Water quality risk assessment of automatic fire sprinkler design HFS102 for Class 1 buildings

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1 Document information

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2 Acronyms, abbreviations and glossary

Abbreviation	Meaning
ABCB	Australian Building Codes Board
ADWG	Australian Drinking Water Guidelines
AFAC	Australasian Fire and Emergency Service Authorities Council
AHPPC	Australian Health Protection Principal Committee
AS/NZS 3500.1	AS/NZS 3500.1. Plumbing and drainage Part 1: Water services.
AS/NZS 4020	AS/NZS 4020:2018. Australian/New Zealand Standard. Testing of products for use in contact with drinking water
BPAA	Backflow Prevention Association of Australia
BETG	Built Environment Technical Group
Dead leg	Plumbing line that feeds a dead end or seldom used fitting
Dropper	Plumbing line feeding the sprinkler – the vertical line of a T-piece
EnHealth	Environmental Health Standing Committee
FPAA	Fire Protection Association Australia
FRNSW	Fire and Rescue NSW
HFSCA	Home Fire Sprinkler Coalition Australia
NCC	National Construction Code
PCC	Plumbing Codes Committee
PFC	Proposal For Change
PTRG	Plumbing Technical Reference Group
QMRA	Quantitative microbial risk assessment
TRA	Toxicological risk assessment
WSAA	Water Services Association of Australia
WSP	Water Safety Plan

3 Executive summary

3.1 Purpose

The purpose of this review was to provide an independent, evidence-based and referenced report that assesses the proposed residential sprinkler design as set out in the Home Fire Sprinkler Coalition Australia's (HFSCA) Technical Specifications "HFS102-2024 Automatic Fire Sprinkler System For Class 1 Homes" (HFS102 hereafter).

The review was undertaken by an independent drinking water quality specialist experienced in assessing risks arising in buildings from plumbing systems with more than one plumbing system (e.g. plumbing for recycled, irrigation, process, flushing, low flow, and dead leg waters).

3.2 Context

HFS102 responds to a call for the installation of more fire sprinklers to prevent deaths, serious injury and property damage arising from fires. The scope covers National Construction Code (NCC) Class 1 buildings (typically standalone residential dwellings).

The proposed change to the NCC will allow fire sprinklers to be connected directly to domestic plumbing lines. This is a change from the current situation in which fire sprinklers must be supplied via their own dedicated fire service line that is in turn connected to the water main via a testable backflow prevention device (BFPD).

Under HFS102 three proposed requirements will minimise risks to water quality:

- Droppers feeding sprinklers must be ≤ 300 mm in length.
- Droppers must be connected to plumbing lines ≥ DN25 in diameter.
- All materials must be "WaterMark" (suitable for contact with drinking water).

3.3 Approach

A risk assessment considered contaminant hazards (e.g. pathogens and toxicants) and hazardous events (e.g. movement of contaminants from droppers into the connected drinking water system plumbing lines) that may be increased due to HFS102. The assessment assessed risks relative to currently accepted plumbing configurations.

3.4 Stakeholders

Parties interested in the findings of this assessment include the HFSCA, Fire Protection Association Australia (FPAA), Fire and Rescue NSW (FRNSW), Australasian Fire and Emergency Service Authorities Council (AFAC), Australian Building Codes Board (ABCB), ABCB's Plumbing Codes Committee (PCC), AFAC Built Environment Technical Group (BETG), Backflow Prevention Association of Australia (BPAA), Water Services Association of Australia (WSAA), Plumbing Technical Reference Group (PTRG), and the Environmental Health Standing Committee (enHealth) of the Australian Health Protection Principal Committee (AHPPC). In addition, water utilities, plumbing regulators and inspectors may have an interest. The assessment was presented with those informed expert parties in mind, not for the general public or laypersons.

3.5 Summary of principal findings

For the convenience of readers, the principal findings arising from the assessment are summarised as follows. Further details discussing these findings are given in the body of the report.

3.5.1 Risks to human health from enteric pathogens

Implementing HFS102 was not considered to present elevated risks from enteric pathogens[1] when compared to existing plumbing standards. Significant risks were not identified due to the proposed HFS102, and risks were not considered to be elevated relative to risks associated with existing plumbing standards. The principal reason for this conclusion was that droppers, low turnover stagnant water lines, and dead legs in general, are not sources of enteric pathogens, which are faecal-oral in their transmission pathways.

3.5.2 Risks to human health from opportunistic pathogens

Implementing HFS102 was considered to present an increased risk from opportunistic pathogens[2] when compared to existing plumbing standards. The risk estimated to be marginally and incrementally elevated relative to existing standards. HFS102 did not present a step change increase in risk since no new broad categories or classes of hazards or risks were introduced. The potentially incremental increase in risk was related to the presence of the droppers feeding the sprinklers. It was noted that whilst not included by design, plumbing lines with little to no turnover are already commonplace in buildings due to seldom used or abandoned taps and fittings. These risks were considered in more depth within the body of this report and are discussed again within this Executive Summary at section 3.6.

3.5.3 Risks to human health from toxicants

HFS102 was considered to present an increased risk from chemical toxicants[3] when compared to existing plumbing standards. The risk was estimated to be incrementally elevated relative to existing standards. HFS102 did not present a step change increase in risk since no new broad categories or classes of hazards or risks were introduced. Any potentially incrementally increased risk was considered to be insignificant on the grounds that to be hazardous to health, chemicals either need to be acutely toxic at levels that can be ingested without being discernible, or need to be consumed over long periods. Reasonably foreseeable scenarios by which chemical toxicants that had built up to hazardous concentrations in droppers would reach potable water fittings would be expected to be rare, sporadic, short-lived and typically self-evident and self-limiting due

[1] In this context, enteric pathogens are microorganisms that cause gastrointestinal illness, such as diarrhoea and vomiting, as a part of their normal life cycle, e.g. *Salmonella* and *Giardia*. Where they become waterborne they are passed due to faecal contamination of water that is then ingested.

[2] In this context, opportunistic pathogens are microorganisms that do not normally cause illness and live naturally in water at low levels but that can cause illness under certain circumstances if they reach high enough levels in stagnant water lacking a disinfectant residual, e.g. *Legionella* and *Naegleria*.

[3] In this context, toxicants are chemical substances that can lead to adverse health consequences upon ingestion, e.g. plumbing materials that rise to elevated concentrations above guideline values.

to the discernibly poor aesthetic quality of stagnant water. Furthermore, HFS102 requires WaterMark-certified drinking water plumbing lines and fittings.

3.5.4 Risks to human perception from poor aesthetic water quality

HFS102 was considered to present an increased risk from poor aesthetic water quality[4] compared to existing plumbing standards. The risk was estimated to be incrementally elevated relative to existing standards. HFS102 did not present a step change increase in risk since no new broad categories or classes of hazards or risks were introduced. Any potentially incrementally increased risk was considered to be insignificant because poor aesthetic water quality arising under rare, sporadic, short-lived scenarios would be likely to be considered acceptable given the overwhelming and self-evident benefits of having a fire sprinkler system where one might otherwise not be. In addition, such events would be readily mitigated by simply flushing the water for a very short period given the limitations placed on the lengths of droppers within HFS102. Furthermore, HFS102 requires WaterMark-certified drinking water plumbing lines and fittings.

3.5.5 Conclusions

HFS102 presents no increase in risk associated with enteric pathogens relative to existing plumbing standards.

HFS102 presents at an incremental but not a step change increase in risks associated with opportunistic pathogens, toxicants and aesthetic water quality relative to existing plumbing standards.

The potentially increased risks associated with toxicants and aesthetic water quality presented by HFS102 are sufficiently low and insignificant that further study and analysis is not warranted and no modification to HFS102 needs to be considered.

The potentially increased risks associated with opportunistic pathogens were considered potentially significant enough to warrant further review of HFS102.

3.6 Further consideration of risks associated with opportunistic pathogens

Droppers increase the propensity for opportunistic pathogens to be present in plumbing systems. The water within droppers can become warm, stagnant, and low in disinfectant residuals. These conditions favour the proliferation of opportunistic pathogens in both the water and biofilms within the droppers. Transfer of those pathogens to the building plumbing lines, and in turn to faucets and showers where exposure to persons may arise, could occur through three principal mechanisms:

- Periodic hydraulic or thermal displacement as water flows past the tee-off.
- Continuous diffusion via Brownian motion.
- Continuous biological movement of motile cells or via invertebrates.

A review of the scientific literature found that most sporadic cases and outbreaks of disease associated with opportunistic pathogens arose from their presence in showerheads, faucets, cooling towers, or spas. Dead legs were not directly causal. However, dead legs were singled out as one of many risk factors. Their presence is

[4] In this context, aesthetic water quality refers to perceptible aspects of water, e.g. colour, odour or taste.

discouraged in plumbing guidelines, and their removal is often required following outbreaks associated with buildings.

The literature review identified that most reports of opportunistic pathogens causing outbreaks or sporadic cases of illness due to plumbing fittings were associated with the hot water services in health and aged care facilities. An explicit statement should be included in HFS102 to firm up that fire services should not be supplied from hot water plumbing lines. There may be some vulnerable persons in some Class 1 buildings, but HFS102 is for Class 1 buildings only, not for Class 3 or 9c buildings (health and residential aged care), which already have a mandatory requirement for AS 2118 sprinklers.

3.7 Conclusions relating to opportunistic pathogens

The principal consideration in agreeing the fine details of HFS102 should be whether the potentially incrementally increased risk associated with opportunistic pathogens relative to existing plumbing standards is acceptable. Whilst other risks are noted, the risks from opportunistic pathogens are the most significant and can be considered to be the limiting factor for decision-makers. If controls within HFS102 are sufficient to adequately mitigate these limiting risks from opportunistic pathogens, then those controls should more than adequately mitigate other risks.

Based on the risk assessment presented here, the controls proposed within HFS102 would reduce the risks posed by opportunistic pathogens arising from the fire sprinkler system droppers to a level that is in addition to, but not a step change higher than, the existing risks posed by other stagnant water lines that are seldom used and hence behave as dead legs within buildings. These existing stagnant water lines are:

- Potentially longer than the 300 mm maximum dropper length in HFS102.
- Not necessarily connected to DN25 diameter plumbing lines to help with dilution.

Therefore, were a building to have plumbing of a nature, and water of a quality and temperature, that it would support hazardous levels of opportunistic pathogens arising, HFS102 would present a risk from fire sprinkler droppers that was in addition to, but in and of itself similar to, or lower than, that posed by other stagnant water lines that are seldom used within the same building.

