance logbook).

Source: Adapted from Office of Industrial Relations, Australia, 2018

4.11.1 System assessment after decontamination

Chemical treatment of the cooling tower water should be reviewed at this stage and the entire cooling tower installation examined for faults in design, operation and maintenance procedures. These faults should be corrected, and a more reliable water treatment procedure instituted if necessary.

4.11.2 Bacteriological examination after decontamination

The water of a decontaminated cooling tower should be tested bacteriologically to assess the effectiveness of the procedure.

Avoid sampling for at least 72 hours after system operation following disinfection, slug dosing with biocide, decontamination or cleaning procedures to allow conditions to stabilise.

Water should be retested within three to seven days of plant operation (as described in Appendix A of AS/NZS 3666.3) after recommissioning, for the determination of HPC and the presence of *Legionella* spp.

The HPC should be less than 1,000 cfu per mL, and *Legionella* spp. not detected. If this is the case, a further check on these parameters should be taken after one month and again a month later. If *Legionella* spp. are not detected, no further testing should be carried out for *Legionella* unless future events indicate the need for it.

If the testing of water samples still shows the presence of *Legionella* spp., the cooling tower should again be decontaminated, along with a critical review of all associated equipment and the water treatment protocol.

4.12 Future design considerations

When undertaking major modifications or maintenance tasks on an existing cooling tower, or when a new tower is to be purchased, consideration should be given to features which

facilitate inspection, operation and maintenance procedures (without putting any persons or adjoining premises at risk). These include:

- smooth, graded basins which drain to an outlet of large bore at the lowest point for easy cleaning
- components and internal surfaces which are easily cleaned
- durable materials which resist corrosion, various chemical treatments and water jets used in cleaning
- exclusion of direct sunlight from wet surfaces
- high-efficiency drift eliminators
- large access panels for ease of inspection and removal of components
- minimal internal components such as structural brackets that can collect sediment
- siting of cooling towers with attention to location of air inlets, localised wind patterns, height and design of adjacent structures.

4.13 Operation and maintenance records

The value of accurate records cannot be overstressed because a lack of accurate and up-to-date records is a common feature of systems associated with disease outbreaks. Records should be kept on-site for inspection and should include information about:

- layout of the equipment and system, including safe access
- correct and safe operating (including shutdown) procedures
- maintenance, cleaning and disinfection procedures, and their frequency
- condition of the equipment
- regular water treatment procedures
- bleed-off rate
- testing requirements and results of previous testing:
  - pH
  - total dissolved solids or conductivity
  - bacterial counts
  - all other test results
- disinfectant levels
- safety precautions
- person or contracting agency responsible for:
  - overseeing and recording the work
  - ensuring that the plant operates normally.

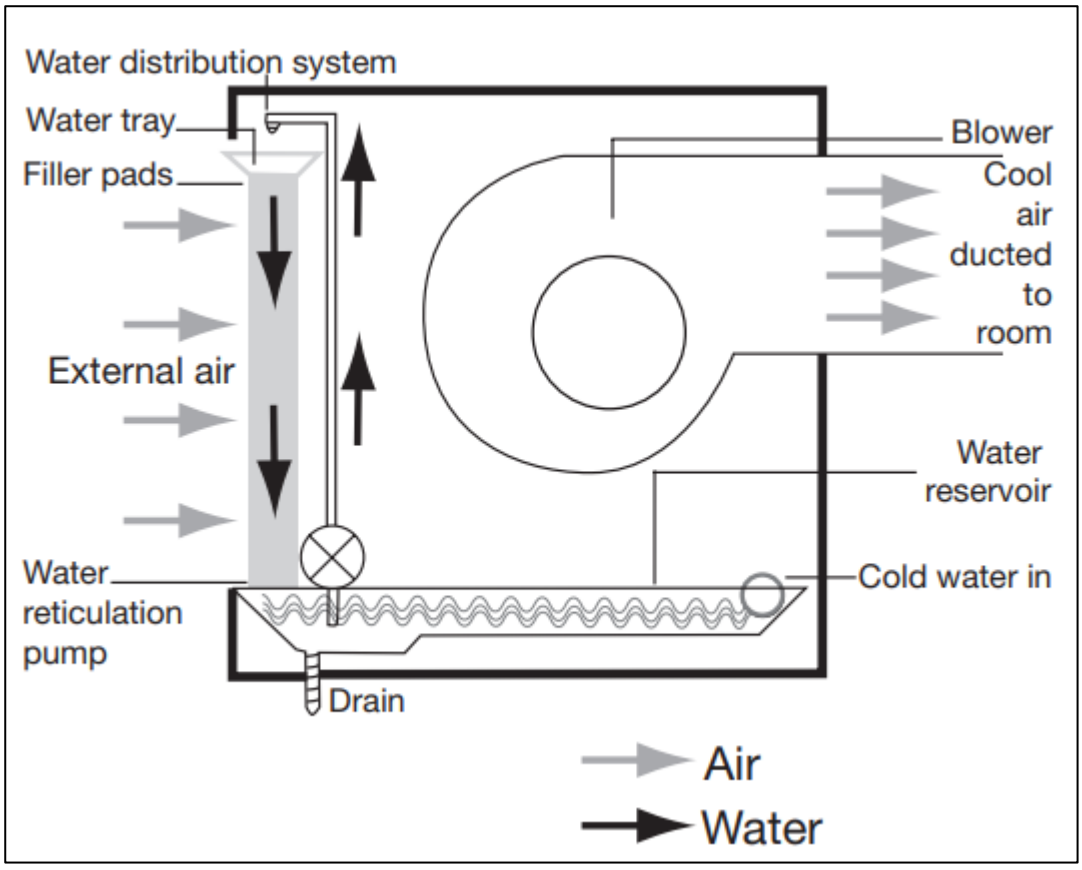
5 Evaporative (air) coolers

There is a wide range of evaporative (air) coolers in use in industrial, commercial and domestic applications. A common feature of these coolers is that air is drawn from outside the building, through wet filter pads and discharged inside the building. Cooling is affected by evaporation of water in the filter pads. These pads are kept wet by water which is pumped from the basin of the cooler to a distribution system at the top of the unit where water gravity feeds through the filter pads back to the basin.

If water is allowed to stagnate in the basin of a dormant evaporative cooler, conditions may arise that facilitate the growth of micro-organisms, including *Legionella*.

Air drawn across the wet surfaces of an evaporative cooler may carry fine water droplets through very short lengths of unrestricted duct work into the building being serviced (see Figure 9). This precludes the use of biocides and other water treatment chemicals when the unit is in operation.

Figure 9: Evaporative air cooler



Source: New South Wales Department of Health (2004)

5.1 Cleaning and disinfection

When not in use, during the off season or any other prolonged break, the equipment should be cleaned and left dry. This involves turning off the inlet water, isolating the unit electrically and hosing down the wet surfaces with the drain valve in the open position. The cooler should be allowed to stand in this condition, preferably with a slip-on weatherproof cover.

The operation of any overflow, bleed-off or water replacement system should be checked regularly. Evaporative air coolers should be operated and maintained in accordance with AS/NZS 3666.2.

Water discharge from evaporative coolers should be drained to waste as approved by the territorial authority. This water should not be allowed to discharge into gutters that feed drinking water tanks.

Before bringing an evaporative (air) cooler back into service, remove the slip-on cover and thoroughly clean the equipment. Remove the filter pads and hose them with clean water. Clean all waterways, including the bleed-off system and sump, to ensure free flow of water when the unit is in use. Refit the cleaned filter pads, close the drain valve and open the water inlet valve to allow the unit to fill with fresh water.

With the fan isolated and the pump circulating water around the unit, add a small quantity of household bleach (10 mL of 4 percent available chlorine per 10 L of circulating water) and allow the disinfected water to circulate for 30 minutes. Run the water to waste and refill with fresh water, circulate for five minutes, and again run to waste. Repeat this freshwater rinse and dumping and then refill with water and place the unit into normal service. Check that the equipment is operating correctly.

5.2 Water replacement

5.2.1 Fixed water bleed-off

A continuous water bleed-off should be incorporated in the sump of the unit and adjusted to prevent the deposition of normally soluble substances and to limit the accumulation of suspended matter. Incoming water quality and airborne debris will have a major influence on the rate of bleed-off required.

5.2.2 Electrically operated water replacement systems

Electrically operated dump valves and the intermittent pumping to waste are two methods which are used to control water quality in evaporative coolers.

A recent innovation involves the solenoid operation of the inlet water and drain valves in conjunction with the water pump. Whenever the pump is switched on, the inlet water valve

is opened, and the drain valve closed. The reverse occurs when the pump is switched off, allowing the unit to be drained rapidly and to remain in a drying-out condition until the water pump is switched on again.

These electrically controlled systems can be particularly useful if sedimentation, biological fouling or other water quality problems become evident, and they may be fitted to existing systems.

5.3 Maintenance and cleaning frequency

The off season is an appropriate time to carry out preventive maintenance on evaporative coolers. For example, deteriorating filter pads should be replaced and the water filter, water pump and fan examined according to the manufacturer's instructions. Corrosion should be appropriately treated, and any badly corroded parts replaced.

Some evaporative (air) coolers are in continuous use and appropriate times must be selected to clean and maintain the equipment. It is recommended that this be carried out every three months for an initial period of two years. If the water system is free of biological fouling, sedimentation and other water quality problems, the interval between cleaning may be increased. This increase should be carried out gradually to a maximum of 12 months. In some locations, a dusty environment or water quality problems may indicate that more regular cleaning is required. Refer to Appendix A illustrating a sample (template) service log sheet for cooling towers and evaporative condensers.

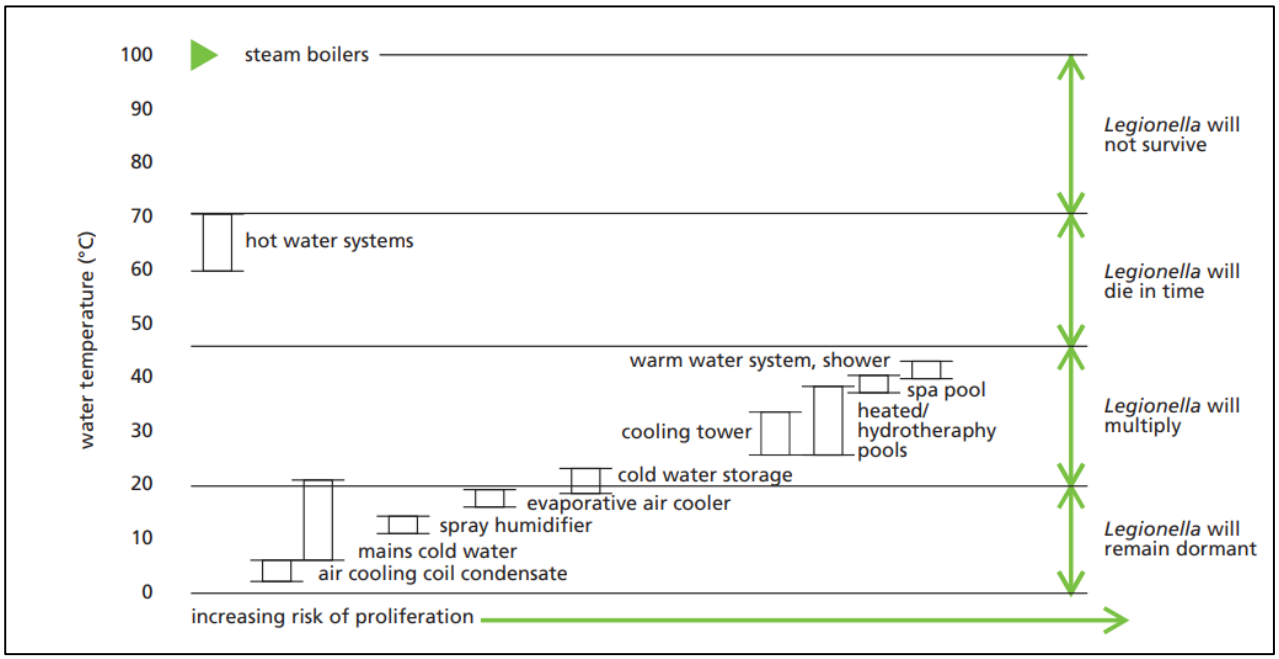
Some types of evaporative (air) coolers incorporate a heating cycle. When the heating section is operating, the cooling section of the unit should be cleaned and left in a dry condition. In the heating mode, cold air is normally drawn through the dry filter pads, forced through the heating section and discharged into the building. It is important that airways are not restricted by covers when the units are in use.

6 Hot and cold water systems

6.1 General

Piped hot and cold water systems within buildings have long been associated with legionellosis cases, both as sporadic and outbreak cases. These cases are more common where the reticulated pipework is complex (likely to include multiple storage tanks, and multiple outlets – showers, toilets and sink taps), where there are large numbers of people using the sanitation services, and where those more susceptible to a *Legionella* infection are likely to be in residence (advanced age, or immunocompromised). The potential for *Legionella* to grow in such systems is shown in Figure 10.

Figure 10: Water temperature and increasing risk of *Legionella* proliferation



Source: South Australia Department for Health and Ageing (2013)

Sporadic cases are also associated with those residing in single dwelling unit (Bates et al., 1998). Hot water systems are a common infection source that most people will be exposed to in their everyday life. Showers have been identified as the leading source of legionellosis in a residential setting (Hamilton et al., 2019). Lower hot water temperatures (< 48.8°C) have been shown to be significantly associated with the presence of *L. pneumophila* in residential water systems (Lee et al., 1988).

A New Zealand study found evidence of legionellae in electrically heated hot water systems of 100 houses in the order of 6 to 12 percent (Bates et al., 1998). Hospital warm water systems are commonly contaminated with *Legionella*, with one study finding more than two-thirds of institutions affected (Alary and Joly, 1992). One New Zealand study showed *Legionella* to be the main microbial cause of nosocomial pneumonia (Everts et al., 2000).

6.1.1 Identification of potential Legionella risk in building water systems

Since legionellae are ubiquitous water and soil-borne bacteria, any water system under the appropriate physical and chemical conditions can potentially become contaminated with *Legionella*. There are several recognised factors that increase the *Legionella* contamination risk within a water system. These include:

- no biocide treatment of incoming source water
- inadequate maintenance of an active biocide residual within the pipework
- low or no water flow in parts of the system allowing stagnation

- the use of water storage (either hot or cold)
- water temperatures in any part of the system between 20 to 50°C
- water that is recirculated
- the presence of rust, scale, sludge or matter that supports microbial growth.

The control of waterborne pathogens in any water system relies on appropriate sound engineering design, chemical disinfection, temperature control and system maintenance. Water systems supplied with raw water (untreated, rainwater, ground water or spring water supply) are more likely to be contaminated with Legionella than a treated municipal supply containing an active chlorine residual above 0.1 ppm when it entered the building. A sentinel surveillance strategy can be set up to monitor for *Legionella* contamination in these situations.

6.1.2 Requirement for routine testing of building water systems for *Legionella*

Routine water sampling for *Legionella* in hot and warm water systems is not a requirement of the New Zealand Building Code and is generally not recommended in most other countries. However, regular water sampling and testing (every three to six months) is recommended for hospitals and other high-risk health care establishments where immunocompromised people (ie, people with poor ability to fight infections due to reduced immunity) may be exposed to *Legionella*.

Regular water testing for *Legionella* bacteria should be part of a wider water safety plan implemented for hospitals and aged care facilities for the management of waterborne pathogens. The testing is primarily to identify possible lapses in control measures. When a failure is detected with the isolation of *Legionella* bacteria or other potential water-borne pathogens, then immediate remediation is required.

6.1.3 Monitoring and maintenance of complex water systems

In buildings with complex water systems, such as hotels, hospitals and aged care facilities, the persons responsible for the operation and maintenance of water systems should have clear instructions describing the operational characteristics of each system.

