

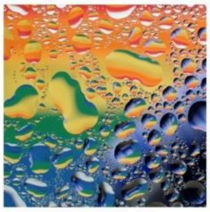
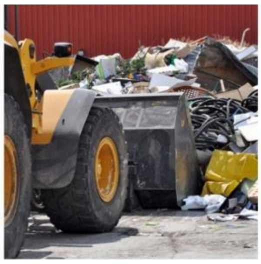


Considerations for design and operation of fire sprinkler systems

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1. Water Quality Implications

1.1 Microbiological implications

The installation of fire sprinklers in residential and domestic premises has raised concerns that such systems could have adverse consequences for microbiological water quality. This has been attributed to their potential either for encouraging the growth of organisms that may contaminate the mains supply in the absence of adequate back-flow prevention or expose individuals to harmful bacteria, such as *Legionella*, when in operation.

The purpose of this section is to review the significance of these risks and to determine if they differ between fire sprinklers supplied directly from the mains or through water stored in a tank.

1.1.1 Introduction

In the UK, a disinfectant is applied to all public supplies of water to preserve its microbiological quality during distribution through the network. However, its concentration decays during transit and eventually may lead to conditions that permit microbial growth.

Once the disinfectant residual is no longer inhibitory, the amount of growth depends primarily on the availability of nutrients and the prevailing temperature. Nutrients can be conveyed by the flow of water, although the amount depends on the type of water; surface derived sources tended to have more nutrients than groundwater sources.

The predominant site for microbial activity is the biofilm although growth in the bulk water can occur under certain conditions. All surfaces in contact with water can support a biofilm including pipes, walls and sediment. Non-metallic materials can act as a substratum for biofilm development, but approved materials will not supply nutrients to support significant growth.

The micro-organisms which grow under these conditions are those naturally present in the mains water supplying the building. These micro-organisms are a mixed population and may comprise heterotrophic bacteria, fungi and yeasts.

A plumbing installation represents a more favourable environment for microbial growth than the distribution system. This is attributed to the longer residence times and the warmer water temperatures. The most serious of these concerns is their potential for encouraging the proliferation of *Legionella*, although microbial growth in general could have deleterious consequences on water quality.

1.1.2 Impact of fire sprinklers on microbiological quality

Observations on water quality deterioration

A limited number of studies have specifically examined water quality in sprinkler systems. Alleman *et al*. (1982) compared the quality of water in sprinkler system pipes with that from the mains supply for the building. The survey was restricted to a university campus, and was conducted over a period of six months. The numbers of heterotrophic bacteria in water obtained from the sprinkler pipes varied widely, although the authors could not rule an external source contamination during sampling. Generally, copper sprinkler systems did appear to have less total count activity than the steel lines.

A more extensive survey by Duranceau *et al*. (1998) determined the quality of water within 84 wet-pipe fire sprinkler systems in North America. Coliform bacteria were predominantly absent, and occasional presence was attributed to unsanitary construction activities recently performed on the sprinkler systems. However, the numbers of heterotrophic plate counts exceed recommended guidelines for drinking water. In the UK, there are no specific limits on the numbers of heterotrophic bacteria in water supplies, but any significant increase in numbers of these bacteria would be considered unacceptable. A 12 month study by Soja (2006) examined the deterioration in water quality in a domestic fire sprinkler system, which was combined with the household water supply, installed in a roof space. It was stated that the microbial quality of the water would not be hazardous to health where pipe dead legs were up to 4.5 metres long for a water supply of equal or better quality to that used in their study.

Consequences of stagnation

Growth of *Legionella*

In the event that stagnation does occur in sprinkler systems, the disinfectant residual would decline and no longer be able to prevent microbial growth. However, microbial activity would consume the available oxygen, eventually leading to anaerobic conditions. As a consequence, there would be shift in the predominant types of micro-organisms.