3.8 Overall conclusions

Implementing HFS102 does not present new classes or categories of risks from enteric pathogens, opportunistic pathogens, toxicants, or aesthetic hazards that are not already present in existing potable plumbing systems. All such plumbing systems have the potential to contain some dead legs with very low or no turnover that can in turn influence the potable water system hydraulic movement, diffusion, or biological mobilisation, either affecting the plumbing fittings that are directly connected, or having more widespread effects via backflow.

Relative to a building with no fire sprinkler system, implementing HFS102 adds the potential for some additional dead legs, and increased stagnation in the plumbing lines (due to DN25 rather than DN20 lines), and warmer water (due to more lines in roof/ceiling spaces than walls or floors), and, hence, an incrementally increased risk from certain hazards. However, HFS102 includes several controls to reduce those risks for the fire sprinkler systems to lower than the levels associated with many other dead legs, namely:

- limiting droppers to maximum 300 mm lineal lengths, with most likely to be a few tens of mm; and
- providing for a dilution factor for material being returned by droppers since the plumbing line feeding the sprinkler lines must be at least DN25.

The presence of such controls means that incremental increases in existing risks from having HFS102 fire sprinkler systems in place is small relative to existing risks presented by existing plumbing dead legs.

In summary, whilst there are risks arising from implementing HFS102, those risks are comparable to accepted risks found in potable plumbing systems, including those with no fire sprinkler systems but having some dead legs. The fire safety risks from having no automatic fire sprinkler systems are well established. Therefore, if HFS102 encourages the uptake of fire sprinkler systems where they might otherwise not be implemented, e.g. where installing conventional separate fire sprinkler systems is considered impractical or cost prohibitive, HFS102, with its controls to protect potable water quality, presents an acceptable, practical solution to increase the uptake of home fire sprinkler systems.

Given that the fire sprinkler system has a self-evident benefit, whereas the other stagnant water lines do not, the proposed HFS102 presents an acceptable practicable solution since it encourages the installation of fire sprinklers where they might otherwise be absent, using a plumbing arrangement that minimises dropper lengths, hence without presenting more than a marginal, incremental increase in existing risks.

3.9 Study limitations

The conclusions are not based on objective evidence from in-building field studies or test rigs, but rather on reasonable inference and professional judgement.

3.10 Recommendations

The recommendations are summarised as follows:

- HFS102 should note that sprinklers must not be fitted to hot water plumbing. This is implied and presumed to be the intent but needs strongly and explicitly emphasising.
- HFS102 should explicitly cite and highlight the existing plumbing requirements to separate cold and hot water plumbing to reduce warming of cold water. This will draw heightened attention to those existing requirements.
- HFS102 should explicitly cite and highlight the existing good practice plumbing recommendations to minimise the formation of stagnant water, including minimising the presence and length of all dead legs in the plumbing system. HFS102 should promote reasonably minimising the length of droppers feeding the sprinklers, not just noting the maximum length of 300 mm.
- HFS102 should explicitly cite and highlight the existing good practice construction code recommendations to insulate roof spaces since these recommendations should help reduce the risk of cold water plumbing in those roof spaces reaching temperatures that promote the proliferation of opportunistic pathogens.

- HFS102 should explicitly cite and highlight that the standard does not apply to Class 3 or 9c buildings (aged and healthcare facilities).
- Benefits from fire sprinklers are self-evident. To help weigh the benefits of reduced fires against the risks of increased opportunistic pathogens, applied empirical research is recommended. This should obtain objective empirical evidence of the effects of the HFS102 plumbing configuration on the proliferation of opportunistic pathogens in constructed, occupied, 'real world' buildings, compared to those with current plumbing arrangements lacking such sprinklers. Note that due to the slow rate of growth of opportunistic pathogens, and the many variables to be considered, such research would take many years to complete, and would need to be undertaken in multiple settings. Therefore, such research should not delay finalisation and implementation of a final version of HFS102, but rather be undertaken to provide evidence to either validate it, or guide its future modification.

4 Introduction

4.1 Purpose

The purpose of this review was to provide an independent, evidence-based and referenced report that assesses the proposed new residential sprinkler design as set out in the HFS102 (draft at the time of writing). The review was undertaken by an independent drinking water quality specialist experienced in assessing risks arising in buildings from plumbing systems with more than one plumbing system (e.g. plumbing for recycled, irrigation, process, flushing and dead leg waters).

4.2 Context

HFS102 was a draft at the time of writing with the most recent draft, as seen when completing this review, updated and dated to 2024. HFS102 was developed for HFSCA to mandate sprinklers in Class 1 buildings. The proposed change will provide for fire sprinklers for such buildings to be directly connected to the domestic water supply plumbing rather than being fed by a separate firefighting plumbing system. The sprinklers will be fed from plumbing supply lines that feed other parts of the property.

4.3 Scope

The document reports on health and aesthetic risks to persons residing in buildings that have fire suppression systems meeting HFS102 as proposed.

4.4 Approach

The physical system under consideration was first described in summary form based on what is documented in HFS102. Risks were then assessed for that system. The risk assessment focused on what is different about a plumbing system in a building that meets HFS102 distinct from other more conventional plumbing systems. Risks inherent in the existing, more conventional systems are not assessed in this document since they are considered to be existing, accepted risks. However, direct comparisons are made between risks associated with HFS102 and those existing within buildings that meet existing plumbing standards or are known to typically exist within current buildings. This comparison with existing systems is important as it provides a basis for defining a level of acceptable, or at least currently accepted, risk.

5 System description

5.1 Overview of proposed plumbing system

The proposed plumbing system considered in this risk assessment is described in detail in HFS102. A summary is illustrated in three forms in this document: a schematic plumbing diagram (Figure 5-1 for inline and Figure 5-2 for looped configurations); photographs (Figure 5-3 for close up, and Figure 5-4 for illustration of installation); and a process flow diagram (Figure 5-5). The diagrams and photographs are illustrative, with actual configurations being specific to each installation. The purpose of the diagrams and photographs is to conceptually illustrate the principal water flows and process steps.

5.2 Departure from conventional plumbing systems

The plumbing system is conceptually consistent with conventional Class 1 building drinking water supply plumbing. The three departures are:

- short dropper plumbing lines are permitted of up to 300 mm in length to feed each of the wet sprinklers, (albeit most are anticipated to be much shorter);
- the plumbing feeding the property will be ≥ DN25 (vs. DN20 as convention); and
- any potentially exposed sprinklers and feed plumbing materials must be metallic.

5.3 Comparison with conventional plumbing systems

Compared with current plumbing and construction codes and standards, HFS102 will:

- No new hazardous materials will be introduced. The materials constituting the dropper plumbing lines and sprinklers must be compliant with the potable water plumbing 'WaterMark' standards (AS/NZS 3500.1).
- A new hazardous event scenario will be intentionally introduced to the plumbing system due to the intentional introduction of droppers of up to 300 mm in length. These may permit concentrations of chemical, physical and microbial hazards to rise within plumbing lines and sprinklers to levels above those in water that receives turnover. These hazards may move from the dropper back into the conventional drinking water plumbing line via three main mechanisms, being, (in author-estimated order of probable significance, from high to low), as follows:
    - Periodic hydraulic or thermal displacement as water flows past the tee-off.
    - Passive continuous diffusion via Brownian motion.
    - Continuous active biological movement of motile cells or via invertebrates.
- Another new hazardous event scenario is reduced turnover in DN25 vs DN20 plumbing, by a factor of approximately 1.6-fold, that may increase stagnation.
- Finally, plumbing lines will be in the roof/ceiling, rather than the wall or floor, which may increase the temperature of water in the plumbing lines.

These 'new' hazardous event scenarios already exist, unintentionally, to varying extents within Class 1 (and other) buildings. For instance, dead legs are not intentionally introduced in conventional plumbing systems, and are actively discouraged in high-risk settings such as healthcare and aged care facilities (enHealth 2015; CDNA 2017). However, many dead legs, or plumbing lines with low, and in some cases no, turnover do exist. These include abandoned capped sections, and lines feeding seldom-used taps and fittings (e.g. spare bathrooms, kitchens, laundries, water features, and garden taps).

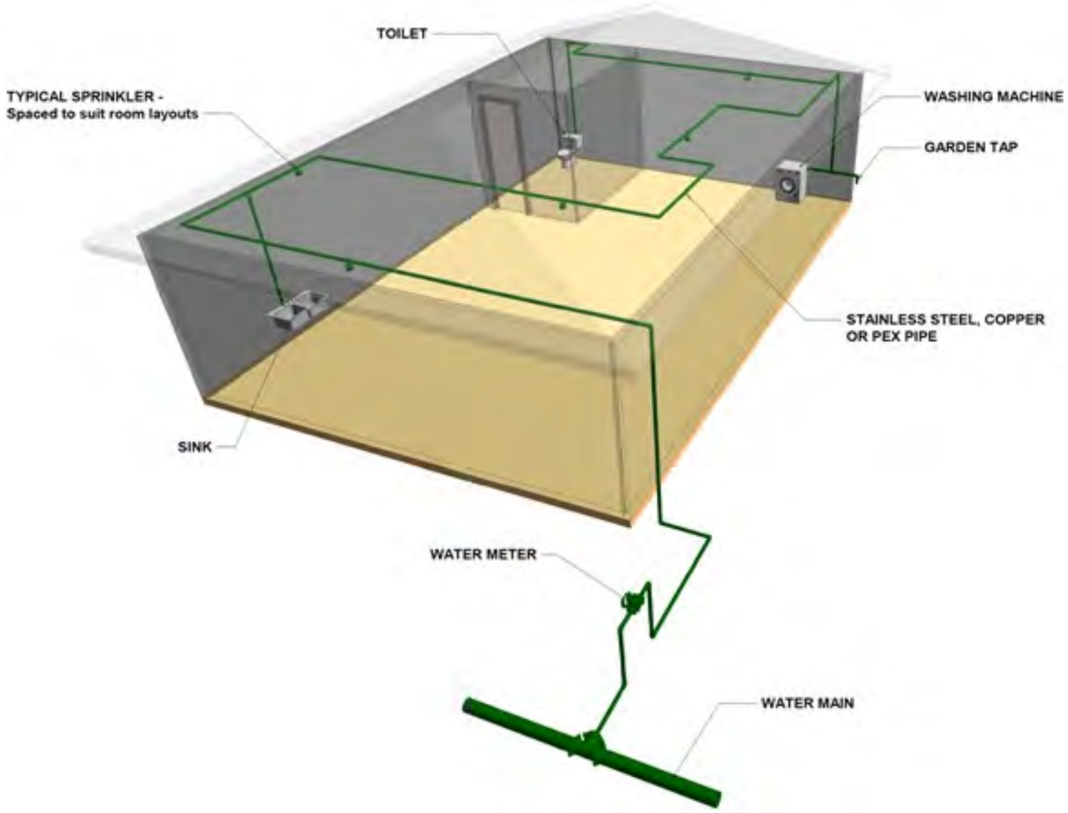

Figure 5-1. Example HFS102 inline pipe configuration (HFSCA, 2024).