Accurate installation drawings with any modifications should be available on-site to facilitate maintenance procedures and identify risk points. The piping system plan should detail the position of all hot, warm, and cold pipework within a building, as well as the choice of materials used in pipes and plumbing fittings, along with the location of all system components such as valves (TMV’s, non-return and shutoff), filters and strainers, water heaters, calorifiers, boilers, cisterns, showers, tap outlets, water softeners, filtration units etc. All parts of the system should be easily accessible for maintenance purposes.

Protocols for system and component cleaning, disinfection, and replacement must be available, and records kept of any maintenance or changes to system components.

Monitoring for *Legionella* contamination in high-risk areas of healthcare facilities, such as those accommodating immunocompromised patients might also be appropriate, especially if nosocomial legionellosis has occurred.

6.1.4 *Legionella* risks from plumbing fittings

6.1.4.1 Pipe and fitting sealants

The materials used in a building water system should not encourage the growth of bacteria. Both natural rubber and nitrile butadiene rubber sealants along with those containing silicone are used extensively in plumbing fixtures. These materials have been found both in New Zealand and overseas to provide nutrients and a favoured environment for the growth of *Legionella* (Colbourne et al., 1984).

All sealing washers should therefore be of neoprene or other suitable synthetic material which does not support microbial growth. Similarly, Polytetrafluoroethylene (PTFE)-type jointing tape should be used, not plumber's hemp. Porous and organic washers (eg, leather) should not be used. Ethylene propylene diene monomer (EPDM) rubber can support the growth of Legionella, so any flexible hoses made from EPDM should be replaced with safer alternatives (Moritz et al., 2010). Ideally, hoses made of EPDM should not be used in healthcare settings. Pipe fittings used for hot water must be suitable for the temperatures and pressures within that system. This is a requirement of the *New Zealand Building Code* G12/AS1.

6.1.4.2 Sensor taps

Sensor taps, frequently installed in healthcare settings, food preparation areas, and washrooms to allow hands-free operation, can be colonised by *Legionella* bacteria (Sydnor et al., 2012). This is primarily associated with biofilm formation on the sealant components within the solenoid valve that are typically manufactured from either EPDM, silicone-, or nitrile-rubber (Hutchins et al., 2020). Daily flushing from sensor taps should be carried out, along with voiding the first 500 mL of water from the outlet to waste before each use.

6.1.4.3 Aerosol formation

Legionella infections result from exposure to aerosols containing the bacterium. Aerosols are produced whenever a water flow is broken and as water moves from a pressurised system into the atmosphere. Actions such as opening a tap will create an aerosol. Factors such as a pressure drop at the opening, water flow speed, and the opening diameter influence the amount of aerosol produced. Plumbing fittings such as showerheads, tap aerators, and spray nozzles will generate respirable aerosols (<5.0 µm diameter). Aerosol generation can be reduced by increasing the showerhead hole size to more than 1.0 mm, and reducing water flow. In areas where aerosols are produced, effective ventilation is important to remove aerosols rapidly to minimise exposure time. In high-risk areas, such as healthcare settings, tap aerators should be removed to lessen aerosol production.

6.1.5 Descaling, and sanitising plumbing fittings

Plumbing fittings such as showerheads and hoses, as well as strainers and tap aerators will over time accumulate scale and allow for the development of biofilm. This provides an environment that allows for the growth and survival of legionellae, pseudomonads and other opportunistic pathogens. Periodic maintenance and cleaning are required to reduce any infection risk (Figure 11).

Descaling

Periodically (at least every 3 months) outlet fittings (showerheads, shower hoses and connectors, tap aerators, strainers) must be removed, and physically cleaned with a soft brush to remove loose deposits, then soaked in a prepared solution of a commercial acidic descaler for the removal of calcium or lime scale – the usual culprits for drinking water. Follow the manufacturer's instructions for use of descalers (usually 30-60 minutes soaking, followed by repeat soft scrubbing, then rinsing with clean water). The cycle may have to be repeated if scale build up is high.

Sanitising

Do not begin the sanitising step until all visible scale and biofilm has been removed. After descaling, soak fittings in a bucket of 5% bleach solution (or other oxidising biocide, such as hydrogen peroxide) for 15 minutes to sanitise the fitting. All fittings must be completely submerged. Ensure all air is removed from shower hosing. Rinse with clean water, assess physical cleanliness by eye and if satisfactorily clean, the fittings can be reassembled. Repeat the sanitation step where it is difficult to remove stubborn dirt. Descaling must be carried out before sanitising because the scale will prevent full penetration of the biocide. The descaling process will also remove biofilm.

Figure 11: Scale build up on plumbing fixtures

Tap aerator showing scale build-up

Shower rose with excessive lime scale

6.1.6 Avoidance of cross-connections

Water supply should be designed and installed to comply with the *New Zealand Building Code* G12/AS1. Backflow or cross-connection of pipe work and drains is prohibited. Water traps and air breaks must be installed to prevent such occurrences. All pipework must be colour marked or coded in accordance with New Zealand Standard 5807: 1980 *Code of practice for industrial identification by colour, wording or other coding*, and comply with the *Water Services Act 2021* (section 27).

6.2 Cold water systems

The following recommendations apply only to cold water systems serving cold water fixtures. They do not apply to storage tanks serving flushometer (automatic toilet and urinal flushing) and fire suppression water systems (sprinklers).

Temperature control is the simplest way to control for *Legionella* growth in cold water systems. Ideally, cold water should be stored and distributed through pipework at a maximum of 20°C. Outbreaks of legionellosis overseas have been associated with cold water storage tanks when the water storage temperature has risen above 20°C and dormant *Legionella* have multiplied (Hoebe et al., 1998; Wagenvoort and Sijstermans, 2004).

For most of the population, domestic potable cold water in New Zealand is supplied by a territorial authority and is chlorinated. This reduces, but does not eliminate, the potential for *Legionella* bacteria to colonise the cold water system. If the water supply is not chlorinated and is from a bore, spring or roof catchment, the potential for *Legionella* bacteria to colonise the cold water system is significantly increased. In these situations, serious consideration should be given to implementing a water treatment programme using a suitable chemical or physical biocide.

The volume of cold water stored on site in tanks should be minimised to avoid water stagnation and improve water turnover. If the storage tank is kept free of sediment and the storage temperature does not exceed 20°C, conditions favourable to the growth of *Legionella* should not occur, and any *Legionella* present in the incoming mains water will not be able to proliferate. Where storage capacity is required to be longer than a day's supply, secondary biocide treatment of the stored water needs to be seriously considered. For complex water systems, secondary biocide treatment of the incoming cold water supply should be implemented, especially for hospitals, aged care facilities, and hotels.

Cold water tanks and pipework should be insulated, if necessary, to ensure that the temperature does not exceed 20°C from thermal gain. This can occur when tanks or pipework are in the building roof space or next to heat generating systems such as boilers. Where cold water pipes run in parallel with hot water pipes, both should be insulated - the

cold to minimise thermal gain from the hot water, and conversely, the hot to minimise heat loss.

All cold water storage tanks should be fitted with a tight-fitting lid, and an appropriately sized drain valve and associated pipework to facilitate flushing, cleaning and decontamination. Overflow pipes should be fitted with a mesh to exclude mosquitoes, vermin, leaves and other extraneous material. Sufficient space should be available to permit easy inspection and maintenance of these systems.

If multiple tanks are used to supply a common cold water system, they should be designed, installed and maintained to ensure that the flow rate through each tank is similar and that the water in the tanks does not become stagnant.

On commissioning of any new system, storage tanks and all associated pipework should be flushed and cleaned to remove all debris, sludge and sediment. It is recommended that the tanks be regularly inspected and cleaned, initially on an annual basis. The frequency of cleaning may be altered, depending on the levels of corrosion, sludge and sediment experienced.

For cold water pipes that lie idle for more than one week, regular flushing should be undertaken at full flow for a minimum period of three minutes each week. This is to remove stagnant water, recharge the system with disinfectant, and help remove sediments.

Care should be taken to minimise the generation of aerosols during routine cleaning operations. Cold water storage systems have been linked to legionellosis cases.

6.3 Hot water systems

Temperature control is the simplest way to control for *Legionella* growth in hot water systems. Ideally, hot water should be stored and distributed through pipework at a minimum of 60°C and tempered only at the point of use where there is a scald risk (see Section 6.5 for reducing scald risk).

It is important that water storage and pipe systems be kept low in sediment and corrosion products and that the water is stored at a minimum temperature of 60°C. Hot water storage vessels and hot water pipework should be well insulated to prevent heat loss and cool spots where *Legionella* may survive.

Care should be taken to ensure that temperature stratification within large storage cylinders does not occur. Appropriate pipework modifications or alterations to cylinders should be carried out if stratification is a problem, such as installing a shunt pump to circulate hot water from the top of the vessel to the bottom. Because hot water rises (and cold water sinks), the cold make-up water should flow into the bottom of the hot water

storage heater and the heated water drawn from the top. Cold water should not be able to short circuit through cylinders and the system should be designed to ensure that all water is adequately heat disinfected prior to storage.

The hot water system should be capable of supplying adequate hot water, even at times of peak demand. In complex water systems, consider installing point-of-use water heaters to minimise the need for large capacity hot water storage and long hot water pipe runs. For hot water distributed via a recirculating system (loop system or ring main system) from a centralised water storage heater, the water should be maintained at a temperature of at least 60°C in the storage heater, and be returned to the storage heater at no less than 55°C. The water should be constantly pumped to ensure the temperature is maintained as close as possible to 60°C. Branch pipes to individual outlets must be short, insulated and only tempered at the outlet to control for scald risk.

Where cold water is instantaneously heated for immediate use to a temperature of less than 55°C, then no storage of any unused water should occur. The cold water feed to instantaneous water heaters must be kept below 20°C, and an active chlorine residual maintained above 0.1 mg/L to minimise *Legionella* growth. There have been cases of legionellosis associated with instantaneous water heaters due to a contaminated cold water feed and the thermal hold time is too short (less than 1 minute) and maximum temperature reached is too low (less than 60°C) for any effective thermal disinfection of the water.

Summary: Temperature control in plumbing systems in buildings

The recommended temperature for storage and distribution to prevent *Legionella* proliferation is:

- Store and circulate cold water below 20°C.
- Store and circulate hot water above 60°C.

Ensure hot water at the outlet of all sanitary fixtures used primarily for personal hygiene purposes is delivered at a temperature not exceeding:

- 45°C for early childhood education centres, primary and secondary schools, aged care facilities and hospitals or similar facilities for people with psychiatric or physical disabilities
- 50°C for other buildings.

6.3.1 Avoiding water stagnation in hot water systems

Water should be regularly flowing through all parts of the reticulated pipework. This is important to maintain water quality. In hot water systems stagnation results in temperature reduction, which in turn encourages sedimentation, bacterial growth and biofilm formation. Pipework containing water which lies idle for more than one week should be flushed at full flow for a minimum period of three minutes after the water has reached its normal hot delivery temperature.

Consideration should be given to removing hot water outlets and associated pipework that are infrequently used or that are situated at the end of excessive dead-legs. If these outlets cannot be removed, they should be flushed weekly with water at a minimum temperature of 60°C at the outlets for three minutes. Redundant pipe work containing water that lies idle should be removed as it potentially harbours legionellae that can seed other parts of the water system. Infrequently used showers and mixer taps must be flushed once with the cold water set at the coldest position and once with the hot water set at the hottest position.

Low use outlets should be positioned upstream of high use outlets to ensure water is refreshed in the pipework. Consider fitting self-flushing taps in low flow areas so that an active bacterial residual is maintained by increased water flow.

Tanks and pipe work should be positioned or insulated to prevent the cooling of hot water and the heating of cold water. Dead-legs need to be avoided in warm and hot water systems and, if necessary, pipework should be altered to remove these. Pipework runs should be kept as short as possible between the water heater and the outlets associated with it. Where possible, branch mains should be less than 6m in length to minimise excessive water stagnation.

New systems should have provision for the draining and cleaning of storage cylinders. Existing storage cylinders should be retrofitted with drains if they are not already installed.

6.3.2 Cleaning and maintenance

All piped water systems and associated storage vessels should be flushed clean upon initial installation and prior to system commissioning. This is to ensure that construction debris and dirt is removed before implementation of the water treatment programme and use of the system.

The temperature of the stored water should be checked every six months to ensure that it does not fall below 60°C. Automatic dosing equipment used for the delivery of biocides and other water treatment chemicals must be regularly inspected and maintained. Chemical usage, inspection and maintenance records should be kept.

Where sedimentation is a problem, hot water cylinders should be drained, cleaned and flushed once per year. With solar hot water systems, hot water cylinders should be maintained in a similar manner to normal electric hot water cylinders – hot and cold relief valves should be flushed every six months and the anode in a glass-lined water container should be changed every five years (or more frequently in hard water areas).

Care should be taken to minimise the generation of aerosols during routine cleaning operations. Appropriate occupational safety and health precautions as detailed in section 10 ‘Occupational Safety and Health’ should be followed by personnel carrying out tasks on hot, warm and cold water systems. Appendix A of AS/NZS 3666.2 has further details relating to specific tasks and appropriate personal protective equipment.

6.4 Solar hot water heating system

There are two types of solar water heating systems available in New Zealand.

- Thermosyphon systems use the theory that hot water will rise through cold water, and thus rely on convection to circulate the water through the system. Therefore, the solar panels need to be located below the water storage cylinder to ensure that this convective circulation can occur.
- Pump circulated systems allow more freedom with regards to the positioning of the solar panels and the cylinder as there is a small electric pump in the system. This pump is used to generate water flow within the system.

Requirements for the installation and operation of solar hot water heating systems are described in section 3.5.1 of the *New Zealand Building Code* G12/AS2. To prevent the growth of *Legionella* bacteria, solar water heaters must either:

a) *have a continuously energised heating element fitted within 55% of the bottom of the water tank (by volume) and a thermostat set to 60°C or higher, or*
b) *be controlled so that the water above the element is heated to 60°C once a day, and the element is in the bottom 20% of the water tank (by volume) and no more than 150 mm from the bottom of the tank, or*
c) *be controlled so that all of the stored water is heated to 60°C or higher, once a week for not less than 1 hour. The temperature must be measured by a probe in the bottom 20% of the water tank (by volume) and no more than 150 mm from the bottom of the water tank. For open loop systems the stored water includes the water in the solar collector and water must be circulated through the collector during the heating period*.’
(MBIE New Zealand Building Code Handbook, 2014).

6.5 Managing the scald risk

The risk of burns (scalding) from hot water must be addressed in conjunction with *Legionella* control measures. Where heated water is stored, ideally it must be stored at

temperatures at or above 60°C to prevent the proliferation of *Legionella*. Water heated to over 50°C can cause serious burns in less than a minute (Figure 12). At greatest risk are:

- children, because of their sensitive skin
- older people because they have slower reaction times and thinner skin.

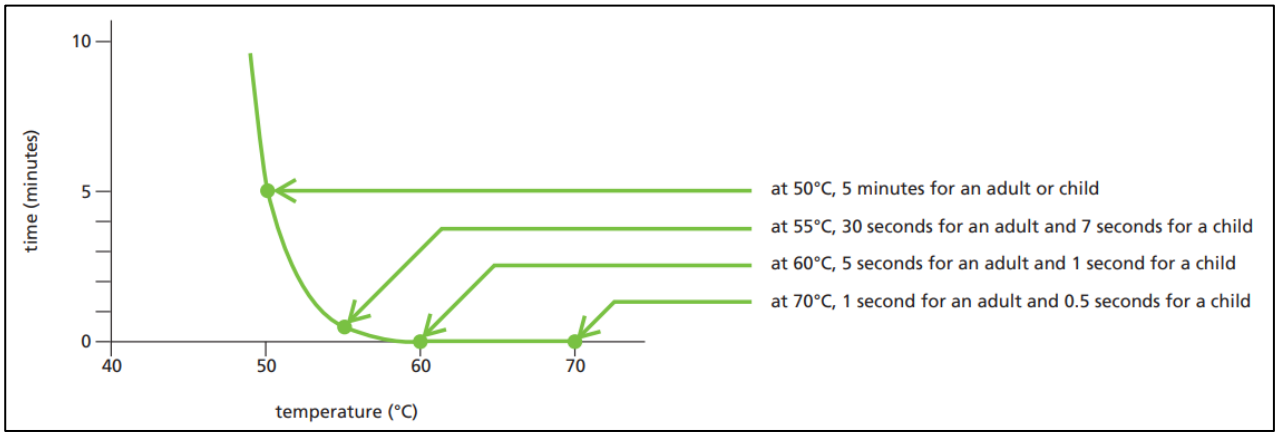
One way of achieving compliance with New Zealand Building Code clause G12.3.6 is the *Acceptable Solution for G12 Water Supplies G12/AS1*, which requires that the temperature of hot water delivered to sanitary fixtures used for personal use (hand basins, baths, bidets and showers) shall not exceed:

- 45°C for early childhood education centres, schools, aged care facilities and hospitals or similar facilities for people with psychiatric or physical disabilities
- 50°C for other buildings.