Prolonged periods of stagnation create unfavourable conditions for the growth of heterotrophic bacteria and *Legionella*. Liu *et al*. (2006) constructed a model plumbing system from PVC pipes that produced three flow regimes to evaluate the effect of varying flow conditions (turbulent, laminar and stagnation) on the occurrence of *Legionella* in microbial biofilm. The plumbing model was designed as a partially open system and was operated at room temperature (24 °C) and with intermittent flow. The lowest numbers of *Legionella* were recovered from the stagnant flow pipes.

A similar conclusion was reached by Thomas *et al*. (2004). A pilot-scale domestic water system was developed which consisted of seven galvanized steel re-circulation loops and copper dead legs (length 13m) where the water was partially replaced every two days. Temperature was maintained at 35 °C. The numbers of bacteria in general and *Legionella* in particular in the water body were comparable in the recirculation loops and the dead legs. In the biofilm however, numbers of bacteria were significantly higher in the recirculation loops, in comparison with the dead legs. As long as the water renewal rate was maintained at 20% per day, no significant change of the numbers of these two populations was observed in the dead legs. The authors proposed that the difference in hydraulics between the loops and dead legs, and the consequences on nutrient availability, probably accounted for this difference in biofilm development.

Maintaining flow is crucial for controlling the growth of *Legionella* in tanks. Ciesielski *et al*. (1984) reported that the stagnation of water in two of four hospital hot-water storage tanks found to contain *Legionella pneumophila* was reduced by keeping the two tanks in constant use for 1 year. *L. pneumophila* colony counts in these two tanks fell quickly to low numbers, whereas the numbers of organisms initially increased in one of the two tanks that were not in use, but declined over the duration of the study.

Microbial Corrosion

The presence of a biofilm has been linked to corrosion in plumbing installations. Keevil (2004) attributed a particular type of pitting corrosion, only observed in soft poorly buffered water, to the action of a copper tolerant biofilm. Also, it has been proposed that “blue water” may be caused by microbial activity (Critchley *et al*. 2004). However, in both these situations the organisms responsible require an aerobic environment for growth, although it was suggested that the presence of a biofilm may create an oxygen deficient micro-environment which promoted corrosion.

The stagnant conditions found in a deadleg may encourage the proliferation of specialised bacteria capable of growing in the absence of oxygen. If present, colonisation by sulphate reducing bacteria (SRB), may take place and cause corrosion, impart to a water supply an unpleasant taste and odour resembling “rotten eggs” and form black deposits (Beech 2003).

1.1.3 Discussion

Sprinkler systems

The impact of fire sprinklers on water quality has been considered in a limited number of investigations using model systems or surveys of installed systems. All have been conducted on direct feed systems and none have compared the differences in water quality with tank fed systems. A brief review published by the Loss Prevention Council in 1999 stated that systems supplied directly from the public supply presented no significant risk of *Legionella* infection, but that a theoretical risk existed from poorly maintained private tanks, mainly for maintenance personnel, fire-fighters and in health care premises. However, although not clear, it would appear that the conclusions were not aimed at domestic installations.

The studies on fire sprinklers have shown that period of stagnation is an important factor affecting microbial growth. Prolonged stagnation, where there is no exchange of water over many months, creates conditions that are unfavourable for the growth of harmful bacteria such as *Legionella*. The risk from *Legionella* would be reduced in those systems having a high turnover allowing the system to be replenished regularly with mains water containing chlorine.

Of most concern are those systems with intermittent flow where the duration is sufficient to avoid creating stagnation, but permitting sufficient nutrient and oxygen exchange to maintain microbial growth. With the evidence available, attempting to define the limits for an acceptable flow would be fraught with uncertainties, but adopting a replenishment rate of 20% of the system capacity per day could serve as an initial value.