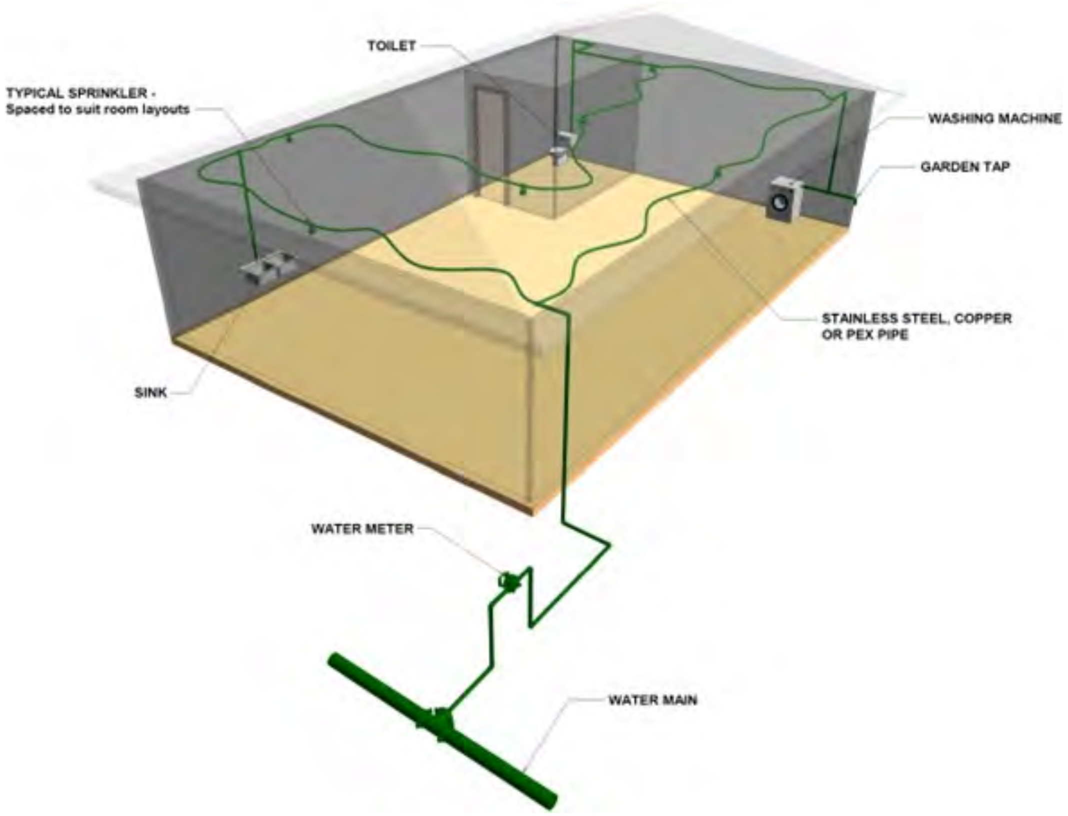

Figure 5-2. Example HFS102 looped pipe configuration (HFSCA, 2024).

Figure 5-3. Fire sprinkler and dropper (image from Shae Mete, 2024).

Figure 5-4. Sprinkler in roof space at rough-in (image from Shae Mete, 2024).

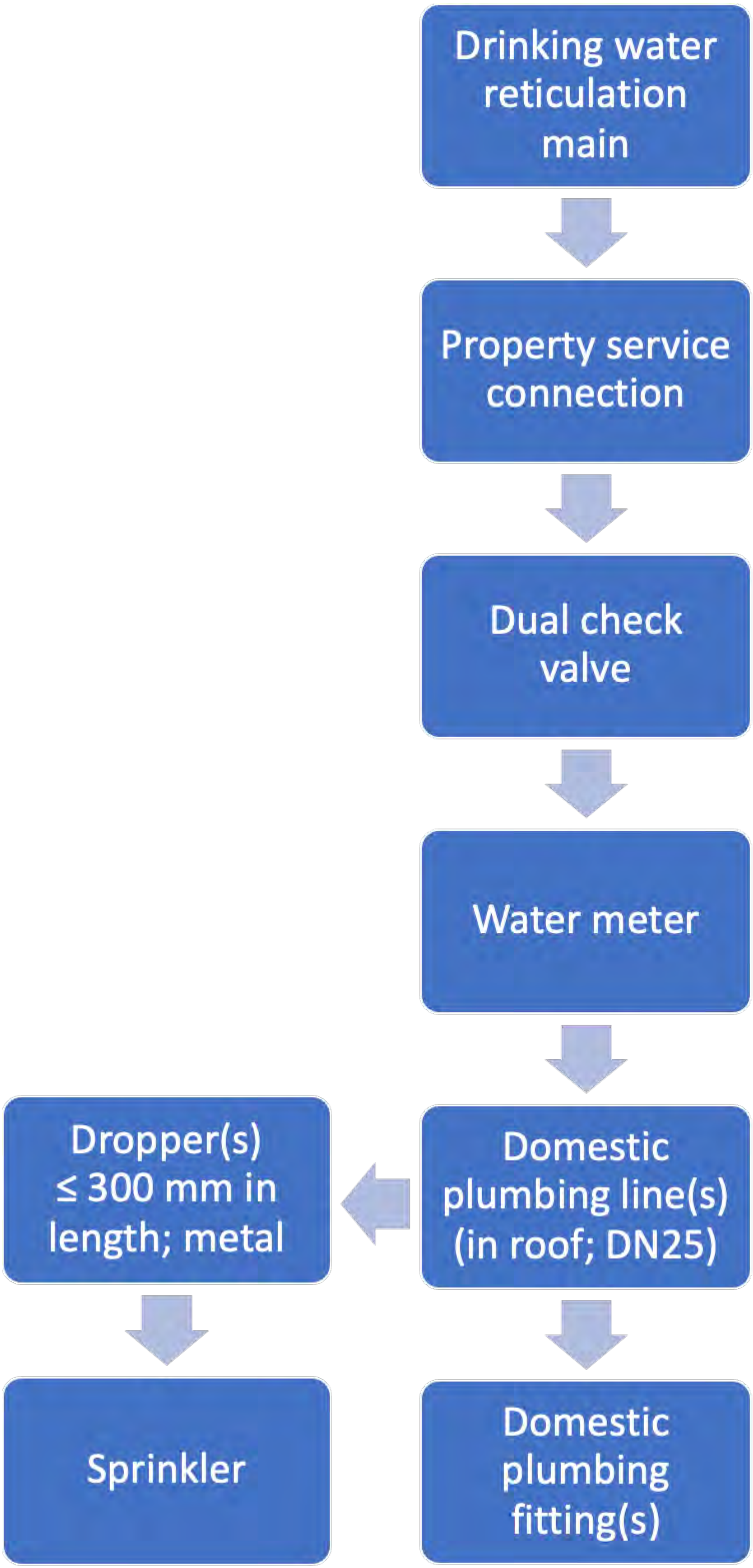

Figure 5-5. Example process flow diagram for the HFS102 system.

6 Risk assessment

6.1 Risk identification

Potential risks that have been identified are described and summarised in Table 4, appended to this report. The assessment can be modified in response to feedback and includes some qualitative risk assessment rankings that are based on professional judgement.

6.2 Risk assessment methodology

For the purposes of presentation, the risk assessment grouped and ordered risks according to process steps identified within the process flow diagram (Figure 5-1). Risks were assessed for the dead leg process step that differs from conventional plumbing.

The risk assessment focused on what was different about HFS102 as distinct from other more conventional plumbing systems. Risks inherent in the existing, more conventional plumbing systems are not assessed in this document since they are existing, accepted risks.

Using the Australian Drinking Water Guidelines (ADWG) approach, for each risk, potential contaminants ('hazards') that might be hazardous to human health or aesthetic water quality, and events by which the contaminants could be introduced and/or exacerbated ('hazardous events'), were noted. Risks were rated as if there were no specific controls given in HFS102 (as 'maximum' risks) and then again with consideration being given to the specific controls given in HFS102 (as 'residual' risks).

6.3 Risk rating criteria

Risks were rated using the ADWG example risk rating criteria, (which is broadly consistent with the approach to risk assessment set out in *AS/NZS ISO 31000:2018 Risk Management – Principles and Guidelines*).

For convenience, the ADWG risk rating criteria are reproduced here in Table 1 (likelihood), Table 2 (consequence), and Table 3 (overall rating).

In addition, a record was retained of the basis of the risk rating and a comment was made on the uncertainty, or level of confidence, in that rating. The rated risks are summarised in Table 4, appended to this report.

6.4 Results of the risk assessment

The results of the risk assessment are given in an attached summary table (Table 4) with the original file being retained as an Excel workbook for ease of future updating.

Table 1. Risk likelihood rating criteria (image extracted from the ADWG, 2011).

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

Table 2. Risk consequence rating criteria (image extracted from the ADWG, 2011).

Level	Descriptor	Example description
1	Insignificant	Insignificant impact, little disruption to normal operation, low increase in normal operation costs
2	Minor	Minor impact for small population, some manageable operation disruption, some increase in operating costs
3	Moderate	Minor impact for large population, significant modification to normal operation but manageable, operation costs increased, increased monitoring
4	Major	Major impact for small population, systems significantly compromised and abnormal operation if at all, high level of monitoring required
5	Catastrophic	Major impact for large population, complete failure of systems

Table 3. Risk rating criteria (image extracted from the ADWG, 2011).

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

6.5 Summary of risk assessment findings

6.5.1 Identified risk pathways

Several risk factors were identified that made a building plumbed in accordance with HFS102 somewhat different to one that was plumbed more conventionally. Water supply distribution and plumbing systems are increasingly being identified as locations in which water supply contamination arises, which can in turn result in waterborne disease outbreaks (Craun and Calderon, 2001). Based on these historical reviews of waterborne disease outbreaks, the major credible and established risk pathways of relevance to HFS102 include the following:

- Physical mass movement of water due to water hammer, pressure transients, changes of pressure, (including loss of pressure), turbulence from passing flows, and thermal density effects. Turbulence associated with water flowing past the tee-off to the dropper will cause mixing and draw some water from the dropper into the connected plumbing line. Warmer, stagnant water in a dropper to a sprinkler will move due to its lower density and greater buoyancy, and be displaced by the cooler water flowing in an above plumbing line.
- Passive diffusion of pathogens can occur via Brownian motion.
- Active migration of motile pathogens (such as bacteria and amoebae) can occur directly, and pathogens can be mechanically carried via other motile microorganisms or invertebrates within the plumbing system.