Section 6.14.2 of the *Acceptable Solution for G12 Water Supplies G12/AS1* states that an acceptable method of limiting hot water temperature delivered from storage water heaters (holding the stored water at 60°C) is to install a tempering valve at the hot water outlet on the sanitary fixture. Ideally, the pipe length between the outlet and the tempering device should be less than 1 metre. For more details refer to Sections 6.5.1 and 6.5.2 of these guidelines.

The use of high holding temperatures for stored hot water (i.e., 60°C) is encouraged because high temperatures kill legionellae. To comply with the Building Act 2004 and associated Building Code regulations, stored hot water in residential dwellings is required to be held at temperatures of 60°C or higher (irrespective of whether a mixing device is installed) and delivered at not more than 55ºC, or 45°C for retirement homes and early childhood education centres, to prevent the likelihood of burns (scalding).

Figure 12: Full thickness burns – contact times with water



Source: South Australia Department for Health and Ageing, 2013

6.5.1 Anti-scald safety valves

These devices consist of a spring-activated valve which senses temperature changes and shuts the water flow to a trickle at 43°C or higher. The valves can be connected to shower heads and outlet fittings. Hot water connected to these devices can be stored at a minimum temperature (60°C), which will kill *Legionella*. Since the valves release a small amount of water in the shut-down mode, a burning (scalding) risk still exists, although greatly reduced from that at full flow.

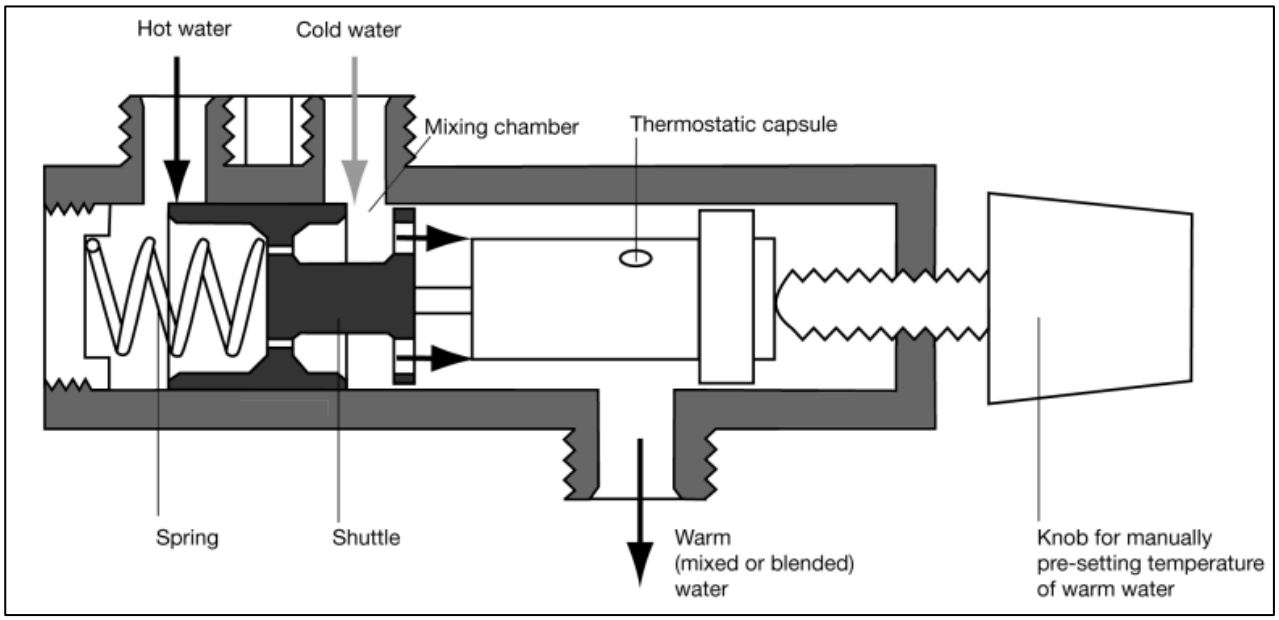
Depending on the occupants of the building, these devices might be considered to adequately reduce the risk of burning (scalding). The anti-scald valve should be checked once a month to determine that it is functioning properly by turning the hot water on and ensuring that the water shuts down before reaching a burning (scalding) temperature. The anti-scald actuator cartridge should be replaced at least every three years.

6.5.2 Thermostatic mixing valves

Warm water can be provided using thermostatic mixing valves (TMV) which mix hot and cold water to provide water at a predetermined temperature (Figure 13). These valves mean long-term storage of warm water is unnecessary and should be located as physically close to the outlet to minimise bacterial growth in the pipework between the valve and the outlet. Ideally, pipe length must be less than 1 metre and the cold-water feed must be treated (chemical or heat) to minimise the risk of bacterial contamination. Periodic flushing from outlets fitted with a TMV should be carried out to remove stagnant water and to further reduce the risk of bacterial contamination within the outlet.

Mixing valves must be fail-safe, and regular maintenance is necessary to ensure correct performance. There is a risk of scalding by malfunction of these valves. In addition, care facilities staff should check the temperature of the water from taps or showers serviced by mixing valves before use by residents to ensure there is no risk of scalding. Where fitted, TMVs must be accessible and serviceable.

Figure 13: Basic layout of a thermostatic mixing valve



Source: New South Wales Department of Health (2004)

6.5.2.1 Maintenance procedures for TMV's and downstream plumbing fittings

Where TMVs are installed, the following maintenance procedures are recommended.

TMV Maintenance Procedures

1. Check the outlet water temperature with an accurate thermometer at least fortnightly to detect the start of any drift in outlet temperature from the required setting.
2. Every 12 months carry out a comprehensive maintenance service involving complete dismantling of the valve for inspection and cleaning. Replace faulty parts and any other parts as recommended in the manufacturer's service instructions. In areas with poor water quality, more regular comprehensive servicing may be required.
3. At least once every 12 months perform a fail-safe test several times on each valve by shutting down the cold-water supply to the valve. Water flow from the outlet should cease within four seconds of the cold-water supply being isolated. Any leakage of water should not exceed 46°C.
4. Fit a new thermostatic capsule at least every three years.
5. Record all service details and fortnightly operating checks on a log sheet for future reference in the event of valve failure.

Refer to Appendix C(ii) & C(iii) for examples of TMV routine service log sheets Cc

Regular inspection, cleaning, and descaling of showerheads, strainers or filters associated with the TMV is also required. Any strainer or filter associated with the TMV must be placed upstream of the valve to protect it from solids that may be present in the water supply.

Flush infrequently used outlets fitted with TMVs weekly. Flush the water to waste until all water in the pipe from the TMV to outlets is replaced with fresh water and the water at the outlet has reached the preset temperature of the TMV. Where there is more than one outlet from a single TMV, all outlets must be flushed. All showerheads downstream of a TMV must be descaled, cleaned and disinfected every three months, or more frequently in high risk areas.

6.6 Chemical control methods used in hot and cold water systems

6.6.1 Free chlorine

Free chlorine as hypochlorous acid (HOCl) and hypochlorite ion (OCl^-) has long been used to disinfect drinking water and is known to be active against legionellae. Most mains water is supplied with a free chlorine level between 0.1 to 0.5 mg/L, although WHO guidelines allow for levels up to 5.0 mg/L. Chlorine levels above 1.0 mg/L are rarely used in drinking water as these levels make the water unpalatable.

The efficacy of chlorination is influenced by the chlorine concentration used, water pH, temperature, turbidity, and concentration of natural organic matter present. Free chlorine is active against planktonic legionellae and prevents the formation of biofilm but cannot penetrate well into surface biofilm to kill sessile bacteria. Free chlorine provides an active residual in plumbing systems, but its efficacy diminishes significantly as pH rises above 7.6. When free chlorine is used as a biocide the pH must be checked and maintained between 7.2 and 7.6 to achieve optimum disinfection.

Even though its bactericidal activity increases with temperature, it is difficult to maintain an active residual in hot water because of its rapid decay. In heavily contaminated systems increasing the level of free chlorine to above 1.0 mg/L can lead to corrosion of both high-density polyethylene and metal pipes and fittings, so contact time should be kept short. Another issue with water chlorination is the potential of the formation of carcinogenic disinfection byproducts (DBPs) such as trihalomethanes (THMs) when it reacts with organic matter present in the water.

6.6.2 Chlorine dioxide

Chlorine dioxide (ClO_2) is an oxidising biocide capable of reacting with a wide range of organic substances and is regarded as an effective means of treating both hot and cold water systems. It is a highly reactive gas that readily dissolves in water but, unlike chlorine,

does not produce THMs. It does, however, produce chlorite nd chlorate, which can cause anemia and an enlarged thyroid, respectively (Department of Health, 2010). Unlike free chlorine, it is active over a wide pH range (5-10) and can better penetrate biofilms (Health and Safety Commission, 2013).

Chlorine dioxide levels of 0.1 - 0.5 mg/L are effective against *Legionella* with the permitted maximum level of 0.5 mg/L in drinking water (calculated as FACE). However, ClO_2 is aggressive to both metal and polyolefins piping (Vertova et al., 2019) and it can be difficult to maintain the desired active residual because of loss due to ‘gassing off’.

6.6.3 Monochloramine

Monochloramine (NH_2Cl) is a colourless water-soluble liquid with the capability to maintain a disinfectant residual in premise plumbing systems. NH_2Cl is formed when hypochlorous acid (HOCl) reacts with ammonia (NH_3). It can penetrate biofilm more easily than free chlorine (Lee et al., 2011) but has a lower disinfection efficacy, requiring a longer contact time or higher dosing if used as a primary disinfectant (Symons, 1978).

Chloramination reduces the formation of chlorinated DBPs such as THM and haloacetic acid (HAA). However, chloramine species, including monochloramine, are commonly associated with the formation of disinfection byproducts such as chlorates and N-nitrosodimethylamine (NDMA), which may be carcinogenic to humans (Selby et el., 2019).

Several operational practices need to be considered for successful application of monochloramine in premise plumbing systems: (1) chlorine-to-ammonia ratio; (2) appropriate pH; (3) chloramine residual maintenance; and (4) monitoring water chemistry such as organic nitrogen.

System optimisation requires a water pH of 8.3 with a chlorine-to-ammonia ratio of 4.5:1. Monochloramine can cause pipe corrosion and degradation of rubber and plastic material in a premise plumbing system (Zhang et al., 2002). Monochloramine degradation by nitrifying bacteria to nitrite and nitrate can be a problem and will reduce the disinfection residual, especially in warm water systems (Zhang & Edwards, 2009).

The presence of chloramines in the water supply serving dialysis is of concern as it results in haemolysis in haemodialysis patients. Chloramines are not removed by reverse osmosis or deionisation and need to be either adsorbed by filtration through granular activated carbon or neutralised by chemical reduction using ascorbic acid (vitamin C) added to the dialysate. Chloramine levels in the incoming water can fluctuate unpredictably, and failures of both systems have occurred when chloramines have exhausted their capacity (Ward, 1996).

6.6.4 Copper-silver ionisation

Copper-silver (Cu/Ag) ionisation is a popular water disinfection method for the prevention and/or control of *Legionella* growth, particularly in health care facilities (Cachafeiro et al., 2007). The disinfection process occurs from the electrolytic generation of positively charged copper and silver ions from metal electrodes that are released into the flowing water.

Legionella growth is inhibited by the silver ions through interference with electron transport, binding to DNA and interaction with cell membranes. The copper ions interfere with cell wall permeability (Lin et al., 1996). On the other hand, copper is required as a trace element for microbial growth, but in its free form is actually antimicrobial (Department of Health, 2010).

The Cu/Ag ionisation system has been proven to be more effective in re-circulating ring main systems. Continuous monitoring of ion levels is required to ensure optimum concentrations are maintained. Parts of the system that remain stagnant with no water flow, for example, dead-legs and piped branches off the ring main, require frequent flushing to ensure an effective ion residual is maintained in the entire water system.

Copper-silver ionisation is regarded as an effective means of treating warm water systems. However, if it is used, it is recommended that:

- it be placed on the hot or warm line rather than on the cold water line to minimise the volume of water ingested by patients, staff or residents
- copper concentrations of 0.2 to 0.4 mg/L and silver concentrations of 0.02 to 0.04 mg/L respectively be maintained and closely monitored.' (Department of Health 2010, p 44).

WHO suggests 20 mg/L of copper as a maximum level and considers that 0.1 mg/L of silver could be tolerated (WHO, 2006a; WHO, 2006b).

The efficacy of the Cu/Ag ionisation system can be affected by water pH, with copper ions decreasing significantly under alkali pH, although silver ions are relatively stable over a pH range of 6-9. The addition of chloride and phosphate chemicals as part of the water treatment programme can react with coper and silver ions, resulting in a diminished disinfection potential. Physicochemical parameters such as organic carbon, calcium, magnesium, bicarbonate, and temperature do not appear to impact the efficacy of Cu/Ag ionisation, however in hard water areas, scale build-up on the silver electrodes can reduce ion release.

6.6.5 Ozonation

Inactivation of water-borne pathogens including *Legionella* by ozone treatment occurs via oxidation of sulfhydryl groups and amino acids on cell components as well as oxidation of

polyunsaturated fatty acids to acidic peroxides, resulting in degradation of the cell membrane.

Ozone treatment of plumbed water systems is available but of limited use as it is only effective at or close to the point of application (Health Protection Surveillance Centre, 2009). Ozone does not penetrate the biofilm and any biocidal effect is local and short-lived primarily because it does not result in a disinfectant residual. One study on the effectiveness of ozone treatment showed a 2 to 3 log reduction for L. pneumophila over a wide temperature (25-45 °C) and pH (7.2-8.9) range (Domingue et al., 1998).

6.7 Physical control methods used in hot and cold water systems

6.7.1 Ultraviolet (UV) treatment systems

UV lamps are commonly used in drinking water treatment systems as a proven technology for decreasing waterborne disease risk from *Legionella* (USEPA, 2016). In these systems, an ultraviolet (UV) lamp is installed on the cold water inlet pipeline to the warm water storage cylinder. Alternatively, for warm water systems which include a re-circulating ring main, the UV lamp can be connected to the outlet pipe of the storage cylinder.

Retrofitting a UV disinfection device to a water reticulation system within a building will not remove resident *Legionella* downstream of the device. If cold water injection tempering (mixing cold water with the heated water to cool it) is used, then the UV disinfection device must be fitted down-stream of the injection point because in-coming cold water risks introducing *Legionella* into the system where the water is now at a temperature conducive for *Legionella* proliferation. Alternatively, any cold water source for tempering must be treated, either chemically or physically, to remove *Legionella* prior to use.

The UV lamps used must be capable of disinfecting the range of water flows that pass through the system. Sensing devices may be located within the lamp mounting to measure UV intensity and to indicate loss of effectiveness and the need to undertake maintenance such as lamp cleaning or replacement. However, bacteria may be protected by particulate matter, and the need for water filtration should be determined prior to fitting the UV treatment system.

Because the water in these systems is not subject to light, photoreactivation of *Legionella* is not a problem. However, dark-repair enzymes may operate.