On this basis, domestic fire sprinklers supplied from a tank would be acceptable provided the installation is operated with very little turnover, or with enough turnover to ensure that the tank and supply pipe would be regularly replenished with mains water. The length of spurs to the sprinkler taps could be unlikely to exert a significant effect on the deterioration of water quality, but this would be very dependent upon the design of the system and size of the property. Despite the perceived risks from *Legionella*, the review of the literature revealed that more concern was associated with the potential of fire sprinklers to contaminate the mains supply. It has been suggested that direct supplied systems would increase the likelihood for cross-connections, although no evidence was found to quantify such incidents. There is a requirement to include a device to prevent back-flow for those systems connected directly to the water mains. The mains supply would be protected from contamination by tank supplied systems through the provision of an air-gap.

Relevant information could not be found for the reliability of back-flow prevention devices. A study conducted around 25 years ago in the United States and reported by Hart *et al*. (1996)

found that the failure rate for double check valve assemblies and RPZ valves was 1.6 % and 1.8 % respectively for pipes between 20 to 25 mm in diameter. It appears to be accepted practice in the United States to install fire sprinklers directly to the mains supply without the requirement for back flow prevention provided all the materials and fittings are approved. The survey by Duranceau *et al*. (1998) reported that the predominant cause for backflow of water within a dedicated wet-pipe fire sprinkler system was related to check valves that have failed in the open or partially-open position.

Mains and supply pipes

The provision of a reliable water supply for direct fed fire sprinkler systems would require an increase in the size of the supply pipe serving properties, and there may be circumstances where a larger main is needed. In such a situation, the turnover of water would be reduced and so increasing the potential for decay of the disinfectant residual. This condition would favour growth of organisms present in the water supply system. Most of these would be organisms that are not harmful, although the activity of certain bacteria may cause water quality to deteriorate, for example, by imparting earthy and, or musty tastes and odours. Also, these conditions may prove favourable for the growth of coliforms. Not only would this have an adverse impact on regulatory compliance, but their presence in such situations would distract from their function as an indicator of the integrity of the water supply system.

1.1.4 Conclusions

- No direct evidence was found that suggested direct and tank supplied sprinkler systems presented a different health risk from exposure to *Legionella*.
- In both types of system, the extent of microbial growth is likely to be low provided a good turnover of water can be maintained.
- Most concern was associated with preventing back-flow and minimising the potential for increased cross-connections; this would be applicable to direct fed rather than tank fed systems.
- Larger diameter supply pipes for direct fed systems could increase the decay disinfectant residual, with a potential impact on microbiological quality at the tap.

1.2 Other water quality considerations

Other processes can cause deterioration in water quality in fire sprinkler systems. Studies have shown that water can contain elevated concentrations of metal ions released by corrosion of the pipework and fittings. The susceptibility to corrosion also depends on the type of metal, but rate and extent of the process can be difficult to predict for a particular water supply. This could impact on mains water quality in the event of a failure of backflow prevention or damage the integrity of the pipework.

Several different processes are known to be responsible, but controversy exists over their significance in fire sprinkler systems. Kochelek (2009) was firmly of the opinion that the reaction between dissolved oxygen and iron or zinc (in galvanised systems) is the primary mechanism for corrosion. The process can occur over the entire surface in contact with the water supply. Several reports have indicated that microbially induced corrosion (See Section 3.1.2.) can have a significant impact on the corrosion process. Damage appears to be localised but the consequences can be more severe. Other types of corrosion can result from debris left inside the system during installation, deposit accumulation or by contact with water known to a have potential for corrosivity.

Problems associated with corrosion would be expected to be avoided for new installations. Water suppliers should have knowledge of the effects of their supplies on the types of pipe material to be used.

1.3 Water quality

There is no evidence from the limited data available that appropriately designed and operated storage of water would cause a chemical or microbiological water quality problem. The microbiological risk, including *Legionella* growth, appears to be lower for stagnant systems because of depletion of nutrients and dissolved oxygen. To minimise microbiological risk systems should be designed for frequent flow-through to obtain the benefits from disinfectant residual in the water, or aim to achieve stagnant conditions. Greatest risk would be with intermittently fed systems, but it is not possible to reliably quantify this in any more detail with available information.

Larger diameter supply pipes for direct fed systems could increase the decay of disinfectant residual, with a potential impact on microbiological quality at the tap.

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