These pathways could lead to the transfer of contaminants from droppers back into the immediately connected potable water supply plumbing. From there the contaminants could be transferred both forward into the downstream plumbing fittings, and potentially via backflow into the drinking water main to other properties.

In all cases there would need to be an exposure pathway for adverse consequences to arise. In relation to failure modes involving the transfer of contaminants into potable water, exposure pathways could include aerosol inhalation, ingestion, and contact with ears, skin, nose or eyes.

6.5.2 Specific controls of significance

Several specific controls given in section 3.1 of HFS102 were of significance in that they significantly reduced maximum risks and thereby reduced the rating given to the residual risks. These significant controls included the following:

- "Dead legs longer than 300 mm are not permitted"
    - This control significantly limits both the potential surface area and volume that could give rise to risks associated with corrosion products and biofilm formation and to stagnant water and leaching within those droppers.
- "All pipe, fitting and sprinkler heads shall be WaterMark approved"
    - This control significantly limits the potential hazardous substances that could leach into the water in the dropper, or the extent of microbial growth that could be supported on the surfaces. No new hazardous materials are introduced that are not already present in plumbing systems.
- "Diameter of all sprinkler supply pipework must be a minimum DN25, excluding the 300 mm dropper"
    - This control helps ensures dilution of any material introduced from the dropper since DN25 is likely to be ≥ the diameter of the dropper.

6.5.3 Summary of risks relating to enteric pathogens

Enteric (gastrointestinal) pathogens are microorganisms that infect the gastrointestinal tract and that can be transmitted by potable water include bacteria (e.g. *Salmonella* spp. and *Campylobacter* spp.), parasites (e.g. *Cryptosporidium* spp.) and viruses (e.g. norovirus) (ADWG). They typically cause diarrhoea and vomiting and can cause more complex symptoms, and sometimes death. In general, in relation to waterborne disease, enteric pathogens are the most hazardous contaminant that over the long term has historically caused the most harm to health from contaminated drinking water. The primary purpose of providing safe water is to prevent transmission of enteric pathogens. Therefore, risks associated with enteric pathogens were considered first.

Enteric pathogens are typically only present in water if that water has become contaminated with faecal matter or putrescing food waste. They are no more likely to be present in dropper fire sprinkler lines than in any other plumbing since they do not typically persist or grow in potable water, but rather they gradually die off over time.

It was concluded that enteric pathogens are primarily derived from fresh faecal matter and are not specifically of concern in droppers or pipework. The relatively low nutrients found in potable water do not typically support the proliferation of enteric pathogens even in the absence of a disinfectant residual, e.g. in droppers.

Significant concentrations of enteric pathogens capable of resulting in significant consequences are not posed by HFS102, even without any dedicated controls, resulting in both a low maximum and residual risk. Therefore, risks posed by enteric pathogens were not considered further.

6.5.4 Summary of risks relating to opportunistic pathogens

6.5.4.1 Overview

Opportunistic pathogens are microorganisms that are naturally present in water and that aren't ordinarily, (as part of their ordinary ecological niche or lifecycle), pathogenic to humans. However, these microorganisms can potentially cause infections in humans 'opportunistically' if the opportunity to infect a person arises. Potable water can provide a means to transmit such pathogens if exposure pathways arise (Bentham *et al.*, 2007). Infections can occur via skin contact, eyes, ingestion, inhalation and nasal contact. In recent years opportunistic pathogens have risen to prominence as the most common causes of outbreaks associated with exposure to water in the United States (US) (Kunz *et al.*, 2024).

6.5.4.2 Risk factors

The higher the concentration of such microorganisms in water, the higher the risk. The relevance to HFS102 is that such opportunistic pathogens can proliferate to levels of concern in stagnant water. The risks rise where the pathogens can form as part of biofilms (e.g. on pipe surfaces), in water lacking a disinfectant residual (e.g. in dead legs where water is not turned over to bring in fresh, effective disinfectant), and in warm water (e.g. in the 20 to 50˚C temperature range, and particularly in water that is continually above 25˚C, or seasonally above 30˚C for months at a time, including in warmed roof spaces).

Of most significance within the Australian context this group of microorganisms includes bacteria, such as *Legionella* spp. (that infects the respiratory system) and amoebae, such as *Naegleria* spp. (that infects the brain via the nose) and *Acanthamoeba* spp. (that infects the eyes).

Without adding any special controls, adding wet sprinkler systems to the potable building plumbing network would present a risk of opportunistic pathogens hydraulically moving, diffusing, or migrating, into the potable plumbing system. Connecting dropper sprinkler supply lines provides the potential for proliferation of opportunistic pathogens to high levels within those dead legs, due to lack of penetration of disinfectant residuals, reduced dilution from water turnover, and warming in roof spaces, resulting in a potentially very high risk if uncontrolled.

To respond to that risk, two controls were noted in HFS102 that reduced the risk relative to what it would have been with no such controls. These controls are summarised in section 6.5.1, above. Briefly, the proposed controls mean that the length of dropper pipework is minimised, and there would be dilution of any water or pathogens passing from the dropper pipework into the potable plumbing system.

The proposed controls will reduce, but not eliminate, the risk of opportunistic pathogens hydraulically flowing, diffusing or migrating back into the potable plumbing system and in turn exposing persons to those pathogens via inhalation, ear, skin or eye contact.

It should be noted that the risk of opportunistic pathogens being present at concentrations of concern is heavily temperature-dependent, and that risks to health are related to the age of exposed persons. With increased global average temperatures, and increased life expectancy and hence more aged persons, the risks posed by opportunistic pathogens is increasing globally. Much of Australia is in climatic zones where water temperatures routinely reside above the 25˚C range at which opportunistic pathogen growth is most problematic. For instance, ambient water temperatures can routinely exceed 30˚C in much of northern Australia and indoor shade air temperatures, in the absence of air conditioning, can often range between the mid-twenties to high thirties of degrees Celsius throughout much of the year. The implications are that all plumbing in Australia can be, and will increasingly be, in the temperature range that will support the growth of opportunistic pathogens to levels of concern in the absence of disinfectant residuals, e.g. in droppers. The scale of buildings that are intended to house the fire sprinkler systems described in HFS102 are likely to be small, isolated dwellings, that may lack insulation or that might not make use of cooling systems.

Whilst the use of DN25 plumbing lines connecting to the ≤ 300 mm long plumbing lines will provide for dilution, at the same time, it may reduce plumbing system turnover. The DN25 is wider than the conventional DN20 plumbing which will lead to an approximately 1.6-fold increase in volume, and hence to a small increase in stagnation.

At present plumbing lines can be fed through the floor, wall, and roof/ceiling. To support sprinklers the proposed plumbing lines feeding the sprinklers will feed via the roof/ceiling, which may increase the temperature of water in those lines relative to walls and floor spaces.

6.5.4.3 Epidemiological evidence

The incidence of opportunistic pathogen infections attributed to drinking water supplies and plumbing systems, (as distinct from established high risk sources, such as cooling towers), has been increasing in recent decades. Some of the best evidence of this comes from the US Centres for Disease Control (CDC) who undertake systematic long-term reporting on waterborne disease. No equivalent reporting is available for Australia, which is why US data is presented in this report.

Trends show opportunistic pathogens overtaking other agents as the major cause of waterborne disease outbreaks associated with drinking water in the US (Figure 6-1 and Figure 6-2).

The most recent US review by Kunz *et al*., (2024), covering the 2015-2020 period, reported a total of 214 outbreaks of which the majority (87%) were associated with opportunistic pathogens, which were associated with the majority (98%) of hospitalisations, and 88 reported deaths (primarily (98%) due to *Legionella*).

The majority (53%) of these outbreaks arose in healthcare facilities, which was the setting for 66% of hospitalisations and 87% of deaths. Tourist accommodation was implicated in 16% of outbreaks, causing 11% of cases, 15% of hospitalisations, and 3% of deaths. Only 3% of outbreaks arose in private residences resulting in 0.3% of cases, 0.7% of hospitalisations, and no deaths. It is noted that HFS102 is not intended for health and aged care facilities since they are not Class 1 buildings.

These opportunistic pathogen outbreaks were most commonly (73%) associated with plumbing at the premise or point of use, such as from showers and devices such as humidifiers. The principal 'contributing factors' listed included warmer water temperatures, low disinfectant residuals, and aging plumbing components. Dead-end water lines or dead legs were identified as a possible 'contributing factor' in 2% of those outbreaks.

6.5.4.4 Dead legs and opportunistic pathogens

Dead legs are routinely identified as a risk factor for opportunistic pathogens in guideline documents, and their minimisation is encouraged. In addition to general statements on minimising dead legs given in the international, national and state/territory guidelines on *Legionella* control in plumbing systems, several refereed journal articles reported on a suspected role for dead legs in *Legionella* or outbreaks. For instance:

- Hart and Makin (1991) reported that dead legs in hot water systems were thought to be a risk factor for *Legionella* in hospitals. Dead legs noted included a range of possible plumbing lines, (including but not limited to those feeding fire sprinkler systems). As part of a broad set of actions to minimise risks from opportunistic pathogens, the authors recommended removing dead legs, along with managing water temperatures, disinfectant residuals, and flushing to prevent stagnation.
- Patterson *et al.,* (1994) reported that dead legs (spurs) on a cold water system feeding fire hydrants were thought to be a contributory factor associated a fatal hospital acquired Legionnaires' disease outbreak in Scotland. The site had 14 such spurs feeding fire hydrants, each of approximately 15 m in length, teeing off from the DN75 cold water plumbing line. A test rig was set up as part of the investigation that demonstrated, (using a fluorescein tracer and thermocouples), that water from a 2.5 m long DN 78 spur pipe was readily exchanged with water in the circulating ring main due to temperature differences between the two. The removal of such dead legs was recommended for hospitals.
- Rampling *et al*., (1997) reported that a dead end hot water pipe of 8.5 m in length feeding a hot water tap resulted in Legionnaire's disease. The *Legionella* present in both the patient and tap were indistinguishable based on genetic analysis. The dead end water line received very limited turnover.
- Stypułkowska-Misiurewicz *et al*., (2007) reported on the removal of dead legs (along with replacement of old hot water reservoirs with new ones, and three rounds of cleaning and disinfection of the hot water system), as part of efforts to reduce *Legionella* to below detectable levels following a hospital acquired Legionnaires' disease outbreak from a hot water system in Poland.
- Tercělj-Zorman *et al*., (2010) and Trop Skaza *et al*., (2010) reported that a dead leg (blind end) on a hot water system feeding two tap faucets was strongly associated with a hospital acquired Legionnaires' disease outbreak in Slovenia. Whilst this outbreak occurred in a hospital, some of the patients were not immunocompromised or vulnerable.
- Whiley *et al*., (2014) reported that dead end pipes in the drinking water reticulation system harboured elevated concentrations of *Legionella* and other opportunistic pathogens once the disinfection residual was lost. Plumbing systems in buildings were not tested. The authors recommended promoting water turnover and disinfectant residual maintenance.