Ultraviolet light is notably less effective if the water distribution system is already heavily colonised with *Legionella* (ie, static population of *Legionella*). The legionellae will persist in the biofilm throughout the water distribution system unless water is reticulated past the UV lamp to eliminate *Legionella* at the point of contact (Yu-sen et al., 1998). Therefore, the

system would need to be cleaned and heat disinfected prior to commissioning, after maintenance, and at other times when necessary.

6.7.2 Self-draining valves

Shower hoses have been linked to the transmission of *Legionella* through inhalation of water aerosol containing the bacteria (Niculita-Hirzel et al., 2022). Proprietary mixing and self-draining valves are available which automatically drain water from the shower head and pipe work when the water supply is turned off. Other self-draining valves can be retrofitted to existing mixing valves and pipe work. Although the need for these valves has not been demonstrated, they are designed to reduce residual warm water in the pipework, which could support the multiplication of micro-organisms. However, as with other systems, biofilm may still remain in the pipework.

6.7.3 Point-of-use filters

There are two types of filters commonly used in drinking water systems: carbon filters and membrane filters. Carbon filters are used to remove compounds from the water that contribute to unfavourable taste or smell but cannot be used to remove microorganisms. *Legionella* bacteria will colonise carbon filters and will contaminate the downstream water and outlets.

Membrane point of use (POU) filters are placed at the outlet to provide a temporary physical barrier preventing pathogens present in the water being discharged from the outlet. The appropriate pore size is between 0.2µm and 0.45µm. The POU filters require replacement every four to eight weeks as any trapped legionellae are not killed and can eventually grow through the filter membrane, contaminating the water.

6.8 Sampling and disinfection of water systems suspected of *Legionella* contamination

If a water system is suspected or implicated as the source of legionellosis, then a risk assessment should be carried out. Identify areas where there is an inadequate disinfection residual or water temperatures that encourage *Legionella* growth. Consider all parts of the system, especially those that are used intermittently.

The collection of appropriate water and biofilm samples for microbiological and chemical testing should be undertaken immediately, along with residual biocide and temperature measurements prior to any remedial action. In some situations, it may be prudent to disinfect any implicated system immediately after the completion of sampling rather than waiting for results of the bacteriological tests because these can take up to 10 days.

Where appropriate a number of fittings, such as taps, shower heads, shower hoses and associated washers and O-rings should be disassembled, and biofilm samples taken and investigated for the presence of *Legionella*. Collect swab samples of biofilm from the inner pipe work as well as the fittings and culture for *Legionella*. To prevent the swab sample drying out, seal in a tube submerged in a few mL of the source water from where the swab was collected. More detailed information on sampling refer to the **ESR Sampling Guidelines**.

Trained persons taking these samples should follow the correct occupational safety and health procedures. A suitable face mask with a particulate filter of at least Class P2 (N95) that complies with AS/NZS 1716 should be worn when there is potential for aerosol exposure. Additional PPE may also include gloves, hardhat, and harness. Appendix A of AS/NZS 3666.2 has further details relating to specific tasks and appropriate PPE (see Section 10).

6.8.1 Water sampling

Water samples should be taken as follows and investigated for the presence of *Legionella*.

- From any representative outlets the moment it is opened to capture the first water. Do not allow water to run to waste.
- From any representative outlets after running the water for a few minutes to obtain samples representative of water in the delivery pipe work.
- Where a sample cannot be collected directly from a storage vessel, then collect indirectly from the outlet closest to the water storage vessel after running sufficient water to obtain a sample representative of water contained in the storage vessel.

Not every outlet needs to be sampled, however as a minimum, the outlets closest to and most distal to the storage vessel should always be sampled, as well as including outlets used by any associated case. Water samples should be collected from different points of the both the hot and cold water lines. Where hot water is recirculated from a central water heater, samples should be collected from the first outlet and the last outlet on the loop served by the water heater. For a branched system with no return, sample from outlets most proximal to the heater and those most distal to the heater on each branch.

When samples are collected from either mixer taps or showers, collect from both the hot and cold side. Samples collected from a TMV outlet it will be mixed with both hot and cold water and will only be representative of the water downstream of the TMV and not the hot or cold water supply. Where possible also obtain samples of the hot and cold feed waters upstream of the TMV.

Sampling should also be targeted to areas where:

- water temperatures are between 20°C and 50°C
- there is no biocide residual

- no or low water usage (infrequently used outlets).

All samples must be adequately identified describing the sampling site. Samples should be kept at ambient temperature, in the dark, and transported to the laboratory immediately. For further detailed information refer to the **ESR Sampling Guidelines**.

6.8.2 Temperature measurement

Water temperatures should be taken throughout the sampling with a digital thermometer accurate to within 0.5°C. Further measurements should be made to determine changes in water temperature at all outlets as water flows from the storage to the outlets.

Data concerning water temperatures and results of bacteriological analysis should be recorded and assessed in relation to water flow patterns throughout the water distribution system.

6.8.3 Decontamination procedures

There are two acceptable methods for the disinfection of drinking water system that have become contaminated with *Legionella* bacteria:

- thermal disinfection, where the water within the entire system is heated to a temperature where *Legionella* will not survive
- chemical disinfection, where a biocide compatible with drinking water (chlorine-based) is flushed through the entire water system at a level that will kill the *Legionella*.

6.8.3.1 Thermal disinfection of hot water systems

These systems can be readily heat disinfected if the water temperature in the water heater can be raised above 70°C by altering the thermostat set point. During this procedure, precautions should be taken to adequately reduce the risk of burning (scalding) to building occupants.

Raise the temperature of the water in the storage vessel to a minimum of 70°C and hold for one hour. Flush sludge from the bottom of the storage vessel using the drain valve. Flush each outlet in turn until the water temperature reaches a minimum of 70°C, then continue flushing for a further five minutes.

Repeat thermal disinfection should be carried out weekly, in conjunction with water analysis for *Legionella*, until the system is no longer considered to be contaminated with *Legionella*. Corrective action may involve simple adjustment of thermostat settings or may require complete or partial redesign and modification of the entire system.

Beware that thermal disinfection of piped water systems at temperatures below 70°C frequently fails and needs to be repeated at the higher temperature. If a water temperature

of 70°C cannot be achieved at all outlets during thermal disinfection, it will be necessary to fill the system with cold water and disinfect with a chlorine-based biocide, as described below.

Thermal disinfection should be carried out on hot water systems before reuse when they have been shut down or remained idle for more than two weeks.

Disinfection of water system by thermal shock treatment

For emergency disinfection only – not recommended as part of standard process for the control of legionellae in heated water systems.

1 Take precautions to adequately reduce the risk of scalding to building occupants during this procedure.

2. Raise the temperature of the cylinder water above 70°C for a minimum of one hour. In a circulating system, pump the water continuously round the entire system for a minimum of one hour. In a branched system, hold the water in the water heater for at least 30 minutes to ensure disinfection of the water.

3. Starting at the outlets closest to the water heater, open each outlet in turn for a minimum of five minutes with water running at a moderate flow. The water temperature must be monitored and not fall below 70°C during the flushing process. Each tap and appliance must be run sequentially at full temperature. *Note: This may not be achievable in some systems, particularly older premises, and impractical in others.*

4. Reinstate thermostat to a minimum of 60°C.

- Thermally disinfect systems that lie idle for two weeks or more as above, before restarting.

- Where there is high suspicion of the reticulation system being contaminated, regular testing of the water for *Legionella* must be undertaken to ensure the disinfection is effective in controlling the *Legionella* risk.

Refer to Appendix B for a sample service log sheet for warm water systems.

6.8.3.2 Chlorine-based disinfection of cold and hot water systems

Super-chlorination is an alternative method to thermal disinfection and can be carried out on both cold and hot water systems using the procedure below. To improve super-chlorination efficacy all sludge and sediments in tanks and pipelines must be removed.

Disinfection of hot and cold water systems by super-chlorination

1. Ensure that the heating source to all water heaters is removed (hot water should be cooled to an ambient temperature before starting super-chlorination to prevent thermal decomposition of the biocide).
2. Ensure that an air break is incorporated between the water main and the premise water storage system to prevent contamination of the public water supply (alternatively, ensure a back-flow prevention device is fitted).
3. Drain any sludge and sediment from the bottom of all water storage tanks. If tanks are accessible, physically remove and clean tank interior.
4. Rinse and refill a storage tank with fresh water and add sodium hypochlorite solution to produce a free chlorine residual of at a minimum of 10 mg/L (10 ppm) as measured by a DPD test kit. Use the turbulence of refilling to help mix the added biocide. Keep the pH between 7.0 and 7.6 throughout the process to increase the availability of hypochlorous acid (HOCl) and improve the disinfection efficacy.
5. Circulate the chlorinated water throughout the entire water system by running the chlorinated water from each outlet sequentially starting at outlets closest to the storage tank.
6. Check the free chlorine residual with the test kit in the water at sentinel outlets including those at the most distal outlets downstream of the tank - this should be not less than 10 mg/L.
7. Ensure the tanks remains topped up with sufficient chlorinated water at 10 mg/L
8. Allow the water to stand for four hours with intermittent checking of the chlorine level at the sentinel outlets – this should not be less than 7 mg/L during the entire 4 hours.
9. Recharge the system with fresh chlorinated water if the free chlorine residual is less than 7 mg/L and restart the time.
10. Drain the storage tank and refill with water and recommission the system.
11. Resample of the water for *Legionella* must be undertaken after 72 hours of normal use to ensure the disinfection is effective in controlling the *Legionella* risk.
12. Document process details in a maintenance logbook, including all test results for future reference.

- Where there is high suspicion of the reticulation system being contaminated with *Legionella*, instigate a regular testing regime.
- The four-hour contact time is a nominal time and is contingent on the amount of biofilm and other organic debris within the system. Contact time can be shortened if a higher free chlorine level is used.
- Repeated superchlorination of metal piping and fixtures can cause excessive corrosion.

7 Spa pools, hot tubs and jacuzzis

Recreational spa pools, hot tubs, and jacuzzis (both public and private) utilise warm water at temperatures between 30°C and 40°C, some with the ability to use air and water jets to produce turbulence and create aerosols. Such aerosols are readily spread to both spa users and those near the pool, and can be easily inhaled.

Operating spa pools on display in a showroom environment can also become contaminated with *Legionella* and present an infection risk. The risk of infection increases if the water jets of display spas are operated (ie, producing aerosols) when the water has not been properly treated. In 2002 a retail store in Auckland was the source of a Legionnaires' disease outbreak causing death. Again in 2003, display spa pools were considered to be the most likely source of *Legionella* infection in the three cases that had visited a retail outlet in Lower Hutt (Ruscoe et al., 2006).

Each year poorly maintained private and public spa pools are identified as the source of sporadic community acquired legionellosis as well as being the most frequent source of legionellosis outbreaks in New Zealand.

The use of spa pools and hot tubs results in an accumulation of soluble matter and organic material in the water that encourages the growth of microorganisms. Many pools are outdoors where accumulation of airborne material and surface run off can occur. Because of this, inadequately maintained pools have the potential to infect large numbers of people. Appropriate water treatment and a testing programme, coupled with an adequate cleaning and disinfection regime will prevent the growth of microorganisms, including legionellae.

7.1 Water quality criteria for spa pools

Microbiological criteria for spa pools

Test	Acceptable level	Minimum frequency of testing *
Standard plate count	< 200 cfu/ mL	monthly
Faecal coliforms or *E. coli*	< 1/100 mL	monthly
Staphylococcus aureus	< 100/100 mL	monthly
Pseudomonas aeruginosa	<10/100 mL	monthly
Legionella	<1/100 mL	monthly

Adapted from NZS 5826:2010.

* testing frequency will be more frequent if the pool does not comply with chemical parameters
over a period of half a day in public pools and over more than a week for domestic pools unless super-chlorination of the system, physical cleaning of all pool surfaces and backflushing of filters has been carried out. The pool water must be fully drained and replaced with fresh water after each super-chlorination event.

Chemical criteria for spa pools

Characteristic	Acceptable range	Minimum frequency of testing Public pool Domestic pool	
pH	7.2-8.0	Prior to daily use, then twice then every 2-hours	After filling, weekly
Alkalinity	100-120 mg/L	After filling, then then weekly	After filling, monthly
Calcium hardness	40 300 mg/L	After filling, then then monthly	After filling, monthly
FAC	2.0 – 10 ppm	Prior to daily use, then twice then every 2-hours	After filling, weekly
Total chlorine (bromine)	4.0 – 10 ppm	Daily	Weekly
Combined available chlorine	<1.5 mg/L	Daily	Not applicable
Cyanuric acid	25-50 mg/L	Fortnightly	Monthly
Total dissolved solids (TDS)	0 – 3000 mg/L	Daily	Monthly

Adapted from NZS 5826:2010

7.2 Maintenance and operation of spa pools

The recommendations for the safe operations of spa pools include:

- testing the free available chlorine level daily before use and every two-hours during use
- maintaining a pH of the water between 7.2–7.8, and a free chlorine residual of 3–5 mg/L (ppm) or a free bromine level of 4–6 mg/L (ppm)
- operating the filter pump when dosing biocides, but not the air blower or venturi
- filtering the water for at least two hours every day, even if the spa is not in use, and running the filter for at least one hour after use
- checking and cleaning the filter regularly, including backwashing of sand filters
- removing at least 10 percent of the water daily and replacing it with clean water – heavily used spas will need to have more water removed
- a complete water change must be made weekly for public pools, and monthly for domestic pools. More frequent changes must be made if the water is not clear, has an unpleasant odour, or exceeds the TDS limit
- keeping spa surfaces clean, including the surrounds, tiles, grout lines, pool cushions and the pool cover
- not using the spa or operating the water jets if the water is not treated properly or the spa has not been maintained
- draining and cleaning the pool when not in use for any extended period
- using overnight superchlorination on a weekly basis or whenever the pool water is changed.

7.3 Use of ozone as a disinfectant for microbial control in spa pool waters

Ozone has been shown to have a killing effect on bacteria. However, as with ultraviolet light, it only ‘disinfects’ the water at the point-of-use and therefore on its own often cannot provide sufficient disinfection to adequately control bacterial contamination in a spa pool. Because of this, additional disinfection by an oxidising disinfectant (eg residual chlorine or bromine) is required to prevent cross contamination in the spa pool water and to deal with the effective breakdown of bather pollution.

Where chlorinating disinfectants are used in conjunction with ozone the residual disinfectant concentration required in the spa pool water will be dependent on spa pool design and attaining satisfactory microbiological results. The microbiological results should indicate low colony counts and the absence of *Pseudomonas aeruginosa* and *Legionella* bacteria.

Optimal microbial control can only be attained by using ozone in conjunction with residual disinfection. The type of ozonisation used depends on the spa pool installation. Where spa pools are installed as an integral part of a public pool water treatment system, spa pool water treatment is sometimes combined with that of the main pool and ozone treatment would normally be followed by deozonisation prior to adding residual chorine or bromine disinfection. Even with ozone use, free chlorine residuals will still need to be maintained between 3-5 mg/L (3-5 ppm), bromine at 4-6 mg/L, polyhexamethylene biguanide (PHMB) at 50 mg/L and isocyanurates at 3-5 mg/L to ensure adequate disinfection.

Alternatively, trickle stream ozonisation is used sometimes where the ozone is not removed by a deozonisation bed prior to the addition of the residual disinfectant. The ozone should be at such a concentration to ensure that 0.01 ppm ozone is not exceeded in the atmosphere above the spa pool water. Again, the residual disinfectant used in conjunction with ozone can be any of those listed in the previous paragraph.

The ozone generator should be checked daily to ensure it is operating correctly. The system must be maintained and cleaned as specified in the manufacturer's instructions.

7.4 Use of hydrogen peroxide as a disinfectant for microbial control in spa pool waters

Hydrogen peroxide on its own is not considered a strong biocide in water systems, although it is a powerful oxidizing agent. It can be used in combination with UV light or PHMB to provide enhanced biocidal activity. However, hydrogen peroxide is not compatible with diatomaceous earth filters commonly used in home spa pools.

