Supplement 1

Part B

Treatment Methods

1.B1 Cooling systems

Biocides

Biocides are used for the long-term control of microbiological activity in cooling systems, and can be oxidising or non-oxidising. The frequency and quantity of additions will depend on the microbiological activity of the system.

Biocides have been shown to be effective in preventing the proliferation of Legionella when applied and controlled as part of a comprehensive water treatment programme. Many factors will influence the selection of chemicals required for the treatment programme. However, the success of the treatment programme is dependent on:

a) Compatibility of all chemical components used;
b) Adherence at all times to the recommended application, monitoring and control procedures.

Biocides are routinely applied at the tower sump or the suction side of the recirculating water pump but should be dosed so that the biocide will circulate throughout the cooling system. However, in air conditioning systems where the tower can be bypassed, the biocide needs to be added to the suction side of the recirculating pump.

Specific surfactants (biodispersants) function by wetting biofilms and aiding penetration of the biocides into them. In microbiologically dirty systems that contain or readily grow biofilms, the use of biodispersants can improve the efficiency of oxidising biocides. Most non-oxidising biocide formulations already contain surfactants to improve performance.

Hazard data sheets should be available for all chemicals used in treatments applied to cooling towers and an assessment drawn up to ensure that those handling and applying them do so safely. Where a biocide has been selected specifically for control of Legionella the supplier should be able to present test data to demonstrate its efficacy.

Oxidising biocides

The halogens are dosed to give a free-chlorine or free-bromine reserve. This is a measure of the free-halogen, the hypochlorous/hypobromous acid (HOCl/HOBr) and the hypochlorite/hypobromite ion (OCl^- /OBr^-). In all cases the applied dosage should be sufficient to maintain a free reserve in the range of 0.5-1mg/l chlorine/chlorine dioxide and 1.0-2.0 mg/l bromine in the return water. Reserves consistently above 2mg/l free chlorine/bromine should be avoided (except in exceptional circumstances) as this may cause system corrosion. The activity (in terms of time taken to have an effect) of chlorine is significantly reduced at alkaline pH and additions of this biocide need to be adjusted to take account of this. This can be overcome by continuous dosing. It is, in any case, preferable to apply oxidising biocides on a continuous basis but if they are applied as a shot dose, the effective concentration should be present for at least 4 out of every 24 hours. In large industrial systems, the dosage is based on water recirculation rate. This has to be sustained for a period of time, ranging from a few minutes to several hours, or even continuously, depending on the operating characteristics of the cooling system.

For small systems, such as air conditioning installations, halogen addition would normally be based on system volume. The system and its water chemistry will influence the choice of the best method of addition to obtain effective microbiological control. Once halogenation is stopped, the free halogen reserve is quickly lost, leaving the system open to re-infection and re-population by micro-organisms.

Oxidising biocides are also used for disinfection either in emergency or as part of the routine cleaning programme. For disinfection, much higher doses of up to 50 mg/l may be used.

Oxidising biocides have the advantage that they can be readily monitored by simple chemical tests that can be performed on site, are relatively cheap and are easy to neutralise for microbiological monitoring and disposal. Their major disadvantage is that they can be corrosive and their activity, particularly for chlorine, is pH dependent.

Non-oxidising biocides

Non-oxidising biocides are generally more stable and longer lasting than oxidising biocides. However, their concentration will reduce because of depletion via water losses from the system, and by degradation of the active material.

To achieve the right non-oxidising biocide concentration to kill micro-organisms, it should be added as a shot dose but may sometimes be added continuously. The frequency and volume of applications are dependent on system volume, system half-life and the biocide contact time, typically four hours. These need to be considered to ensure that the biocide concentration necessary to kill the micro-organisms is achieved. In systems with smaller water volumes and high evaporation rates it is particularly important that the above parameters are accurately determined. In the case of systems that have long retention times, the half-life of the biocide is the controlling factor.

A non-oxidising biocide programme should use two biocides on an alternating basis. Once the concentration of any biocide has been depleted to below its effective level, the system will be open to re-infection. The efficacy of non-oxidising biocides may be influenced by the pH of the water in the system and this should be taken into account to ensure that the biocide programme is effective. The following points are important in selecting a non-oxidising biocide programme:

- Retention time and half-life of the system;
- Microbiological populations;
- System contaminants;
- Handling precautions;
- Effluent constraints.

1.B2 Hot water systems

National water regulations may prescribe a maximum value for the level of biocide being used in potable water supplies. It is important that installers of treatment systems are aware of the need to avoid any breach of these regulations and maintain biocide levels below the maximum allowable concentration.

Thermal shock

Thermal shock treatment at 70-80ºC for relatively short periods has been used both for emergency disinfection, and also for periodic disinfection of systems, as part of long-term control programmes.

Thermal disinfection is carried out by raising the temperature of the whole of the contents of the hot water storage heater to 70-80°C then circulating this water throughout the system for up to three days. To be effective, the temperature at the hot water storage heater should be high enough to ensure that the temperatures at the taps and appliances do not fall below 65°C. Each tap and appliance should be run sequentially for at least five minutes at the full temperature, and this should be measured. For effective thermal disinfection the water system needs to be well insulated. Some authors recommend emptying the hot water tanks in advance, cleaning them and decontaminating them with chlorine (50 mg/l for one hour or an equivalent) but this may cause corrosion.

It is essential to check that during the procedure, the temperature of the water in distal points reaches or exceeds 65°C.