It is noteworthy that most of the outbreaks occurred when there were dead legs on hot water systems. Under HFS102 droppers to sprinklers would presumably only be placed on cold water systems. This requirement could be explicitly and strongly documented in HFS102. The only report of an outbreak related to dead legs on a cold water system was from a hospital with multiple (14) fire hydrant feed dead legs of great length (≈15 m) and wide diameter (DN75).

Review of the discussions of outbreaks leads to the inference that the concern for HFS102 would be less about persons being directly exposed to pathogens moving from the short (≤ 300 mm) narrow diameter (≤ DN25) droppers that feed the sprinklers and back into the drinking water plumbing directly causing harm. The concern from droppers in the context of HFS102 arises primarily from their role as a potential harbourage of pathogens, shielded from disinfectant residuals, that may be seeded on an ongoing basis into the drinking water supply plumbing. From there the pathogens could either cause isolated sporadic cases of illness, or of more concern, proliferate in the drinking water plumbing systems, showerheads and faucets, during periods of low disinfectant residual and warm temperature, resulting in outbreaks. Importantly, dead legs are not the only risk factor. For plumbing contexts amenable to *Legionella* proliferation, the absence of dead legs feeding sprinklers won't be sufficient to adequately control risk. For instance:

- Makin and Hart (1990) reported that converting dead end feeds supplying showerheads (not dead legs feeding unused pipes) reduced the *Legionella* concentration in those feeds to the showerheads, but did not reduce the concentration of *Legionella* in the showerheads themselves since those showerheads remained stagnant between uses. Flushing of the showerheads themselves was required to control *Legionella* proliferation in those fittings. Makin and Hart (1991) reported similar results evaluating the effect of maintaining circulating hot water above 50˚C, noting that dead end feeds to showerheads were often stagnant and below 50˚C.
- Farhat *et al*., (2009) reported experimental evidence of recolonisation resulting in elevated concentrations of *Legionella* in dead legs after thermal treatment of a plumbing test rig. However, recolonisation was also thought to have occurred from the *Legionella* naturally present in the mains water supply, along with *Legionella* thought to have persisted in biofilms after the thermal treatment – i.e. the dead legs were just one of the sources of recolonisation.

In addition, there is evidence that stagnant water can be lower in the nutrients and oxygen required to promote the growth of opportunistic pathogens. For instance:

- Liu *et al*., (2006) found that under stagnant conditions, *Legionella* grew slower than under conditions associated with either flowing or turbulent water. This was attributed to reduced nutrient and oxygen levels under stagnant conditions. The authors went as far as to state in their conclusions "Plumbing modifications to remove areas of stagnation including deadlegs are widely recommended, but these modifications are tedious and expensive to perform. Controlled studies in large buildings are needed to validate this unproved hypothesis."
- Similar findings were observed by Lehtola *et al*., (2006), who found that biofilm formation increased with water flow velocity, coincident with increased nutrient utilisation. This was attributed to the mass transfer of nutrients due to elevated flow rates playing a major role in biofilm growth even in the presence of consistent nutrient concentrations.

These results are consistent with dead legs not being an ideal environment for high level proliferation of *Legionella*. These studies do not detract from their importance as harbourages of pathogens, sheltered from disinfectant residual, that can seed the plumbing system. However, the focus of *Legionella* control is on ensuring a disinfectant residual and water temperatures unfavourable to pathogen growth in the active parts of the potable water supply, and the building plumbing system, including the faucets and showers from which exposure can arise. As such, dead legs are a risk factor, but not the only or principal one.

The studies taken together illustrate that removal of dead legs alone is not sufficient to reduce *Legionella* concentrations below detection or to target levels. Managing temperature and disinfectant residuals, along with turnover of water to dead-end points of exposure (particularly showerheads), is required. Therefore, whilst the presence of dead legs increases the challenges associated with controlling *Legionella*, their removal is not sufficient in and of itself to control *Legionella* in the absence of managing other risk factors (temperatures, disinfectant residuals and stagnation).

In summary, for opportunistic pathogens, the risk assessment rated the residual risk as rare in likelihood but captured the fact that, being fatal, opportunistic pathogens can present major localised consequences. This risk needs careful evaluation as is discussed below (section 7) to decide whether the controls are adequate such that the risk is acceptable.

It is noted that short dead legs are already widespread within existing plumbing systems, and many don't have any length limitation, as proposed with HFS102 (≤ 300 mm). It is probable that, on balance the risk is not significantly higher than the risk associated with conventional plumbing systems. The risk associated with conventional plumbing systems is currently accepted and plumbing systems are not operated as zero risk systems. Nonetheless, given the high 'consequence' rating for this risk, i.e. that opportunistic pathogens can cause death, the risk requires special deliberation in evaluating HFS102. These risks were considered in more depth in section 7.1.3 of this report.

The high disease burdens and risks of severe illness and death due to *Legionella* and similar opportunistic pathogens is borne primarily by the elderly and those with underlying medical conditions. Most outbreaks are associated with cooling towers and warm water systems that generate aerosols, such as spas and showers. Most outbreaks related to drinking water plumbing arise from showerheads and are associated with health and aged care facilities. As good practice, those facilities should have 'Water Safety Plans' (WSPs), 'Risk Management Plans', or similar systems in place, specifically targeted at controlling risks from *Legionella* and similar opportunistic pathogens. However, such facilities are not within the scope of HFS102. The only buildings that are potentially within the scope of HFS102 that may house at risk individuals are sheltered housing properties, or housing for frail persons not yet committed to health and aged care facilities. Such persons are already at risk if there is a lack of systematic management of *Legionella* in those residences. Resolving the risks from vulnerable community members potentially exposed to *Legionella* in showers is a broad task, necessitating involvement of water utilities that supply water with disinfectant residuals, construction code proponents that define how plumbing systems should manage risks to such vulnerable persons, plumbers, and community extension workers providing advice on personal protective actions.

Singling out fire suppression systems for special consideration of their dead legs, and preventing the installation of such systems, in the absence of a broader framework, is unlikely to help significantly mitigate risks to such vulnerable persons. Furthermore, such vulnerable persons are among those most at risk of fire.

In Australia the number of notified cases of legionellosis is approximately 400 per year (CDNA, 2017), with deaths due to *Legionella* being approximately a dozen per year (DHAC, 2016). These cases and deaths are not typically associated with *Legionella* from plumbing in Class 1 buildings, but rather with showers and faucets in health and aged care facilities, as well as from exposure to aerosols from cooling towers and spas lacking adequate disinfection. This compares to an estimated 64 preventable residential fire fatalities in Australia per year, and the associated injuries, losses, damage and economic impacts (as noted in HFS102). The addition of short droppers to plumbing systems to feed sprinklers in Class 1 buildings will marginally increase the risk of legionellosis.

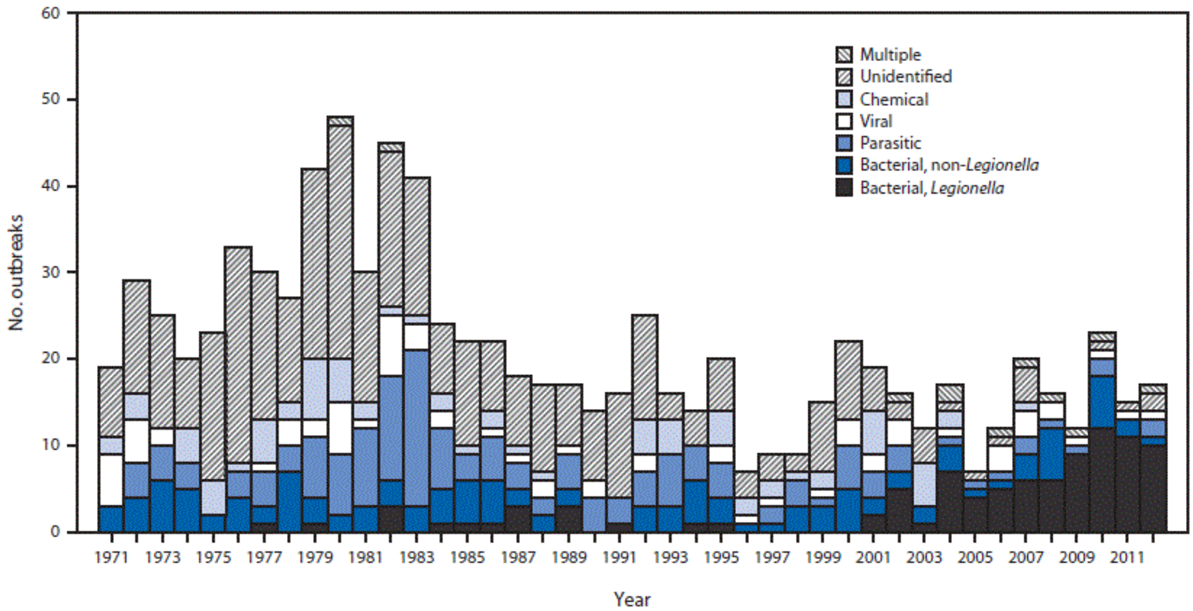

Figure 6-1. Aetiology of 885 drinking water–associated outbreaks, by year — United States, 1971–2012. US Centres for Disease Control (Beer *et al.*, 2015).