Additionally, hydrogen peroxide is required to be added at significantly higher levels than chlorine-based biocides to achieve effective microbial control. It is usually maintained in the 30 to 40 ppm range in low use pools, but as high as 100 ppm in heavily used pools. Levels must be closely monitored, because hydrogen peroxide dissipates rapidly from aerated or agitated pool water.

7.5 Use of silver as a disinfectant for microbial control in spa pool waters

Although silver has long been known to have some antimicrobial activity, it is unproven as a primary disinfectant in both drinking water systems and recreational waters, such as spa pools. Both colloidal silver and silver salts have been proven to provide ineffective disinfection of spa pool waters when used as the sole biocide.

Although silver appears to reduce planktonic bacteria levels in some drinking water systems, it does not appear to have any effect on biofilm formation microorganisms

(Silvestry-Rodriguez et al., 2008). In the three years between 2020 and 2022 there have been three separate cases of legionellosis traced to spa pools where a silver salt has been used as the sole water treatment chemical. It is not recommended that silver is used as a disinfectant in spa pool waters for microbial control.

8 Compost, mulch, and other soil conditioners

There are a significant number of sporadic cases of Legionnaires' disease caused by *Legionella longbeachae*, accounting for as many as 50% of cases in New Zealand (Graham et al., 2023a). This organism is frequently isolated from composts, soil conditioners and mulches, soils for landscaping and garden use, and potting mixes.

Composted materials frequently contain *Legionella* species other than *L. longbeachae* and some of these species (*L. bozemanae, L. micdadei,* and *L. pneumophila*) have also been implicated in *Legionella* infections from composted organic matter. In 2021, garden mulch was definitively proven as the source of a *Legionella pneumophila* serogroup infection using whole genome sequencing analysis to show a 100% match between both the clinical and environmental isolates.

It is suspected that transmission from the compost material is via the inhalation of dust aerosols containing the *Legionella* bacterium. Results from an investigation into 22 cases of *L. longbeachae* infection in South Australia during 1988 and 1989, found that those affected were regular gardeners and a common feature of their gardens was the presence of ferneries with hanging baskets (Cameron et al., 1991). *L. longbeachae* was subsequently isolated from potting mix (which consisted mainly of composted pine bark), providing a plausible natural habitat for this bacterium (Steele et al., 1990a).

Further links between *L. longbeachae* infection and potting mixes and other composted vegetative matter have been made in Australia, Japan, Europe and the United States, through case-series and laboratory evidence (Steele et al 1990b; Gabbay et al 1996; Koide et al., 2001). In a soil survey in Australia, 33 (73%) of 45 potting soil mix samples tested positive for *Legionella*; 26 (79%) of the 33 (79%) contained *L. longbeachae* (Steele et al., 1990a). A survey of 17 soil samples in Japan in 1998 yielded 31 different strains of *Legionella*; 8 of the 17 samples (47%) contained *L. longbeachae* (Koide et al., 1999). Following a period of enrichment, 15 of 24 commercially prepared composts were shown to be culture-positive for *Legionella* species, including *L. longbeachae* (Curry et al., 2014).

While the link with materials like potting mix, pine bark and sawdust has been reported (Steele et al., 1990b; Speers and Tribe, 1994), facets of the transmission of infection are unclear, as are the full array of virulence factors that the bacterium possess. Factors

including the production process of potting mix and the presence of other micro-organisms may play a role in the ecology of the *Legionella* in this natural terrestrial environment.

8.1 Prevention

There is no statutory requirement in New Zealand for potting mixes and other compost materials to have warning labels attached. This is because most manufacturers have volunteered to use an industry-agreed warning label (Figure 14) as recommended by NZS 4454: 2005 *Composts, soil conditioners and mulches*.

Figure 14: Recommended labelling of bagged products and bulk handling areas

Warning label 1 – Bags

CAUTION

Ordinary garden soil and products like compost and potting mix may contain a variety of living micro-organisms, some of which, on rare occasions, can cause illness in humans.

Serious infection is rare. However, for older people or those with reduced immunity, infection can be life threatening. We recommend the following precautions:

- AVOID OPENING BAGS IN ENCLOSED AREAS (INCLUDING HOT-HOUSES AND FERNERIES)
- ALWAYS WEAR A P2 OR N95 MASK WHEN HANDLING COMPOST OR POTTING MIX
- AVOID INHALING DUST OR AEROSOLISED PARTICLES FROM THE MIX
- ALWAYS WEAR GLOVES AND WASH HANDS AFTER USE.

See your doctor if you develop high fever, chill, breathlessness or cough.

Warning label 2 – Bulk handing areas

CAUTION

Ordinary garden soil and products like compost and potting mix may contain a variety of living micro-organisms, some of which, on rare occasions, can cause illness in humans.

Serious infection is rare. However, for older people or those with reduced immunity, infection can be life threatening. We recommend the following precautions:

- AVOID INHALING DUST OR AEROSOLISED PARTICLES FROM THE MIX
- ALWAYS WEAR A P2 OR N95 MASK WHEN HANDLING COMPOST OR POTTING MIX
- ALWAYS WEAR GLOVES AND WASH HANDS AFTER USE
- WHILE WORKING AROUND BULK STOCKPILES WEAR A MASK TO PREVENT INHALING THE WATER VAPOUR.

See your doctor if you develop high fever, chill, breathlessness or cough.

To prevent *Legionella* infection from potting mix and other compost materials, people should take precautionary steps, including the following:

- wear a N95 face mask, covering the mouth and nose to reduce the risk of inhaling airborne dust
- wear gloves
- open any bag using a blade slowly and with care to avoid creating dust aerosols
- moisten the contents of the bag on opening, by making a small opening and inserting a garden hose to dampen the potting mix
- avoid potting-up plants in unventilated areas, such as enclosed greenhouses or sheds
- avoid transferring potting mix from hand to mouth (eg, rubbing face with a soiled hand or glove)
- always wash hands after handling potting mix, even if gloves have been worn, as *Legionella* bacteria can remain on hands contaminated by potting mix
- store potting mix in a cool place, away from the sun
- keep soils and potting mix damp
- avoid raising soil near evaporative coolers and air conditioners
- water gardens and composts gently, using a low-pressure hose
- when handling bulk quantities of potting mixes or other soil products, follow procedures that minimise dust generation.

Face masks should be N95 (equivalent to P2) particulate masks, as specified in AS/NZS 1715: 2009: *Selection, use and maintenance of respiratory protective equipment,* or AS/NZS 1716: 2003: *Respiratory protective devices.* These must be tightly fitting over the mouth and nose with no air gaps between the mask edge and the skin. Excessive facial hair and skin wrinkles and folds will negatively impact on mask integrity. Mask fit-testing should be carried out to ensure any mask used is appropriate for the purpose. Surgical masks are not appropriate for this use. It is recommended good practice for retailers of potting mix and compost to also offer protective masks at point of sale.

The Ministry of Health has developed a resource titled *Safer and Healthier Gardening* to help reduce the risk for the home gardener, which could also be made available at point of sale. This resource is available on the **HealthEd website**.

8.2 Bulk handling

Regardless of the quantity of soil, potting mix or compost being handled, basic control procedures such as those outlined above should be implemented. However, when handling bulk products, remember to:

- keep the soil, potting mix or compost damp, to minimise the spread of particles

- avoid double handling of soil, potting mix or compost whenever possible
- if working in an enclosed vehicle, ensure that the cabin is sealed, and air filters are cleaned regularly
- plan the work to minimise the need to move bulk soils, potting mix or compost, to reduce the risks of creating dust
- wear protective equipment, including both gloves and a face mask.

If bulk compost, soil or un-bagged potting mix is being bulk stored at commercial sites such as retail outlets or nurseries, it is recommended that bins are designed to minimise wind disturbance of the contents and have barrier walls to reduce the risk of inhaling potentially contaminated dust, or dust being blown off-site into neighbouring properties. Bulk bins should be located in full shade and the materials should be well-watered.

9 Other sources of *Legionella* infection

9.1 Proven exposure sources

Sporadic and outbreak cases of legionellosis have frequently been associated with cooling towers, spa pools, roof-collected rainwater systems, and compost material. This section gives more details on less common sources of *Legionella* infections that have occurred in New Zealand or overseas.

9.2 Geothermal pools

Natural hot springs and geothermal spring waters are also a source of legionellae (Bornstein et al., 1989; Martinelli et al., 2001). Legionellae have also been isolated from natural streams and pools fed with geothermal water in New Zealand and have been implicated in cases of legionellosis both overseas (Mashiba et al., 1993) and in New Zealand. Legionellosis cases have been traced to both non-recirculated geothermal pools and natural geothermal stream waters in New Zealand.

For *Legionella* control in geothermal pools, the pool should be operated on a flow-through principle with at least a quarter of the pool volume replaced every hour. The pool must be drained and scrubbed clean each day using 50 g calcium hypochlorite/10 L of water. The pool water must be protected from surface water run-off and soil contamination. During periods of non-use, the pool should be drained of water and left dry.

9.3 Water-based metal-working fluids

Metal-working fluids are specially developed coolants and lubricating fluids used in the grinding, cutting, and drilling of metals. These coolants are often mixed with water and

support the growth of micro-organisms, including legionellae. When aerosols are generated during their use these can be inhaled leading to legionellosis. Personal protective equipment is advised to be worn when using metal working fluids to prevent the inhalation of aerosols.

The growth of micro-organisms can be controlled by regular cleaning and following the directions for use of the metal-working fluid. This includes the correct use of biocides and reduction of aerosol generation and exposure. Although not a means of detecting *Legionella* growth, carrying out weekly dip slide testing for bacteria can be used to quickly monitor the level of bacterial contamination in water-based metal-working fluids.

In equipment cooled using plumbed potable water systems where, for example, water is sprayed onto a grinding wheel, periodic inspection and disinfection of the equipment should be undertaken to avoid a build-up of biofilm and *Legionella* bacteria. Any stored or recirculated water needs to be kept visually clean and disinfected.

The disinfection can be carried out using a 5% sodium hypochlorite solution (domestic bleach) for a minimum of one hour. This will help dislodge biofilm and kill any bacteria present. The disinfection should be undertaken month or more frequently if visible biofilm is present. The addition of a mild detergent to the disinfection solution can aid penetration of the disinfectant aiding both biofilm removal and the effectiveness of the disinfection.

During periods of shut down the equipment should be drained of water and left dry.

9.4 Respiratory therapy equipment including continuous positive airway press (CPAP) machines

Portable room humidifiers, CPAP machines, and oxygen nebulisers (spray generators) are commonly used by patients with underlying lung disease and whom often have weakened immunity against infection. There have been reported instances where tap water has been used in these types of equipment, become contaminated with *Legionella* bacteria due to improper maintenance, and resulted in legionellosis.

For the safe operation of this equipment:

- use only sterile water. Potable (tap) water must be boiled and allowed to cool before using
- empty the reservoir, drain, and dry after each use
- at least once per week, all tubing, the face mask or mouthpiece and reservoir should be dismantled and washed with hot soapy water before rinsing and drying. The parts should then be stored dry and never rinsed with tap water
- where air filters are fitted, ensure these are replaced at least every six months

- the reservoir must never be topped up without first removing any remaining water, thoroughly cleaning and disinfecting before refilling with sterile water.

9.5 Indoor fountains and water features

Aerosols are created by splashing or spraying of water in a fountain. Fine droplets or mists present a greater risk than larger droplets. The re-circulating water in such systems may be inadvertently heated, such as through submerged lighting, direct sunlight or high ambient temperatures, producing conditions that may favour the growth of *Legionella*. These factors should be considered during the design and installation phases, and when planning cleaning and maintenance schedules.

Most Legionnaires disease outbreaks linked to fountains have been associated with decorative fountains in enclosed areas or atria where aerosols are more likely to persist (Hlady et al., 1993) and water temperatures are usually close the indoor ambient air temperature. The risk is considerably increased with water temperatures above 20°C, if the water is recirculated, or if biocide control is absent or inadequate.

Maintenance schedules and water treatment plans for water features should include regular draining and physical cleaning of the entire system (including associated pipe work, pumps, filters sumps and drains). Microbiological control should also be undertaken using biocides commonly used in swimming pools and monitored in a similar way to ensure control is effective. Maintenance records should be kept showing the frequency of system cleaning and biocide use.

9.6 Grocery misting machines, humidifiers, and dental unit water lines

These devices have been proven sources of *Legionella* infection overseas. Documented incidents are low; however, some of these have been the source of outbreaks and show that any contaminated water-based system that generates an aerosol has a potential legionellosis risk. Again, this risk increases with water temperature, a build-up of slime, or inadequate or absent biocide control.

Humidification systems are used to humidify air that enters occupied spaces. There are many different designs of humidifiers, some of which operate on the principle of evaporation of cold water. These systems should be maintained in a thoroughly clean condition and stored dry when not in use. In some instances, it may be appropriate to replace water types with steam-generating humidifiers in which *Legionella* will not survive.

Other water-based systems such as high-pressure water blasters have the potential to disseminate *Legionella* into the environment as an aerosol. These systems have in common a supply of water that at times is allowed to stagnate and may result in the water

temperature and other factors becoming conducive to the proliferation of *Legionella*. When such a system is activated after being idle, contaminated aerosols may be produced. These systems include high-pressure cleansing and cooling processes, and above-ground storage tanks which feed aerosol generating equipment.

Actions that should be taken if these systems are of concern may vary according to the circumstances. Periodic and regular flushing of the system to remove stagnant water (in a manner that does not produce aerosols) will suffice in some situations; the use of biocides may be appropriate in others. Storing water in a way to prevent temperatures rising above 20°C, such as in underground tanks, may be a solution. Each situation should be individually assessed, and the appropriate action taken.

9.7 Systems using recycled water, including vehicle washes

Systems that use recycled water, particularly as a spray, have been identified as the source of *Legionella* infections. These types of systems may be found in crate washing systems, powder coating systems and vehicle wash systems, and include those frequently found on service station forecourts.

Several risk factors have been identified that typically contribute to the growth of *Legionella* bacteria in any system using recycled water. They are:

- recycled water that does not contain an active biocide residual
- winding pipes and tanks that provide reservoirs for bacterial growth
- the presence of “dead-legs”
- water that can reach optimal temperature for bacterial growth
- high nutrient loading
- the build-up of biofilm, or the presence of lime scale or rust within piping and tanks
- the use of natural rubber seals and flexible rubber hosing
- infrequent usage
- the lack of appropriate biocide control.

Safety considerations for washing systems include:

- considering an appropriate bleed-off rate to minimise the TDS levels and replacement with fresh top-up water
- considering whether the water temperatures can be kept either below 20°C or above 60°C to discourage *Legionella* growth
- evaluating flow rates of water through tanks or pipework to eliminate stagnation and material build-up

- removing and replacing rubber hosing and seals used in the system as rubber encourages the growth of biofilm and *Legionella*
- implementing a regular regime of cleaning all pipework and storage tanks, giving attention to the removal of sludge and sediment
- regular replacement of cartridge filters and cleaning of filtration equipment
- implementing regular disinfection and maintenance based on inspection and microbiological monitoring. (Commission for Occupational Safety and Health 2010, p 20).

9.8 Natural birthing pools

Aspirational legionellosis can result in neonates following birth in *Legionella*-contaminated pools where the water has been preheated and recirculated for up to two weeks prior to the birth (Collins et al., 2015). Proliferation of *Legionella* bacteria has occurred due to the lack of appropriate disinfection. The *Legionella* has been potentially seeded from contaminated residual water remaining in the pool from previous use, or from the most recent water fill. Pools should be either filled just prior to use to minimise the risk, or control measures put in place to ensure adequate continuous disinfection.

10 Occupational safety and health

10.1 Introduction

Commissioning, maintenance, cleaning, decontamination, and other procedures should be designed to minimise the risk to personnel working on or in the vicinity of cooling towers and other potential sources of *Legionella*.