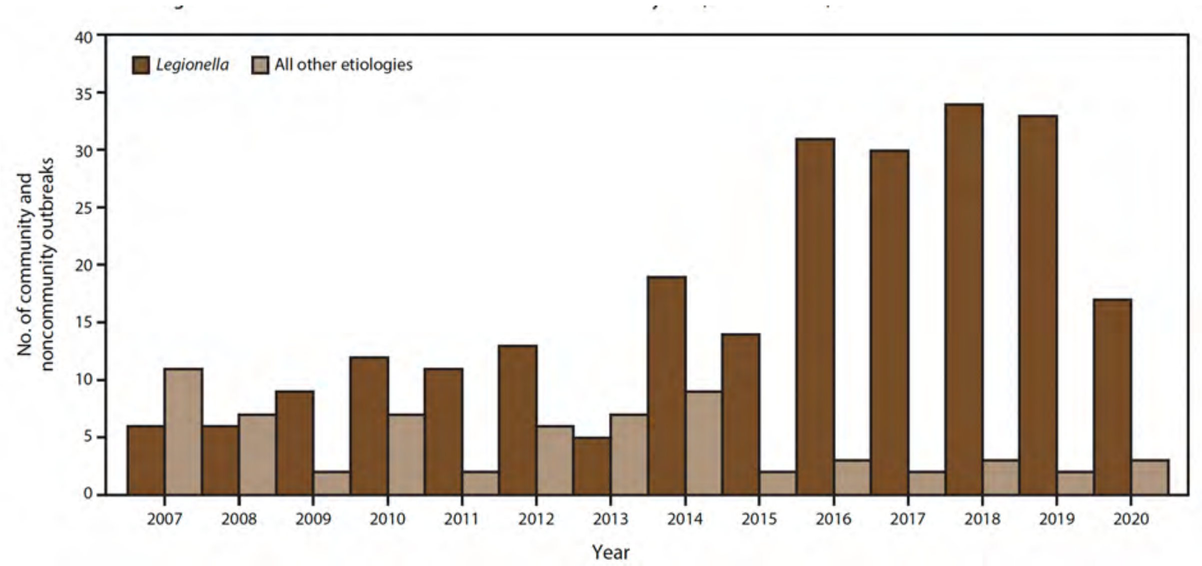

Figure 6-2. Comparison of Legionella with other aetiologies for 306 drinking water–associated outbreaks, by year — United States, 2007–2020. US Centres for Disease Control (Kunz *et al*., 2024).

6.5.5 Summary of risks relating to toxigenic chemicals

Toxigenic chemical hazards can arise from plumbing fittings, (e.g. copper, lead, cadmium, chromium, nickel, antimony, plastics, microplastics, or plasticisers), leached and/or corroded from plumbing dead legs. Over time the concentrations of chemical substances that may leach from pipes, or from corrosion products and then leach into the dead leg water, could readily reach levels that exceed ADWG guideline values. More likely than not one or more chemicals will exceed ADWG guideline values in stagnant water residing in plumbing pipes and fittings even if they comply with the WaterMark certification scheme, which includes compliance with *AS/NZS 4020:2018. Australian/New Zealand Standard. Testing of products for use in contact with drinking water* (AS/NZS 4020) or an internationally recognised equivalent. These standards and compliance systems reduce the risk of toxigenic chemicals being present in plumbing, but only provide a high level of assurance of such protection for pipes and fittings that are adequately turned over. That is, WaterMark-compliant plumbing may be less subject to corrosion and leaching than non-compliant plumbing, but dead legs can still permit contamination to rise to levels above health-related guideline values, albeit probably to lower levels than would arise from plumbing that was not WaterMark compliant.

It was considered that the proposed HFS102 will provide the potential for chemicals to reach concentrations of concern within droppers, resulting in a potentially high risk if this water were regularly and consistently ingested.

The controls proposed within HFS102 (summarised in section 6.5.1) mean that the length of dropper pipework is minimised, and the water running through the DN25 plumbing will provide a dilution factor and a hydraulic buffer of water that is turned over between the dropper pipework and plumbing fittings. These controls will reduce, but not eliminate, the risk that chemicals reaching levels that exceed guideline values are ingested. However, with such short droppers, very limited exposures would occur, for isolated events. Furthermore, ‘slugs’ of highly contaminated water would typically be evident through colour, taste, particulates, or odour, and unlikely to be consumed in large quantities, and not reasonably foreseeably consumed for prolonged periods on an ongoing basis. The latter point is important since it renders the risks relating to toxigenic chemicals self-limiting. For instance, elevated metals in stagnant water would typically be evident from both colour and taste.

In practice, whilst short term exceedances of chemical guideline values might arise, exposure periods would be too short, exposures too infrequent, and adverse aesthetic properties too self-limiting, to present significant health consequences. It was concluded that the risk is acceptable and is similar to, and at worst only incrementally and marginally higher than, the risk associated with conventional plumbing systems. Therefore, risks posed by toxicants were not considered further.

6.5.6 Summary of risks relating to aesthetics

Aesthetic hazards in water can reach levels that cause perceptible taste, odour, particulates and colour. Over time the concentrations of substances that may leach, form in biofilms, or arise in corrosion products could reach levels that are detectable as colour, particles, tastes, or odours. As noted in section 6.5.5, the WaterMark certification scheme and AS/NZS 4020 only assure full protection for pipes and fittings that are adequately turned over. That is, WaterMark-compliant plumbing likely will be less subject to corrosion and leaching than non-compliant plumbing, but droppers can still permit contamination to arise to levels above aesthetic guideline values, albeit to lower levels than would be anticipated from plumbing that was not WaterMark compliant

It was considered that the proposed HFS102 will provide the potential for substances to reach discernible concentrations within droppers resulting in a potentially moderate risk.

The controls proposed within HFS102 (summarised in section 6.5.1) mean that the length of dropper pipework is minimised, and the water running through the DN25 plumbing system will provide for some dilution and a hydraulic buffer of water that is turned over between the dropper pipework and plumbing fittings. The controls will reduce, but not eliminate, the risk of substances reaching levels that are discernible. However, with such short droppers, very limited exposures would occur, for isolated events, and not reasonably foreseeably for prolonged periods.

In practice, whilst short term exceedances of aesthetic guideline values might arise, exposure periods would be too short, and instances too infrequent, to present significant consequences. Furthermore, the risk is acceptable and is similar to, and at worst only incrementally and marginally higher than, the risk associated with conventional plumbing systems. Therefore, risks posed by aesthetic hazards were not considered further.

7 Discussion of findings of the risk assessment

7.1 Priorities and limiting hazards

There were low, moderate and high consequence hazards identified in the risk assessment. However, in practice, the controls required to reduce the risks from higher consequence hazards to an acceptably low level are likely to more than adequately reduce the risks posed by less consequential hazards. Therefore, the focus of an assessment of HFS102 should be on ensuring that the controls aimed at managing the higher consequence hazards are adequate. The principle is that if higher, limiting, risks are adequately controlled, then the lower risks will, by default, be adequately mitigated, provided the mitigation measures identified are relevant to both groups of risks. Since the recommended controls proposed under HFS102 (as summarised in section 6.5.1) are largely physical and hydraulic in nature, they will mitigate the various hazards in similar ways, which supports relying upon management of the limiting and most significant hazard and risk as being justifiably the focus of this assessment.

7.1.1 Low consequence hazards

The low consequence hazards include materials that may cause aesthetic, but not health-related, consequences. These may present as colour, taste, particulates or odour. Such risks could arguably be accepted on the basis of their low 'nuisance' rather than moderate or high 'health' consequence. In addition, as noted above, hydraulic mitigation of higher, limiting, risks should serve to mitigate these lower risks. Therefore, risks posed by aesthetic hazards were not considered further.

Similarly, enteric pathogens are not discussed further since they were considered to present no additional risk as a result of adopting HFS102 since enteric pathogens arise from faecal matter rather than stagnation in dead ends.

7.1.2 Moderate consequence hazards

Moderate consequence hazards include chemical toxicants that will potentially be present above guideline values, but only for brief periods and infrequently, and most likely in association with colour, particulates, taste or odour, limiting the likelihood of their ingestion. Therefore, such risks could arguably be accepted on the basis of their moderate consequence. In addition, as noted above, hydraulic mitigation of higher, limiting risks should serve to mitigate these more moderate risks. Therefore, risks posed by toxicant hazards were not considered further.

7.1.3 High consequence, limiting hazards

The only high consequence hazard presented relates to opportunistic pathogens. The key to ensuring that the risks associated with HFS102 are acceptable is to reduce the risk posed by opportunistic pathogens to an acceptably low likelihood. The controls required to reduce this opportunistic pathogen risk to an acceptably low likelihood are likely to more than adequately reduce the risk posed by the less consequential hazards, noted above. The key question relates to whether limiting the dropper to 300 mm in length, and the requirement to connect the dropper to a minimum DN25 plumbing line, is sufficient as a set of controls.

7.2 Currently accepted risks

A key finding when considering these risks was that there are routinely many low turnover and zero turnover dead leg pipes and fittings in existing plumbing systems. Therefore, HFS102 presents risks similar in nature and magnitude to those associated with conventional plumbing and reticulation systems. Examples of such existing stagnant water in pipes and fittings in plumbing systems may include:

- Entire building plumbing systems of infrequently used properties, e.g. short-term lease properties or holiday units, that may go unused for some weeks or even months between uses.
- Entire building plumbing systems in sites that close down for prolonged periods, e.g. seasonal holiday buildings, educational establishments, commercial or industrial facilities, that may not be in use for many weeks at a time.
- Entire building plumbing systems in sites that sit idle for prolonged periods after plumbing construction and wet testing until the site is routinely used.
- Infrequently used plumbing lines, taps and fittings supplying points outside buildings, such as hose fittings to taps that are seldom used, or seasonally used taps and fittings, such as outdoor showers, garden taps, irrigation connections, or pool filling points.
- Infrequently used plumbing lines, taps and fittings inside buildings, such as rooms with ensuites that are not in use, abandoned showers or baths that not in routine use, or taps supplying appliances that are no longer routinely used.
- Rarely used plumbing lines and safety fittings, such as eye wash stations or emergency showers.
- Abandoned and plugged pipe lengths arising when properties are modified and pipes are left in place and remain plumbed into the water supply plumbing, forming a dead leg with no turnover.

In addition, there are dead legs in the reticulated public water supply network, such as fire hydrants and air valves and their associated risers, along with disused or unused property service connections.

7.3 Relative risk assessment relating to opportunistic pathogens

As noted above (section 7.2), currently accepted risks included some low, or even no, turnover taps and fittings within buildings, and similar situations within reticulation systems.

Installing additional no turnover fittings, in this case fire sprinkler feed droppers, within buildings, as recommended under HFS102, unquestionably increases the risks associated with opportunistic pathogens. The risk is increased by virtue of the increased surface area presented and increased length of pipe installed that is intended to be subject to no significant turnover relative to the normal situation.

However, from a relative risk perspective, HFS102 as proposed presents an *incremental increase* in risk rather than a *step change* in risk or a *new* risk. That is, the extent of low and no turnover plumbing pipes and fittings will increase above current levels under HFS102, but no completely new or currently non-existent category of risk is introduced.

Furthermore, as noted in section 6.5.1, additional controls are proposed in HFS102 for the wet sprinkler systems: turnover of the plumbing line feeding the droppers using the existing DN25 and above plumbing systems; and limiting droppers to at most 300 mm linear length. These controls significantly reduce the extent of the incremental increase in risk. The key question to be addressed is: are those controls sufficient, and is the incremental increase in risk acceptable? This question is considered in the following discussion.