Procedures that create aerosol sprays, such as high-pressure hosing, should be avoided whenever possible. If this is unavoidable, suitable respiratory protection should be worn to minimise the risk of inhaling water droplets contaminated with *Legionella*.

To reduce the risk to maintenance staff, decontamination and routine cleaning of cooling towers described in this document including chlorination of the tower water should be carried out before any physical cleaning is undertaken.

Water treatment should be carried out by or under the direction of suitably qualified and experienced persons. Chemicals should be handled with care by personnel wearing appropriate protective clothing, including goggles and gloves, to prevent direct contact with these agents.

Personnel involved in the above procedures should be adequately trained in safety procedures, including the use and maintenance of protective equipment. Caution must be

exercised so that occupants of the building and others in the vicinity are not put at risk by any procedures undertaken or by the chemicals being used.

10.2 Safety standards

Appropriate respiratory, skin and eye protection should be selected by a qualified occupational safety and health professional. It is the employer's responsibility under the Health and Safety at Work Act 2015 to provide protective equipment and to train staff in its correct use. WorkSafe can provide further advice if required.

10.3 Safety practices and procedures

The following safety practices and procedures should be observed when working on, or in close proximity to, cooling towers.

10.3.1 General inspection and routine maintenance work

When inspecting or working in or on cooling towers where aerosols might be created and inhaled, cartridge respirators of the recommended type should be worn for the duration of the inspection or work. These respirators should contain a particulate filter of appropriate efficiency. Hands should be washed and thoroughly dried after inspection and maintenance work, and before eating, drinking, or smoking.

If chlorine compounds or other biocides are handled in this type of work, appropriate precautions to prevent skin contact should be used. These precautions should comply with those outlined on the relevant material safety data sheet and may include wearing gloves, a face shield and a waterproof apron.

10.3.2 Decontamination and cleaning tasks

These tasks involve the generation of mists and the handling of a variety of chemical substances. The protective clothing outlined below should be considered the acceptable minimum. More stringent precautions may be necessary in some circumstances, for example, during work in a confined space.

Personnel carrying out decontamination and cleaning procedures should wear the following protective equipment:

- goggles or face shield
- hardhat and harness
- waterproof clothing or coverall
- protective gloves
- a suitable face mask with a particulate filter of at least Class P2, or powered air purifying respirators with a P2 filter that complies with AS/NZS 1716 which should be

used in accordance with AS/NZS 1715 when inspecting a water cooling system which is in service. If there is also a risk of inhalation of low levels of chlorine, a combination acid gas and particulate respirator may be suitable. If aerosol sprays are created, personal protective equipment to protect the eyes should also be worn, such as goggles, face shield, waterproof clothing or coverall, protective gloves and a full-face respirator.

Table A1 of Appendix A of AS/NZS 3666.2 can be considered as the minimum requirement for personal protective equipment during any activity associated with water cooling systems, including maintenance.

10.3.3 Chemical handling

Chemicals such as biocides, cleaning agents, acids and alkalis may be used in cleaning and decontamination procedures. These materials may be corrosive to the skin and, if inhaled, may cause respiratory irritation. Material safety data sheets should be obtained for each chemical agent used and the recommended preventive measures and first aid procedures followed.

The handling and storage of chemicals used in cleaning and decontamination procedures need to conform to AS/NZS 3666.2 and AS/NZS 4452 – *The storage and handling of toxic substances*. In addition, water treatment chemicals used for cooling tower cleaning and decontamination are controlled by the Hazardous Substances and New Organisms Act 1996 (HSNO). HSNO regulations may require:

- a Location Test Certificate for the premises (previously a Dangerous Goods Licence)
- an Approved Handler Test Certificate for employees responsible for the handling of certain highly hazardous chemicals.

When handling chemicals of this nature, the following guidelines should be observed.

1. Comply with any instructions on the product label or container.
2. Avoid mixing the chemicals during storage or transport. Handle only one chemical at any time in one place.
3. Keep lids on containers except during removal of contents.
4. Prevent the spread of chemicals by using sand or other suitable methods when cleaning up spills. Dispose of the contaminated sand in an appropriate manner. If possible, avoid washing spills into storm water drains.
5. If skin comes into contact with chemicals, wash immediately with copious quantities of clean water.
6. Wear goggles or a face shield, and impermeable gloves.
7. Wear respiratory protection if there is a risk of significant contamination of the air by a chemical substance in the form of vapour or powder. This may occur in a confined area where ventilation is limited.

If hazardous substances such as chlorine are used in a domestic setting, they need to be stored so that any leak or spill is contained to avoid harm to people, property or the environment. Some hazardous substances can be highly poisonous to people. These chemicals must be kept secure under lock and key when unattended so that children and unauthorised people cannot access them.

10.3.4 Working in confined spaces

More stringent safety procedures may be needed when work is carried out in a confined space, such as inside a cooling tower. The safety requirements are detailed in the WorkSafe's publication *Confined spaces: planning entry and working safely in a confined space* (WorkSafe New Zealand, 2020).

10.3.5 Protective clothing and equipment

The safety equipment and procedures outlined above are specially aimed at the cleaning and decontamination of cooling towers but can reasonably be extended to cover maintenance tasks associated with other systems.

The following equipment should be used for specific tasks in addition to normal protective clothing such as overalls and dust coats:

- respiratory protection – Properly fitting protective devices conforming to the following New Zealand Standards:
  - AS/NZS 1715: 2009 Selection, use and maintenance of respiratory protective equipment
  - AS/NZS 1716: 2003 Respiratory protective devices
- full-face masks with a particulate filter of at least Class P2 that complies with AS/NZS 1716
- skin protection – the following waterproof clothing:
  - waterproof overalls (with hood) – either disposable or reusable rubber/vinyl suit
  - rubber or vinyl knee-length boots
  - rubber or vinyl gloves
- eye protection – goggles or face shields conforming to AS/NZS 1337.1: 2010, Part 1: *Eye and face protectors for occupational applications*.

Part 2: Guidelines for the follow-up of cases of Legionellosis

11 Introduction

These guidelines have been revised to assist hospital staff and public health officers in the investigation and control of potential or actual outbreaks of legionellosis in New Zealand. Guidelines for the public health management of *Legionella* require periodic updating as more becomes known about the bacterium and its impact on human health.

11.1 Case definition

Clinicians should maintain a high index of suspicion for legionellosis in any patient with unexplained fever and pneumonia, especially when there is immune impairment, and they should treat such cases appropriately.

The current definition for a legionellosis case uses a combination of clinical and laboratory tests to distinguish legionellosis from other types of pneumonic illness with similar symptoms. Periodic updates to the definition occur to accommodate developments with new and improved diagnostic methods. The Communicable Disease Control Manual (Health NZ) uses a three-tiered case classification for legionellosis cases: 'under investigation' or 'probable' or 'confirmed'. Correct and complete ethnicity data should be collected for all cases.

Under investigation – notified to the Medical Officer of Health only:

- laboratory testing is still to be completed to classify as either 'probable', 'confirmed' or 'not a case'.

Probable case – clinically compatible illness with the following laboratory finding:

- one or more elevated (≥ 512) serum antibody titres to a specific Legionella species by the indirect immunofluorescence antibody test (IFAT) using species-specific antigen and validated reagents.

Confirmed case – requires a clinically compatible illness with or one or more of the following laboratory testing:

- the detection of *Legionella* species nucleic acid by PCR or other NAAT detection methods
- the isolation by culture of *Legionella* species from respiratory secretions or other clinical samples
- a fourfold or greater rise in IFA titre against *Legionella* species to ≥256 between paired sera tested in parallel using pooled antigen at the same reference laboratory
- detection of *Legionella* species antigen in urine.

For further information refer to section 2.7 'Laboratory diagnosis'.

11.2 Notification

The criterion for notification of legionellosis in New Zealand by an attending medical practitioner is on suspicion of disease with a clinically compatible illness. Medical laboratories must also immediately notify when laboratory testing returns a positive result for legionellosis. The initial notification does not require laboratory test confirmation.

Medical practitioners or the laboratory clinicians must notify the Medical Officer of Health serving the health district in which the patient resides. The requirements for direct laboratory notification to the Medical Officer of Health on confirmation or suspicion of legionellosis supports the detection of both sporadic cases and investigation of suspected outbreaks. A standard data set for each case is obtained and entered into EpiSurv, the database of notifiable diseases.

An enhanced *Legionella* data collection form to be used by investigating public health personnel is included in Appendix D. Public health personnel should follow best practice guidelines for the collection of patient information including being respectful of the needs of different cultural groups including Māori.

Often public health authorities will, with index case approval (under the Privacy Act 2020), inform the appropriate occupational safety and health personnel if an industrial source is implicated.

11.3 Communication

After the identification of a case of legionellosis, these steps are followed.

1. The Medical Officer of Health should inform the appropriate health district staff, including the relevant local infection control committees, particularly if the cases may have been acquired in a hospital setting.

2. Epidemiological information on a single case should be forwarded to ESR's Legionella Reference Laboratory so that it can be disseminated to other health regions of the National Public Health Service and health agencies as required.

3. In the event of an outbreak, the Medical Officer of Health should consider contacting the Legionella Reference Laboratory at ESR immediately for advice.

4. If public messaging is released about an outbreak, it should be clear and easy to understand. It should and be available in different mediums that is tailored to Māori and other priority populations, and that is accessible to our disabled populations. Localised, community-specific messaging led by Māori for Māori may be appropriate to make information engaging, and culturally appropriate.

11.4 Case management

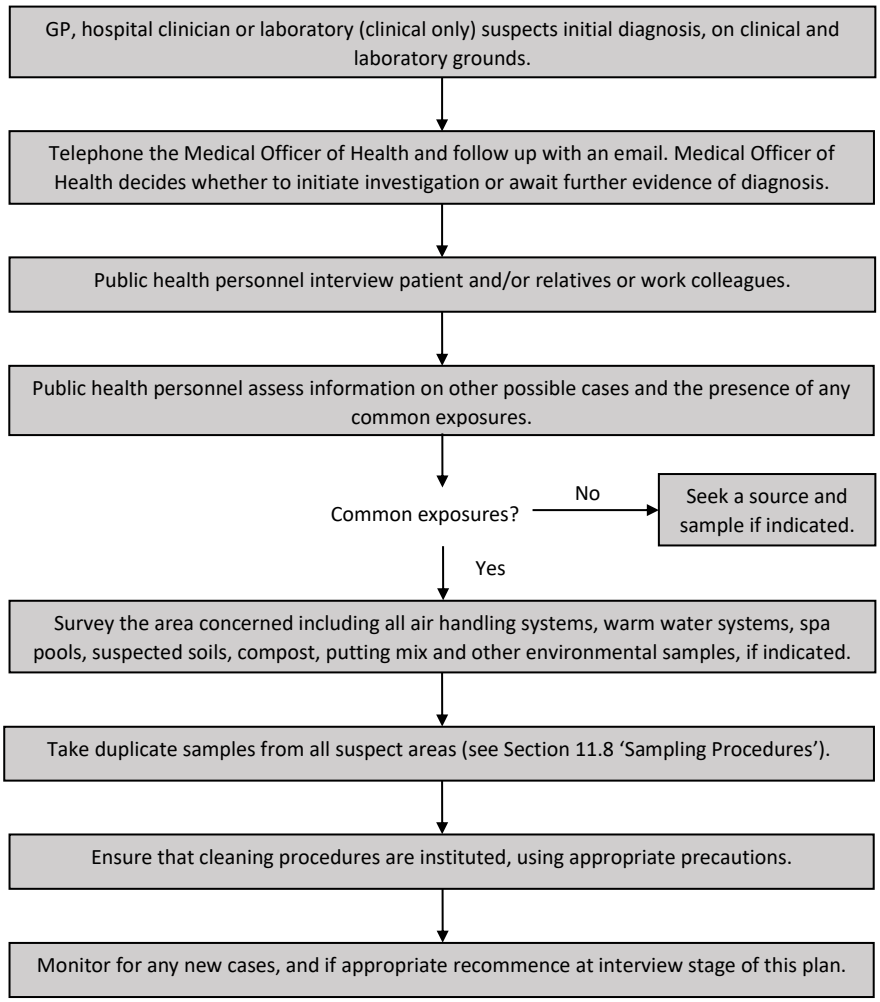
Isolation is not necessary. Erythromycin has been the drug of choice; however, macrolide and fluoroquinolone antibiotics are the most potent agents and have become the first choice for the treatment of *Legionella* infections. The new macrolide antibiotics, such as clarithromycin and azithromycin, show more effective in-vitro activity and better intracellular and tissue penetration than erythromycin, as do the fluoroquinolones. Ciprofloxacin is a fluoroquinolone available in New Zealand and is known to be effective in treating legionellosis.

If a common environmental source has been implicated, additional cases should be sought (eg, households, businesses).

11.5 Recognition and control of outbreaks

A summary of the public health investigation process for *Legionella* is shown in Figure 15.

Figure 15: Public health action plan to investigate one or more cases of legionellosis



Investigations of single case reports are important because they may uncover other cases and may point to common exposures, such as contaminated soil, air, or water in commercial or institutional settings during the incubation period. Such settings include shopping centres, clubs, cinemas, hospitals, hotels and spa pools. If *L. longbeachae* infection is identified, then it is likely to have been caused by close or direct contact with potting mixes or soils (O'Connor et al., 2007).

A single hospital-acquired case should prompt testing of the institution's water system because of the potential risk to immunosuppressed and otherwise susceptible patients.

Suspected occupational sources such as a nursery or commercial composting operation should also be thoroughly investigated.

Other sporadic cases, however, may not warrant extensive investigation because of the frequent difficulty in identifying the specific source and the likelihood of detecting a variety of natural or human-made water distribution systems naturally colonised with other *Legionella* strains. Most such strains are rarely pathogenic and do not warrant interventions that are expensive, time consuming and have little impact on the risk of further cases.

For cases of *L. longbeachae*, the investigation should focus on gardening activities and the use of commercial potting mixes, or any activity where there may have been exposure to aerosolised soil or organic dust (eg, excavation and landfill operators). When two cases are not linked by a common exposure (which is very unusual), the investigation does not need to proceed further.

When common exposures can be identified for two or more cases, health protection officers should ideally conduct environmental investigations face-to-face based on the exposure histories obtained. A survey should be undertaken of all air handling systems, warm water systems and spa pools in the area where patients' exposure may have occurred.

Ideally duplicate samples should be taken from all suspected sites, including aquatic (natural or human-made settings) and organic/soil environments. For cases of *L. longbeachae,* when exposure to soil or potting mixes has been established, samples of suspected soils should be collected (as described in section 11.8 'Sampling procedures'). If laboratory tests demonstrate *Legionella*, cleaning procedures should be undertaken, using appropriate precautions, upon informing the owners of the implicated facilities.

At all times when an outbreak is suspected, surveillance for past and new cases should be intensified, to establish the extent of the outbreak and determine if there is ongoing community exposure to *Legionella*. Information sources including local laboratories, GPs and hospital clinicians should report presumptive cases immediately. Releases to the

news media may be helpful in increasing community awareness in the search for additional cases.

11.6 Organising an outbreak investigation

When a potential outbreak has been detected, the Medical Officer of Health must lead the field investigation and should assess whether communications help will be required to handle media queries and report updates. This person would act as a liaison person and spokesperson. Other staff that are likely to be involved include health protection personnel, laboratory personnel, clerical staff, and personnel from ESR, including the Legionella Reference Laboratory.

Outbreak investigations require the coordinated collection of appropriate environmental samples for identifying the source. The following equipment has been found to be of value in conducting outbreak investigations:

- a supply of sterile 1L water sampling bottles
- calibrated thermometers
- personal protective equipment in accordance with Appendix A of AS/NZS 3666.2, namely a minimum of a N95 face respirator, ordinary work clothing
- torches
- kits for measuring pH, chlorine and bromine.

11.7 Choosing the sampling site

Sampling sites should be chosen to be representative of all the identified risk areas where *Legionellae* can reside and grow. Individual samples should be collected from each of these sites. The approach taken for choosing sample sites is generally dependent on the nature of the site. For large sites this may necessitate taking multiple samples. To begin with, survey the site to establish all systems using water or compost, with careful consideration of the following:

- areas which contain water at temperatures likely to support the growth of *Legionella*
- cross-contamination between ‘dead’ (still or stagnant) and ‘live’ (flowing) water
- locations where water aerosols can be created and released into the atmosphere
- sites where organic matter is being composted that may release dust.

All water storage tanks, hot water cylinders, decorative fountains, spa baths, spa pools, thermal pools, misting machines, water spraying devices, water blasters, cooling towers, humidifiers, and any reticulated water system with either re-circulating water or water reservoirs where water can reach temperatures greater than 20°C but less than 60°C, must be considered potential sources for the growth of *Legionella* bacteria.

All the systems or items listed above must be seriously considered for taking environmental samples for *Legionella* bacteria culture when investigating suspected and confirmed cases of legionellosis.

Reticulated water systems may become contaminated with *Legionella* from the deposition of wind-blown dirt into an exposed reservoir. Contamination of reticulated water systems can occur during construction activity or alterations to a building and where earthworks are carried out. Another common source of *Legionella* contamination of reticulated water systems is through soil contamination during plumbing work. When investigating sources of exposure for legionellosis cases, determine if there has been recent plumbing work at the implicated building or construction work at or near the site.

Another major recognised source of *Legionella* infection is compost and material containing compost, such as potting mixes, seed-raising mixes and garden mulches, such as bark mulch. Use of these products in the 10-day incubation period before the onset of symptoms implicates them as a possible infection source.

If the sampling sites include marae, kohanga, papakāinga, or other culturally significant sites, the process of taking samples from the site should be discussed with mana whenua for that site to confirm if there are any protocols or restrictions that would affect the sampling.

When all risk sites have been identified, the appropriate samples can then be collected.

11.8 Sampling procedures

The laboratory should be contacted for advice prior to taking samples.

Everyone involved in taking samples from suspected equipment or soils during an outbreak should wear correct personal protective equipment in accordance with Appendix A of AS/NZS 3666.2. At a minimum this includes a N95 face mask when there is a risk of exposure to aerosols, along with gloves when there is a risk of exposure to water treatment chemicals used in non-potable water.

Ideally samples of each sample type must be taken during an outbreak of legionellosis (a minimum 1 litre for water samples from raw or potable water sources, or 100 mL water samples from cooling towers and recirculated industrial process waters, or 50 grams for soil or compost samples).

Mixed water and sediment samples can be collected as a single sample from sampling sites where it is not possible to separate these in the field. These should be separated in the laboratory and tested individually. The samples must be shipped immediately to the laboratory in a container at ambient temperature **without ice packs** to minimise temperature fluctuations and exposure to light.

When collecting samples for microbiological examination, scrupulous care is necessary to ensure that samples are representative of the water or soil being examined, and to avoid accidental contamination of water samples during collection. Sampling personnel should be properly trained, as the way in which samples are collected has an important bearing on the results.

If several samples are being collected on the same occasion from the same source, collect the sample for microbiological examination first. This is done to avoid contaminating the sampling point during the collection of the other samples.

Pre-sterilised disposable plastic sample containers to which sodium thiosulphate (which neutralises any active chlorine) has been added should be used if chlorinated water is being sampled. The level of active chlorine residual present at the sampling point, and the water temperature should be measured at the time of sampling.

The sampling bottle should be kept unopened until it is required for filling. During sampling, the stopper or screw cap and neck of the bottle should not be allowed to touch anything which may contaminate the sample. The bottle should be held in one hand at the base while the screw cap is retained in the other hand to ensure the sodium thiosulphate does not fall out. The bottle should be filled, without rinsing, and the screw cap should be replaced immediately.

Changes occur in the bacterial content of water samples during storage. Therefore, it is important that samples be examined as soon as possible after collection. Examination should ideally be started within six hours of collection of the sample, but the interval between collection and the beginning of examination should never exceed 24 hours.

Appendix D has additional information for notification via EpiSurv. Appendices D to H contain some specific instructions for various samples to be collected.

11.8.1 Air conditioning systems (use form in Appendix E)

Cooling towers: Duplicate samples should be taken from the sump water when the water cooling system has been turned off. If this is impractical, sample from the circulating water.

Evaporative coolers: Duplicate samples should be taken from the sump water when the evaporative cooling system has been turned off. If this is impractical, sample from the circulating water.

The “bleed rate” is the rate at which water is drained from the collection reservoir at the base of the cooling tower. The “pump cycle rate” is the rate at which water is pumped from the cooling tower reservoir back to the packing material.

11.8.2 Warm water storage systems (20 - 60°C) (use form in Appendix F)

Duplicate samples should be taken from three sites: One set should be taken from the closest outlet fixture, one set from the furthest outlet fixture, and one set from any storage tanks or vessels. Separate sludge or sediment samples should be collected if present in any storage vessel.

11.8.3 Spa pools (use form in Appendix G)

One set of duplicate samples should be taken from the water in the spa, and one set should be taken from the filter media or backwash water.

11.8.4 Potting mix, compost, and soil conditioners (use form in Appendix H)

Check to see if health warnings are visible and explicit on the bag. Note the make or manufacturer of the material. Check condition of the material. If dry, ensure the sample is collected only from the ‘dampest’ material.

Thoroughly mix the suitable material to ensure a representative sample is obtained. If the material cannot be mixed, then take samples from several different points and combine to obtain a representative sample. The sample container should remain unopened until just prior to sampling. Using sterile sampling equipment, eg, scoop, spoon, etc, transfer approximately 100 grams into a sterile container. A freshly disinfected scoop, etc, must be used for each subsequent sample.

If a sterile scoop is unavailable, an alternative method to obtain a sample is as follows:

- put on fresh latex gloves and wash the outside of the gloves with an alcohol disinfectant
- allow gloves to air-dry to remove excess alcohol then with gloved hands turn a zip-lock plastic bag inside out and place the bag over a gloved hand
- using the gloved hand inside the bag, take a handful of compost material and with the free hand pull the bag over the fist, capturing the material in the bag
- seal the sample bag to prevent the material drying out. Clearly label the sample.

Testing for legionellae in potting mixes, composts, soil conditioners and soils follows methods detailed in AS/NZS 5024 (Int):2005 *Potting mixes, composts and other matrices – Examination for Legionellae*. This withdrawn standard is based on the work on potting mixes and composts by Steele et al., 1990a. The Standard sets out a qualitative test method for testing for *Legionella* spp. in particular *L. longbeachae* in potting mixes, composts and other solid matrices.

11.9 Submitting samples

Samples of water, soil, potting mix or compost should be submitted for examination, after consulting staff at ESR, to:

Street address:
Legionella Reference Laboratory
Environmental Health
Institute of Environmental Science & Research Ltd
Kenepuru Science Centre
34 Kenepuru Drive
Porirua

Postal address:
Legionella Reference Laboratory
Environmental Health
Institute of Environmental Science & Research Ltd
Kenepuru Science Centre
PO Box 50-348
Porirua

Send the completed relevant data sheet (Appendices E–H) with the sample.

The Legionella Reference Laboratory can be contacted via email at:
KSC.Legionella@esr.cri.nz

11.10 Decontamination of implicated sites

Decontamination of implicated sites should occur immediately after completion of environmental sampling. The start of decontamination and cleaning processes should not wait until results are obtained from the sampling as results are frequently unavailable for up to 10 days after sampling at the earliest. Cleaning and disinfection procedures for air conditioning and water systems in buildings are as described in earlier sections of this document.

11.11 Clinical specimens

Clinical specimens are usually tested in hospital laboratories but can also be referred to:

Legionella Reference Laboratory
Environmental Health
Institute of Environmental Science & Research Ltd
Kenepuru Science Centre
34 Kenepuru Drive
Porirua

The Legionella Reference Laboratory (LRL) at ESR undertakes *Legionella* culture, and performs molecular tests including *Legionella* PCR, Sanger sequencing and whole genome sequencing on clinical specimens. Paired serology testing for the presence of *Legionella* antibodies is also undertaken within the LRL.

With each specimen, the sender should complete the ESR standard laboratory request form used by the Legionella Reference Laboratory that is testing the specimen. Seal the specimen in the sealable compartment of a plastic biohazard bag, with the form placed in the side pocket.

The following clinical specimens to be collected by medical staff are appropriate for the laboratory diagnosis of legionellosis.

11.11.1 Specimens for culture, or PCR/NAAT testing

Molecular detection of *Legionella* using PCR or other DNA amplification platforms is currently the method of choice for acute diagnosis. PCR testing is agnostic in the sense that it will amplify the nucleic acid from any *Legionella* strain present in the sample with equal efficacy when using primer and probe sets that target housekeeping or virulence genes present in all legionellae. New Zealand's clinical laboratories testing for *Legionella* use methods targeting either the *mip* gene or the rRNA operon or both.

Assays with specificities that do not include all *Legionella* species will present bias test findings. The collection and processing of appropriate clinical samples from symptomatic patients also influences test findings and lower respiratory tract samples have a greater positive predictive value than those collected from the upper respiratory tract.

Legionella culture testing

Any invasive lower respiratory tract specimen, including:

- bronchoalveolar lavage fluid
- endotracheal aspirates (any bronchial or tracheal aspirate or brushing)
- transtracheal aspirates (TTA)
- expectorated sputum (especially following TTA collection)
- deep throat swab – from trachea. Collect specimen with dry cotton bud swab and place in sealed container with sufficient sputa to prevent drying in transport. Alternatively, add 0.5 to 1.0 mL of sterile and 0.1µm-filtered water to the swab. (Do not add any other solutions, especially saline).

Where appropriate, biopsy and post-mortem specimens (freshly collected) especially in cases of:

- endocarditis with negative blood culture
- gram-negative bacilli infections that cannot be cultured by standard methods.

Notes:

- Avoid collecting lower respiratory tract samples with sodium salt-based buffers as these have been shown to be harmful for *Legionella* culture. Instead, use potassium salt-based buffers.
- Repeat sampling of any respiratory tract samples is useful to increase the chance of recovering *Legionella* since the organism may be initially absent in the sample or may be present, but in very low numbers.
- Ideally, samples should be taken prior to initiation of antibiotic treatment, although samples can still be culture positive after antibiotic treatment has begun.
- Pleural fluids rarely yield positive results. Upper respiratory tract samples rarely yield positive results.

*Legionell*a NAAT/PCR testing

All samples listed for *Legionella* culture are acceptable for *Legionella* PCR.

Note: The positive predictive value of urine, serum or blood specimens for NAAT/PCR testing is low when compared with results using respiratory tract specimens.

11.11.2 Specimens for serological testing

Serologic testing for the diagnostics of legionellosis is a retrospective test and is not of value for acute diagnosis. It is useful as a surveillance tool and in outbreak investigations where the window for the collection of acute phase samples from suspected cases may have passed. Proper collection and testing of specimens from all suspect cases must be undertaken to assess the extent of an outbreak. A total of 0.5–1 mL of each serum is required for this test.

Paired sera only (for retrospective diagnosis)

An acute-phase serum is taken within the first week of onset and stored frozen. A convalescent-phase serum is taken three weeks later with both tested in parallel. A follow-up serum is taken at six weeks if seroconversion has not occurred, or the first test is negative. If subsequent antibody testing is negative, a further sample should be provided at 90 days post-onset, as maximum sensitivity for seroconversion occurs at 90 days for some patients. Paired convalescent-phase sera should be collected at least 14 days apart.

Single serum testing

This is not considered a valid diagnostic test sample unless done as an adjunct test on convalescent serum following up a positive *Legionella* NAAT to determine the serogroup of the causative agent. When diagnostically appropriate, a single acute-phase serum sample should be retained and tested in parallel with the convalescent-phase serum when that is collect.

Appendices

Appendix A: Service log sheet for cooling towers and evaporative condensers

1.	Name of establishment:.....
2.	Address:..... .....
3.	Responsible person:.....
4.	Phone number:.....
5.	Type of unit: ..... Cooling tower c Evaporative condenser c

6.	Location of unit: ....
7.	Make: ..... Model:.....
8.	Capacity: ..... KW
9.	Approximate water capacity:..... litres
10.	Required bleed-off rate: .....litres/second

Date	Water sampled	Chemicals added	Bleed-off rate okay	Unit cleaned	Unit inspected	Unit decontaminated	Name of contractor	Serviced by (signature)	Heterotrophic plate count (HPC)	Remarks
	Yes/No		Yes/No	Yes/No	Yes/No	Yes/No				
	Yes/No		Yes/No	Yes/No	Yes/No	Yes/No				
	Yes/No		Yes/No	Yes/No	Yes/No	Yes/No				
	Yes/No		Yes/No	Yes/No	Yes/No	Yes/No				
	Yes/No		Yes/No	Yes/No	Yes/No	Yes/No				
	Yes/No		Yes/No	Yes/No	Yes/No	Yes/No				
	Yes/No		Yes/No	Yes/No	Yes/No	Yes/No				

Recommended service periods

Item	Period	Item	Period
Dip slide	Weekly	*Legionella* testing	Monthly *or* Six-monthly
HPC plate count	Monthly	Physical inspection	Monthly
Cleaning	Three to six-monthly	Decontamination	When HPC > 100,000 cfu/mL or *Legionella* >1000 cfu/mL

Appendix B: Service log sheet for warm water systems

Name of establishment: ..... Contact:.....

Phone number: .....

Address of establishment:.....

.....

Cylinder location: .....

Storage temperature setting: ..... Number of outlets:.....

Date of service	Heat disinfection at 70°C			Cylinder drained	Remarks	Serviced by
	Cylinder	Piping	Fittings			
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Appendix C(i):
Commissioning log sheet for thermostatic mixing valves

(Use a separate sheet for each valve.)

This work is to be carried out in strict accordance with the valve manufacturer's or supplier's published maintenance/service instructions.

Name of establishment: ..... Contact: .....

Phone number: .....

Address of establishment:.....

.....

Make of valve:..... Model number:.....

Valve location: ..... Room designation:.....

Purchased from: ..... Installation date:.....

Valve installed by:.....

Number of outlets served: Baths (.....) Basins (.....) Showers (.....)

Prescribed temperature range for associated water: ..... to .....°C

Total number of mixing valves at the site:.....

i Installation complies with the manufacturer's published installation instructions: .....
(YES/NO)

ii Installation complies with the current requirements of the local water supply authority:
(YES/NO)

iii Temperature of hot water supply: ..... °C

iv Temperature of cold water supply: ..... °C

v Temperature of warm water delivered at outlet fitting: ..... °C

vi Dynamic pressure of hot water: ..... kPa

vi Dynamic pressure of cold water: ..... kPa

viii Check fail-safe operation: (hot water at least 20°C above warm water)
(PASSED/FAILED)

Commissioned by:.....

Company name: .....

Date: .....

Appendix C(ii):

Routine service log sheet for thermostatic mixing valves

Name of establishment: ..... Contact: .....

Phone number: .....

Address of establishment:.....

.....

Make of valve:..... Model number:.....

Valve location: ..... Room designation:.....

Date of service	Outlet water temperature	Outlets flushed for 15 seconds YES / NO	Shower heads disinfected YES / NO	Remarks	Serviced by
/ /					
/ /					
/ /					
/ /					
/ /					
/ /					
/ /					
/ /					
/ /					
/ /					
/ /					
/ /					
/ /					
/ /					
/ /					
/ /					

Recommended service periods:

Item	*Period*
Outlet water temperature	Fortnightly
Flushing of outlets	Weekly
Disinfect shower heads	Monthly

Appendix C(iii):

Twelve-monthly service log sheet for thermostatic mixing valves

Name of establishment: ..... Contact: .....

Phone number: .....

Address of establishment:.....

.....

Make of valve:..... Model number:.....

Valve location: ..... Room designation:.....

Date of service	Element OK / faulty	O-rings OK / U / S	Strainers OK / dirty	Non-return valves OK / faulty	Fail-safe test OK / faulty	Remarks	Serviced by
/ /							
/ /							
/ /							
/ /							
/ /							
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Note: A new thermostatic element should be fitted at least every three years.