7.4 Professional assessment of the risk from opportunistic pathogens

A quantitative assessment of risk is discussed but was not undertaken for the reasons explained below (7.5). Therefore, the exercise of professional judgement, based on the objective evidence, has been used to inform a professional opinion on the acceptability and adequacy of the controls proposed under HFS102. In order to support such judgement, existing evidence was assembled and reviewed.

7.4.1 Length of droppers

In the opinion of the author of this report, the most important control identified in the HFS102 standard is to draw a line with respect to how long droppers can be. Whilst drawing such lines based on evidence and theoretical risk can be difficult, and there may be varying views on where that line should be drawn, there is likely to be consensus that some working upper limit on the length of droppers should be set.

Fortunately, the proposed HFS102 has been able to draw directly from evidence from research carried out in NZ (Soja, 2006) in setting a limit on the length of dead legs. In that respect, HFS102 can be considered to be evidence-based. That research studied microbial and chemical water quality in domestic fire sprinkler systems over one year. The report concluded:

> "It was found that the microbial quality would not be hazardous to health where range pipe dead legs were up to 4.5 metres long for a water supply of equal or better quality to that used in this research. From this it is recommended that dead legs up to 3 metres could be used in Combination Domestic Fire Sprinkler Systems."

It is noted that one of the controls recommended in HFS102 is to limit linear lengths of droppers to 300 mm (section 6.5.1), which is one order of magnitude shorter. This control appears to be important and drawing the line based on the Soja (2006) study seems appropriate given that more recent evidence has not been identified that suggests that this recommendation should be modified. Therefore, it is considered that the recommendation in HFS102 that droppers be limited in length to 300 mm can be accepted. Furthermore, HFS102 could be modified to promote minimising dropper lengths.

7.4.2 The standard of backflow prevention required

A key decision in finalising HFS102 relates to whether the backflow risks arising are of a magnitude that the backflow protection can just be based on a standard dual check valve non-testable backflow prevention device as currently in place for standard water meter connections, or whether an accessible and testable device is required.

A similar question was considered in a study from the US by NFPA (2009). The study concluded that it was not uncommon for residential combination fire sprinkler systems to be supplied without testable backflow prevention devices, including in warm climate southern US states. Problems with backflow from such residential combination fire sprinkler systems were not commonly reported under routine, field conditions in the research, and backflow prevention was not considered necessary in many of the jurisdictions surveyed.

An earlier US study (Duranceau et al, 1999) found that, under simulated conditions using a single check valve and unrestricted dead leg lengths, backflow from sprinkler system dead legs was observed, with a range of hazardous chemicals and microbial indicators of stagnant water being detected. However, the authors concluded that the risks posed by such events were too low to justify retrofitting backflow prevention to existing residential combination fire sprinkler systems given the relatively low risks implied compared to the very high risks associated with fires.

A useful consideration in making a decision on the level of backflow prevention required in HFS102 is 'relative risk'. Existing plumbing systems contain dead legs that are not routinely protected by any special backflow prevention system. An additional set of dead legs no more than 300 mm in length each will not present a step change in that risk.

Based on the risk being lower than that accepted from existing dead legs, (both due to the presence of some existing dead legs being longer than 300 mm and their lacking enhanced backflow protection), the risks associated with HFS102 are adequately mitigated by reasonably minimising, and limiting, the length of droppers feeding the sprinklers.

7.5 Quantitative risk assessment

7.5.1 Toxicological risk assessment

A toxicological risk assessment (TRA) can be used to set quantitative limits on risks associated with chemicals against defined targets. In this case, a TRA was not undertaken to support this assessment. It was concluded from the qualitative risk assessment that risks from chemicals were not significant given that any exposures to hazardous chemicals arising from plumbing leaching and corrosion would be rare, sporadic, short in duration and typically associated with elevated colour, particulates, taste or odour which would discourage ingestion. No additional assessment was required since the resulting residual risk was considered acceptable.

7.5.2 Quantitative microbial risk assessment

A quantitative microbial risk assessment (QMRA) can be used to set quantitative limits on risks associated with pathogens against defined targets. In this case, a QMRA was not undertaken to support this assessment.

QMRA is often applied to assessing risks from enteric pathogens and would have been completed were enteric pathogens considered potentially of significant risk. However, the qualitative risk assessment concluded that risks from enteric pathogens were not significant and were no higher than existing risks from conventional plumbing systems. No additional assessment, including a QMRA, was considered required since the resulting residual risk was considered acceptable.

QMRA can be applied to assessing risks from opportunistic pathogens. However, at present, such techniques are of very limited value in assessing risks from opportunistic pathogens (Bentham and Whiley, 2018). The major risks of concern in the review of HFS102 related to opportunistic pathogens and not enteric pathogens. Therefore, the above qualitative risk assessment was used as the basis to consider the acceptability of risks and requirements of controls, rather than a QMRA that would be too uncertain to provide a helpful contribution to decision-making. Nonetheless, empirical monitoring of opportunistic pathogens in buildings meeting HFS102, compared to current conventionally plumbed buildings, would be useful to assess relative risk, and to provide data to inform a QMRA.

8 Conclusion

Implementing HFS102 does not present new classes or categories of risks from enteric pathogens, opportunistic pathogens, toxicants, or aesthetic hazards that are not already present in existing potable plumbing systems. All such plumbing systems have the potential to contain some dead legs with very low or no turnover that can in turn influence the potable water system hydraulic movement, diffusion, or biological mobilisation, either affecting the plumbing fittings that are directly connected, or having more widespread effects via backflow.

Relative to a building with no fire sprinkler system, implementing HFS102 adds the potential for some additional dead legs, and increased stagnation in the plumbing lines (due to DN25 rather than DN20 lines), and warmer water (due to more lines in roof/ceiling spaces than walls or floors), and, hence, an incrementally increased risk from certain hazards. However, HFS102 includes several controls to reduce those risks for the fire sprinkler systems to lower than the levels associated with many other dead legs, namely:

- limiting droppers to maximum 300 mm lineal lengths, with most likely to be a few tens of mm; and
- providing for a dilution factor for material being returned by droppers since the plumbing line feeding the sprinkler lines must be at least DN25.

The presence of such controls means that incremental increases in existing risks from having HFS102 fire sprinkler systems in place is small relative to existing risks presented by existing plumbing dead legs.

In summary, whilst there are risks arising from implementing HFS102, those risks are comparable to accepted risks found in potable plumbing systems, including those with no fire sprinkler systems but having some dead legs. The fire safety risks from having no automatic fire sprinkler systems are well established. Therefore, if HFS102 encourages the uptake of fire sprinkler systems where they might otherwise not be implemented, e.g. where installing conventional separate fire sprinkler systems is considered impractical or cost prohibitive, HFS102, with its controls to protect potable water quality, presents an acceptable, practical solution to increase the uptake of home fire sprinkler systems.

A summary of recommendations is given in the Executive Summary of this report (sections 3.8 to 3.10) and is not repeated here.

9 References

AS/NZS 4020:2018. Australian/New Zealand Standard. Testing of products for use in contact with drinking water. Standards Australia and Standards New Zealand, last updated 29 June 2018.

Beer KD, Gargano JW, Roberts VA, et al. Surveillance for Waterborne Disease Outbreaks Associated with Drinking Water — United States, 2011–2012. MMWR Morb Mortal Wkly Rep 2016;64:842-848.

Benedict KM, Reses H, Vigar M, et al. Surveillance for Waterborne Disease Outbreaks Associated with Drinking Water — United States, 2013–2014. MMWR Morb Mortal Wkly Rep 2017;66:1216–1221.

Bentham R, Surman-Lee S, Lee JV, Briand E. and Van de Kooij D., 2007. Potable water and in-building distribution systems. Chapter 4. Pp57-68 Legionella and the presence of legionellosis. Eds Bartram J, Chartier Y, Lee JV, Pond K. and Surman-Lee, S. World Health Organization ISBN 92 4 156297 4.

Bentham R. and Whiley H., 2018. Quantitative Microbial Risk Assessment and Opportunist Waterborne Infections – Are There Too Many Gaps to Fill? International Journal of Environmental Research and Public Health, 15(1150):1-11.

CDNA (2017). Legionellosis, CDNA National Guidelines for Public Health Units, Communicable Disease Network [Australia], 2017.

Craun GF and Calderon RL, 2001. Waterborne disease outbreaks caused by distribution system deficiencies. Journal AWWA 93(9):64-75.

Duranceau S., Pool J. and Foster J., 1999. Wet-pipe fire sprinklers and water quality. Journal - American Water Works Association, 91(7):78-90.

enHealth (2015). Guidelines for *Legionella* control in the operation and maintenance of water distribution systems in health and aged care facilities. Australian Government, Canberra.

Farhat M, Trouilhé MC, Briand E, Moletta-Denat M, Robine E, Frère J. Development of a pilot-scale 1 for Legionella elimination in biofilm in hot water network: heat shock treatment evaluation. J Appl Microbiol. 2010 Mar;108(3):1073-1082.

HFSCA, (2024). HFS102 Automatic Fire Sprinkler System for Class 1 Homes, Working draft, Home Fire Sprinkler Coalition Australia, July 2024.

Hart CA, Makin T. Legionella in hospitals: a review. J Hosp Infect. 1991 Jun;18 Suppl A:481-9. doi: 10.1016/0195-6701(91)90060-l. PMID: 1679819.

Kunz JM, Lawinger H, Miko S, et al. (2024). Surveillance of Waterborne Disease Outbreaks Associated with Drinking Water — United States, 2015–2020. MMWR Surveill Summ 73(No. SS-1):1–23.

Lehtola MJ, Laxander M, Miettinen IT, Hirvonen A, Vartiainen T, Martikainen PJ. The effects of changing water flow velocity on the formation of biofilms and water quality in pilot distribution system consisting of copper or polyethylene pipes. Water Res. 2006 Jun;40(11):2151-60.

Liu Z, Lin YE, Stout JE, Hwang CC, Vidic RD, Yu VL. Effect of flow regimes on the presence of Legionella within the biofilm of a model plumbing system. J Appl Microbiol. 2006 Aug;101(2):437-42.

Makin T, Hart CA. The effect of a self-regulating trace heating element on Legionella within a shower. J Appl Bacteriol. 1991 Mar;70(3):258-64.

Makin T, Hart CA. The efficacy of control measures for eradicating legionellae in showers. J Hosp Infect. 1990 Jul;16(1):1-7.