Appendix D: Legionellosis case investigation questionnaire

Part A: Case details

Date of notification: ..... Notified by: .....

EpiSurv case number: ..... Outbreak number: .....

Case Status: Confirmed c Date:.....

Probable c Date:.....

Under investigation c Date:.....

Home phone: ..... Ethnicity:.....

Occupation (including part-time jobs): .....

Workplace/student institution (address and phone number): .....

.....

Period of exposure (usual incubation period is 2–10 days, rarely beyond 14 days)

Onset date: ..... Day of week:.....

Earliest date and day that the Legionellosis could have been contracted (10 days before onset):

Date: ..... Day of week:.....

Latest dates and day (two days prior to onset)

Date: ..... Day of week:.....

Part B Persons with similar symptoms

Does the case know of anyone with similar symptoms: Y/N

If yes

Name	Address and phone number	Relationship to case	Name of GP	Details

Name: ..... Signature: .....

Designation: ..... Date: ..... Time: .....

Part C: Suspected source of exposure

Sections

1. Home environment
2. Gardening and home maintenance activities
3. Workplace/occupation (include study institutions)
4. Commercial premises visited (include hospital visits, car wash facilities, dental surgery visits)
5. Travel including stay away from home using bathroom facilities: motel/hotel/holiday rental (Air BnB)/crib or batch
6. Recreational activities (include use of spa pools, indoor swimming pools, gymnasium showers, hot pools)
7. Environmental scan (description of potential dust and aerosol sources in the immediate surroundings)

Section 1: Home environment

Plumbed water system (tick the boxes that apply)

Water supply to property	Water heating system type	Mixing valve
Source: Town c Rural c Private c Rainwater c Chlorinated? Yes/No Turbidity: ..... pH:	Electric storage c Electric instantaneous c Gas storage c Gas instantaneous c Solar c Low volume POU c Other (specify): ..... Low pressure c Mains pressure c Gravity system with header tank? Yes/No	Tempering device present? Yes/No Tempering water source ....

Number, location, and storage volume (litres) of each hot water heater on the premises:

.....

.....

Frequency of turning off/on water heaters and for how long periods of time: .....

Location/condition of header tank if applicable: .....

Does water in any part of the piped system stand undisturbed/unused for long periods? Yes / No

Number, location, storage volume, and condition of roof-collected tanks, if applicable: ...

.....

.....

Water heater thermostat setting: .....

Is there any filtration or chemical treatment of stored cold water on site? Yes / No

Does the home use grey water recycling? Yes / No

Details of recent plumbing work on section/ building (6 months): .....

Location and storage volume of water heater	Tank volume (litres)	Temperature (°C)		Frequency of use	Frequency of flushing	FAC
		Initial	Final			
Hot water outlet closest to water heater						
Hot water outlet most distal to water heater						
Cold water inlet						

Hot water system header tank						
Small volume point of use water heater						

Water temperature readings and usage:

.....

Record the presence of systems within the residence that can harbour Legionella

Item	Present Yes/No	Comments	Sample number* (if applicable)
Hot water storage tank			
Point of use low volume water heater			
Cold water storage tank			
Drinking water filtration system			
Plumbed ice maker			
Grey water storage tank			
Spa pool			
Swimming pool			
Ornamental water feature			
Humidifier			
Nebuliser/CPAP machine			
Other			

* Use appropriate data sheets and sampling sheets.

Name: ..... Signature: .....

Designation: ..... Date: ..... Time: .....

Section 2: Gardening and home maintenance activities

During the incubation period (2–10 days prior to symptom onset) was the case involved in any of the following activities? Yes / No

Item	Y/N	Details of use or activities (e.g., ventilation, wetting, material splashing on face)	Sample number* (if applicable)
Potting plants			
Compost use			
Garden centre visits			
Landfill visits			
Plant propagation			
Use of or collection of biosolids or manure			
Clearing of gutters or drains			
Water blasting			
General gardening activities (describe)			

* Use appropriate data sheets and sampling sheets.

Name: ..... Signature: .....

Designation: ..... Date: ..... Time: .....

Section 3: Workplace/occupation

Describe workplace activities undertaken by case (also consider other possible sources of exposure while at workplace). Focus on exposure to water that is either recycled, or warm, or aerosolised.

.....

.....

Site visited Yes / No / Not applicable

Item	Exposure Y/N	Comments	Sample number* (if applicable)
Warm water system			
Hot water system			
Air conditioning system			
Water blasting/spraying activity			
Equipment			
Recycled or sprayed water systems			
Humidifier			
Ornamental water features			
Soil/potting mix/compost			
Other			

* Use appropriate data sheets and sampling sheets.

Name: ..... Signature: .....

Designation: ..... Date: ..... Time: .....

Section 4: Commercial/medical premises visited

During the incubation period (2–10 days)
did the case visit any commercial buildings (including hospitals)? Yes / No

Premises visited	Date(s) visited	Time of visit	Length of visit (hours)	Location of premises
Car wash				
Dental facility				
Supermarket				
Hospital				
Premises with cooling tower				

Do any of the above premises have air conditioning or misting systems? Yes / No

If YES provide details

.....

.....

Name: ..... Signature: .....

Designation: ..... Date: ..... Time: .....

Section 5: Travel

During the incubation period (2–10 days) did the case:

Return or arrive from an overseas country? Yes / No

If YES provide details

.....

.....

Travel in any air-conditioned transport, either overseas or within New Zealand? Yes / No

If YES provide details

.....

.....

During the incubation period (2–10 days) did the case stay at any holiday accommodation? Yes / No

Premises visited	Date(s) visited	Time of visit	Length of visit (nights)	Location of premises
Air BnB				
Hotel				
Motel				
Holiday batch or crib				
Campground				
Mobile home with drinking water tank				
Other				

Provide further details

.....

.....

Name: ..... Signature: .....

Designation: ..... Date: ..... Time: .....

Section 6: Recreational activities

List any recreational activities (eg, spa pools) that the case may have undertaken during the incubation period which may be a possible source of exposure to aerosols or dust.

Premises visited	Date(s) visited	Time of visit	Length of visit (hours)	Location of premises
Gymnasium				
Recreational facility				
Spa pool				
Swimming pool				
Geothermal pool				

Section 7: Other

Environmental scan

Describe any potential sources of aerosol or dust in the immediate environment of the case's home and/or workplace if applicable.

.....

.....

Name: ..... Signature: .....

Designation: ..... Date: ..... Time: .....

Part D: Follow-up action

Did the investigation identify any suspected/confirmed sources of infection? Yes / No

If YES provide details

.....

.....

.....

Was sampling undertaken? Yes / No

If YES did sampling confirm or suggest source of infection? Yes / No

Comments:

.....

.....

.....

What action has been taken?

.....

.....

.....

Summary/outcomes:

.....

.....

.....

Investigation completed

Name: ..... Signature: .....

Designation: ..... Date: ..... Time: .....

Appendix E: Wet cooling systems data sheet

Sample number: .....

Cooling system type:..... Cooling tower: 1
Evaporative condenser: 2

Bleed-off rate: ..... litres/hour; Pump cycle rate: .....

Pump cycle rate: ..... litres/hour

Unit condition: ..... Clean: 1, Fair: 2, Dirty: 3

Date last emptied: ..... Date last cleaned .....

Primary Biocide used: ..... (trade name) dosage: ..... /units: (litres or kilograms)

Dose interval: ..... days

Sump water temperature: ..... °C

pH: ..... pH units

Water turbidity:..... Absent: 1, Present: 2, Extensive: 3

Wall slime: ..... Absent: 1, Present: 2, Extensive: 3

Cooling tower fill material: ..... PVC: 1, Polypropylene: 2, Wood: 3

Condition of fill: ..... Damaged: 1, Visible slime: 2, Visible scale: 3

Condition of Drift eliminators: ..... Damaged: 1, Visible slime: 2, Visible scale: 3

Condition of water basin: ..... Water appears cloudy 1, Visible slime: 2, Visible scale: 3; Visible sediment or sludge: 4, Other: 5 (please specify)

Automatic biocide dosing pump fitted? Yes/No If yes, is this operating correctly: Yes/No

Automatic water treatment dosing pump fitted? If yes, is this operating correctly: Yes/No

Other comments: .....

.....

Signature: ..... Date: .....

Appendix F: Warm water systems data sheet

Sample number: ..... Water supply origin? .....

System type: ..... Gas: 1, Electric: 2, Solar: 3
Other: 4.....

Mixing valve present: Yes / No

Tempering device present: Yes / No

Tempering water source? Yes / No

Estimated tank volume:..... litres

Water turbidity:..... Absent: 1, Present: 2,
Extensive: 3, Not tested: 4

Date last chlorinated: .....

Date of other biocide:.....

No biocide used: .....

Water temperature: .... °C thermostat setting

..... °C at outlet sampled

pH: ..... pH units

Other comments: .....

.....

.....

.....

.....

.....

Signature: ..... Date: .....

Appendix G: Spa pool information sheet

Location: .....

Temperature of pool water:..... °C

pH of pool water:..... pH value

Total active chlorine:..... (optimum level 3-5 mg/L)
OR
Total active bromine:..... (optimum level 4-6 mg/L)

What biocide(s) is used? (please list): .....

Frequency of biocide level checking: .....

Filter type: ..... Sand: 1 Cartridge: 2
Other (specify): 3

Is a balance tank fitted? Yes/No

Frequency of changing filter:.....
OR
Frequency of back-washing filter: .....

Frequency of draining spa: ..... weeks

Date spa last cleaned: .....

Date spa last emptied: .....

Who maintains the spa? .....

(surname) (first names)

Other comments: .....

.....

.....

.....

.....

Signature: ..... Date: .....

Appendix H: Compost, Mulch, Potting mix, Soil data sheet

Sampling Location: .....

Sample type: ..... Compost: 1 Garden soil: 2
Mulch 3 Potting mix 4
Other (specify): 5

Date sample collected: .....

Date material purchased: .....

Date first opened (if bagged): .....

Brand (if commercial product): .....

Manufacturer's warning visible: Yes / No
If yes, give details:

Water content of material: Dry / Moist / Wet

Other comments: .....

.....

.....

.....

.....

.....

Signature: ..... Date: .....

Glossary

For the purposes of these guidelines the following definitions apply.

AS/NZS 3666	Australian/New Zealand Standard 3666: *Air-handling and water systems of buildings – Microbial control*. At present there are four parts to this standard: Part 1: Design, installation and commissioning Part 2: Operation and maintenance Part 3: Performance-based maintenance of cooling water systems Part 4: Performance-based maintenance of air-handling systems (ducts and components)
Air break or air gap	An unobstructed vertical gap from the discharge of a fixture and the receptacle that receives it. This distance must be at least 25mm.
Biocide	A physical or chemical agent that kills bacteria and other micro-organisms.
Biofilm	Microbial communities that occur as surface-attached communities, often embedded in a self-produced extracellular matrix composed of polysaccharides.
Clean	Visually free of sludge, sediment, slime, algae, fungi, rust and scale.
Cleaning	Physical and/or chemical removal of scale, corrosion, biofilm, sludge, sediment and extraneous matter.
Cluster	Multiple cases of legionellosis possibly linked in space and time but with no known common source (see Outbreak).
Cold water	< 20°C (*Legionella* does not grow or multiply)
Warm water	20–60°C (*Legionella* can grow and multiply)
Hot water	> 60°C (*Legionella* will not survive).

Colony forming unit (cfu)	A colony arising from a viable unit of one bacterium or more in a clump. For statistical significance, only 90mm-diameter agar plates with 30 to 300 cfu are selected for counting.
Conductivity	The ability of water to conduct electricity. Conductivity measurement is used for estimating the amount of total dissolved solids in water.
Detergent	A cleansing agent capable of penetrating biological films, sludge and sediment, and having the ability to emulsify oil and hold materials in suspension. Water treatment specialists have developed detergent formulations which are capable of thoroughly cleaning components which are difficult to access and inspect, such as cooling tower fill.
Dead-leg	A section of the piped water system that does not permit the circulation of water or is unused causing the water to stagnate.
Dip slide test	A plastic slide coated with sterile culture media which is dipped into the liquid to be tested. The slide is then incubated for microbial growth and the level of contamination estimated against a reference chart. Results are expressed as colony-forming units per millilitre (CFU/mL) of fluid. *Legionella* does not grow on dip slide media.
DPD test kit	A kit for measuring free, combined and total chlorine residuals using the reagent DPD (N,N-diethyl-p-phenylene diamine). Many test kits available from swimming pool suppliers measure only total chlorine, not free chlorine, and consequently should not be used. Free chlorine residuals in excess of 10 mg/L (10 ppm) are capable of bleaching the indicator colour, rendering the test invalid. Samples of water may have to be diluted with distilled water, or other water which does not interfere with the test, to bring the sample within the range of the kit. Allowance must be made for the sample dilution factor when determining the free chlorine residual in the original sample.

Flushometer	A plumbing device that uses pressure from the water system itself, rather than a gravity-powered tank, to force water into the toilet bowl.
Free chlorine measurement	The measurement of hypochlorous acid (an efficient disinfectant) and hypochlorite ion (a poor disinfectant) in water. The ratio of these two materials in water is pH dependent. The pH range specified (7.0 to 7.6) ensures that sufficient hypochlorous acid is present to facilitate effective disinfection.
Immuno-compromised	When the body's immune system is weakened and unable to fully respond to an infection.
Immunosupp-ressed	When the body's immune system is weakened because of medication or other treatment.
Incubation period	The time interval between exposure to an infection source and development of first symptoms of the disease.
Make-up water	Water feed needed to replace that which is lost by evaporation or leakage in a closed-circuit, recycle operation.
mg/L (ppm)	Milligrams per litre (parts per million). For practical purposes mg/L is assumed to be equal to ppm.
NAAT	Nucleic acid amplification test using PCR or other DNA amplification methods.
National Public Health Service	A part of Health NZ, which works alongside communities to deliver national, regional, and local programmes for achieving pae ora (health futures). Key areas of work include environmental health, communicable disease control, tobacco control and health promotion programmes. Staff include public health statutory officers such as medical officers of health and health protection officers that are designated by the Director-General of Health under the Health Act 1956.
NZS 5826	New Zealand Standard 5826: 2010 *Pool water quality.*

Outbreak	Two or more cases of legionellosis linked in time and space with a common source (see Cluster).
pH	A term used to describe the hydrogen ion activity of a water system. A solution of pH 0 to 7 is acidic, pH of 7 is neutral, pH 7 to 14 is alkaline.
Pneumonia	Typical symptoms include cough, chest pain, fever and difficulty breathing. Diagnostic tools include x-rays and examination of the sputum. Treatment depends on the cause of pneumonia; bacterial pneumonia such as legionellosis is treated with antibiotics.
Pulse dosing	The injection of small doses of water treatment chemicals at regular intervals, usually by some form of metering system.
Slug or shock dosing	The injection of a single, high concentration of water treatment chemicals.
Sodium hypochlorite	A chlorine-releasing material used for disinfection. The strength of sodium hypochlorite solution reduces on storage.
Stagnation	Condition where water stops flowing or remains still for long periods of time allowing the build-up of metals and/or micro-organisms.
Strainer	Coarse filter to remove suspended particles from the water to protect downstream equipment, such as control valves, from damage. It is essential that strainers are designed for easy removal and cleaning.
Surfactant	A soluble surface-acting agent that reduces surface tension between particulate matter and water, i.e., a detergent.
Territorial authority	A city or district council named in Part 2 of Schedule 2 of the Local Government Act 2002.

TMV	Thermostatic Mixing Valve: a valve that blends hot water with cold water to ensure constant, safe shower and bath outlet temperatures to prevent scalding
Total dissolved solids	The total weight of dissolved substances in water, including those which are capable of conducting electricity and those which are not.
Turbidity	A cloudy appearance in water that is caused by a suspension of colloidal or particulate matter.
WHO	World Health Organization.

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