NFPA, 2009. Integration of Residential Sprinklers with Water Supply Systems A Survey of Twenty U.S. Communities, Newport Partners, LLC for The National Fire Protection Association, September 2009.

NHMRC/NRMMC (2011) Australian Drinking Water Guidelines, National Water Quality Management Strategy, Version 3.4, National Health and Medical Research Council and Natural Resource Management Ministerial Council, last updated October 2017.

Patterson WJ, Seal DV, Curran E, Sinclair TM, McLuckie JC. Fatal nosocomial Legionnaires' disease: relevance of contamination of hospital water supply by temperature-dependent buoyancy-driven flow from spur pipes. Epidemiol Infect. 1994 Jun;112(3):513-25.

Rampling A, Butt CJ, West AA, Tully M, Palmer KT. Community-acquired Legionnaires' disease following minimal exposure to a contaminated source. J Infect. 1997 Nov;35(3):300-2.

Soja E., 2006. Domestic Fire Sprinkler Systems – Report On Water Quality, Reliability and Application to Other Property. BRANZ Report, Judgeford, New Zealand.

Stypułkowska-Misiurewicz H, Pancer K, Krogulska B, Matuszewska R. Ognisko choroby legionistów na oddziale okulistycznym. Szpitalne zakazenie Legionella pneumophila po raz pierwszy obserwowane w Polsce [Outbreak of hospital acquired Legionnaires' disease in patients of ophthalmic ward. Nosocomial Legionella infections for the first time observed in Poland]. Przegl Epidemiol. 2007;61(4):657-65.

Tercelj-Zorman M, Seljak M, Stare J, Mencinger J, Rakovec J, Rylander R, Strle F. A hospital outbreak of Legionella from a contaminated water supply. Arch Environ Health. 2004 Mar;59(3):156-9.

Thomas V, Bouchez T, Nicolas V, Robert S, Loret JF, Lévi Y. Amoebae in domestic water systems: resistance to disinfection treatments and implication in Legionella persistence. J Appl Microbiol. 2004;97(5):950-63.

Trop Skaza A, Beskovnik L, Storman A, Ursic S, Groboljsek B, Kese D. Outbreak of Legionnaires' disease in a nursing home, Slovenia, August 2010: preliminary report. Euro Surveill. 2010 Sep 30;15(39):19672.

Whiley H, Keegan A, Fallowfield H, Bentham R. Detection of Legionella, L. pneumophila and Mycobacterium avium complex (MAC) along potable water distribution pipelines. Int J Environ Res Public Health. 2014 Jul 18;11(7):7393-405. Erratum in: Int J Environ Res Public Health. 2014 Nov;11(11):1418-20.

Table 4. Risk assessment summary table.

Process Step (from flow diagram)	Contaminants ('hazards')	How can the hazard be introduced or exacerbated as a result of the proposed FPAA102 standard? ('hazardous events')	Likelihood (A-E)	Severity (1 to 5)	Maximum Risk (no specific controls)	Controls ('preventive measures') that are proposed in FPAA102	Residual Likelihood (A-E)	Residual Consequence (1 to 5)	Residual Risk (with proposed controls)	Notes on basis of the scoring	Uncertainty	Acceptability of risk	Follow up actions
Droppers feeding sprinklers	Enteric pathogens including bacteria (e.g. *Salmonella* spp. and *Campylobacter* spp.), parasites (e.g. *Cryptosporidium* spp.) and viruses (e.g. norovirus).	These pathogens are only present in water contaminated with faecal matter or putrescing food waste. They are no more likely to be present in fire sprinkler dropper lines than in any other plumbing since they do not typically persist or grow in potable water, but rather they gradually die off over time. If water is hydraulically or thermally drawn back, or if pathogens diffuse or migrate, from droppers into the potable plumbing line, persons within the property may be exposed via ingestion. If the water in turn backflows into the potable system persons in other properties may be similarly	E	1	Low	No special controls required	E	1	Low	Enteric pathogens are primarily derived from fresh faecal matter and are not specifically of concern in droppers or other fire srpinkler pipework. The relatively low nutrients found in potable water do not typically support the proliferation of enteric pathogens even in the absence of a disinfectant residual, e.g. in droppers. Significant concentrations of enteric pathogens capable of resulting in significant consequences are not presented by the proposed standard, even without any dedicated controls, resulting in a low maximum and residual risk.	High level of confidence. The source, fate and transport of enteric pathogens in water is well understood.	The risk is acceptable and is no higher than the risk associated with conventional plumbing systems that already include low turnover plumbing lines and fittings, often without length limitations on dead legs.	None.
Droppers feeding sprinklers	Opportunistic pathogens including bacteria such as *Legionella* spp. and amoebae such as *Naegleria* spp. and Acanthamoeba spp.	These pathogens are present naturally in water. They proliferate to levels of concern in stagnant water, particularly where they can form biofilms (e.g. on pipe surfaces), in water lacking a disinfectant residual (e.g. in dead leg pipes) and in warm water (e.g. in the 20 to 50˚C temperature range). If water is hydraulically or thermally drawn back, or if pathogens diffuse or migrate, from droppers into the potable plumbing line, persons within the property may be exposed via inhalation, eye, nose or skin contact. If the water in turn backflows into the potable system persons in other properties may be similarly exposed	C	4	Very High	2.2 No additional backflow prevention is required. 3.1 Droppers longer than 300 mm are not permitted. Diameter of all sprinkler supply pipework must be a minimum DN25, excluding the ≤300 mm dropper. 5.1 Home fire sprinkler system components shall be in accordance with AS/NZS 3500.1:Plumbing and drainage - water services.	E	4	High	The proposed standard will increase the potential for proliferation of opportunistic pathogens by providing increased surface area and dead leg droppers resulting in a potentially very high risk. The controls proposed mean that the length of dropper pipework is minimsed to typically a tens of mm, and at most 300 mm, and the water running through the plumbing line will provide significant dilution. These controls will reduce, but not eliminate, the risk of opportunistic pathogens diffusing, migrating, or being drawn back into the potable plumbing system. The risk is further mitigated by the likelihood that backflow of stagnant water would be associated with elevated colour, particulates, taste or odour. On the other hand, the increased plumbing pipe surface area and volume associated with DN25 rather than DN20 pipes, and their presence in roof/ceiling spaces rather than walls or floors, will increase stagnation and temperature which will increase the risk of opportunistic pathogens. The resulting residual risk is elevated, but remains rare in likelihood, although it could have a major localised impact if the controls fail.	Moderate level of confidence. The presence of dead legs similar to those proposed is not uncommon in existing plumbing systems, and DN25 pipes, and running pipes in roof/ceiling spaces is permitted now, so the likelihood is expected to be rare. However, opportunistic pathogen infections from plumbing systems do occur at times.	The incrementally increased risk needs evaluation to decide whether it is acceptable. It is noted that short dead legs already exist within existing plumbing systems, and the plumbing lines can be DN25, and can by fed through roof/ceiling spaces. It is probable that on balance the risk is not significantly higher than the risk associated with conventional plumbing systems. Nonetheless, given the high consequence rating for this risk, the risk requires special deliberation.	Single out this risk for special consideration.
Droppers feeding sprinklers	Toxigenic chemical hazards from plumbing fittings, e.g. copper, lead, cadmium, chromium, nickel, antimony, or plastics, microplastics, or plasticisers leached from droppers.	Over time the concentrations of toxicants that may leach from pipes, or form in corrosion products, could reach levels that exceed guideline values in dead legs. The AS/NZS 4020:2018 requirements only assure protection for pipes that are adequately turned over. If water is hydraulically or thermally drawn back, or if chemicals diffuse, from droppers into the potable plumbing line, persons within the property may be exposed via ingestion. If the water in turn backflows into the potable system persons in other properties may be similarly	B	3	High	2.2 No additional backflow prevention is required. 3.1 Droppers longer than 300 mm are not permitted. Diameter of all sprinkler supply pipework must be a minimum DN25, excluding the ≤300 mm dropper. 5.1 Home fire sprinkler system components shall be in accordance with AS/NZS 3500.1:Plumbing and drainage - water services	D	2	Low	The proposed standard will increase the potential for toxicants to reach concentrations of concern by providing increased surface area and dead leg droppers resulting in a potentially high risk. The controls proposed mean that the length of dropper pipework is minimsed to typically a tens of mm, and at most 300 mm, and the water running through the plumbing line will provide significant dilution. The controls will reduce, but not eliminate, the risk of toxicants reaching levels that exceed guideline values being ingested. With such short droppers, very limited exposures would occur, for isolated events, and typically with water that is evidently contaminated through colour, taste, particulates, or odour, and unlikely to be consumed in large quantities, and not foreseeably consumed for prolonged periods. In practice, whilst short term exceedances of chemical guideline values might arise, exposure periods would be too short, and exposures too infrequent, to present significant health consequences.	High level of confidence. The leaching and corrosion of substances from plumbing fittings is well understood.	The risk is acceptable and is at worst only marginally higher than the risk associated with conventional plumbing systems that already include low turnover plumbing lines and fittings, often without length limitations on dead legs.	None.
Droppers feeding sprinklers	Aesthetic hazards including elevated colour, particulates, taste or odour, leached from, or arising in, droppers	Over time the concentrations of substances that may leach, form in biofilms, or arise in corrosion products could reach levels that are detectable as colour, particles, tastes or odours. The AS/NZS 4020:2018 requirements only assure protection for pipes that are adequately turned over. If water is hydraulically or thermally drawn back, or if chemicals diffuse, from droppers into the potable plumbing line, persons within the property may notice. If the water in turn backflows into the potable system persons in other properties may similarly notice	C	2	Moderate	2.2 No additional backflow prevention is required. 3.1 Droppers longer than 300 mm are not permitted. Diameter of all sprinkler supply pipework must be a minimum DN25, excluding the ≤300 mm dropper. 5.1 Home fire sprinkler system components shall be in accordance with AS/NZS 3500.1:Plumbing and drainage - water services	D	2	Low	The proposed standard will increase the potential for substances to reach discernible concentrations by providing increased surface area and dead legs resulting in a potentially moderate risk. The controls proposed mean that the length of dropper pipework is minimsed to typically a tens of mm, and at most 300 mm, and the water running through the plumbing line will provide significant dilution. The controls will reduce, but not eliminate, the risk of substances reaching levels that are discernible. With such short dead legs, very limited exposures would occur, for isolated events, and not foreseeably for prolonged periods.	High level of confidence. The leaching and corrosion of substances from plumbing fittings is well understood.	The risk is acceptable and is only marginally higher than the risk associated with conventional plumbing systems that already include low turnover plumbing lines and fittings, often without backflow prevention or length limitations on dead legs.	None.