At the end of the procedure, samples of water and sediment should be collected at distal points of the installation and examined for Legionella. If the result is unsatisfactory, the procedure must be repeated until documented decontamination is achieved. Following decontamination, microbiological checks must be repeated periodically.

Thermal treatment has the advantages that no particular equipment is required so that the procedure can be carried out immediately, provided there is sufficient heat capacity in the system. However the procedure requires considerable energy and manpower and is not normally practical for large buildings but may be suitable for small systems. It will not disinfect downstream of thermostatic mixer valves and so is of limited value where such valves are installed. There is a severe risk of scalding at these temperatures. Although the numbers of Legionella may be reduced, recolonisation of the water system can occur from as little as a few weeks after treatment, particularly if it has not been accompanied by other remedial measures.

Constant maintenance of the temperature between 55-60°C

At 60°C it takes approximately two minutes to inactivate 90% of a population of *L. pneumophila.* The effectiveness of maintaining the circulating temperature at 60ºC has been demonstrated both in hospitals and in hotels. Hot water installations maintained at temperatures above 50°C are less frequently colonised by legionella. Circulating water at 60°C, such that the temperature at each outlet reaches at least 50ºC and preferably 55ºC within one minute of opening the outlet, is the method most commonly used to control legionella in hot water distribution systems. Although raising the temperature to a constant 60ºC has consistently been shown to control outbreaks it does not necessarily eliminate legionella from the system but controls them at a level that prevents further cases. Provided there is sufficient heating capacity it is relatively easy to implement and is easy to monitor continuously. It has the possible disadvantage of increasing energy consumption and there is an increased risk of scalding. Where thermostatic mixer valves are installed to reduce scalding risk, they must be subjected to a programme of planned monitoring and maintenance.

Chlorination

Chlorine has also been used for the treatment of hot water systems. As the bactericidal action of the chlorine is pH sensitive and decreases rapidly at values above 7 the pH of the water will have to be monitored and may need adjustment.

Shock hyperchlorination

This must be carried out in water at a temperature below 30°C, with a single addition of chlorine to the water to obtain concentrations of free residual chlorine of 20-50 mg/l throughout the installation, including distal points. After a contact period of at least two hours with 20 mg/l of chlorine or at least one hour with 50 mg/l of chlorine, the water is drained. Fresh water is then let into the installation until the level of chlorine returns to the concentration of 0.5-1 mg/l.

Continuous chlorination

This is achieved by the continuous addition of chlorine, usually in the form of calcium hypochlorite or sodium hypochlorite. Residual levels of chlorine can vary depending on the quality of the water, the flow, and the amount of the biofilm in the system. However the residual disinfectant must be between one and two mg/l. Where there are stagnant areas or circulation problems in the water distribution system, the chlorine will not inactivate Legionella in these areas.

Although continuous chlorination has been used as a means of control in hot water systems, it is difficult to maintain the required levels of chlorine as it volatilises off from hot water. In addition chlorine is corrosive and this effect is increased with raised temperatures.

Chlorine dioxide

Chlorine dioxide has been successfully used to control Legionella in some hot water systems and can be used in the same manner as chlorine. It has the advantage that it is not as volatile at high temperatures as chlorine and is said to be more active on biofilms.

Monochloramine

There is some evidence that hospitals receiving water that has been treated with monochloramine rather than chlorine are less likely to have outbreaks of legionnaires' disease and are less colonised with Legionella. It is possible that treating hot water systems with monochloramine may prove more effective than chlorine but appropriate dosing systems are not yet available for buildings. Monochloramine is more slow acting than chlorine but persists longer and is therefore said to be more effective against biofilms.

Ionisation

“Ionisation” is the term given to the electrolytic generation of copper and silver ions for use as a water treatment. Metals such as copper and silver are well known bactericidal agents. They act on the cell wall of the micro-organism that alters the cells permeability which, together with protein denaturisation, lead to cell lysis and death.

Copper and silver ions are generated electrolytically and their concentration in the water depends on the power applied to the electrodes. Copper and silver ion concentrations maintained at 400 µg/l and 40 µg/l respectively can, if properly managed be effective against Legionella in the planktonic and biofilm phase in hot water systems. If however the water is softened then silver ion concentrations between 30 to 20 µg/l can also be effective, provided a minimum concentration of 20 µg/l is maintained. This level of silver still requires copper ions to complete the synergy.

The application of ionisation will need to be properly assessed, designed and maintained as part of an overall water treatment programme. It should be noted that in hard water systems, silver ion concentrations can be difficult to maintain due to build up of scale on the electrodes, unless anti-scaling electrode cells are employed. High concentrations of dissolved solids may precipitate the silver ions out of solution. For both hard and soft water, the ionisation process is pH sensitive and it is difficult to maintain silver ion concentrations above pH 7.6. The build-up of scale and concentration of dissolved solids therefore needs to be carefully controlled so that suitable ion levels are consistently maintained throughout the system. This may require additional water treatments.

The method is easy to apply and is not affected by the temperature of the water. However because the system is subject to fluctuations in concentration unless automatic controls are employed, it is necessary to check the concentration of the two metals regularly, as well as the pH of the water at 6-8. This technique is not suitable for systems that employ zinc cathodic protection for water systems because the metal deactivates silver ions. Furthermore, if the treatment is used continuously it is necessary to check that the maximum permissible concentration (CMA) laid down by current legislation for drinking water is not exceeded.

Hydrogen peroxide and silver
Treatment is carried out using a stable concentrated solution of hydrogen peroxide (oxygenated water) and silver, exploiting the bactericidal action of each of the two components and the synergy between them. The technique is relatively recent and requires further experimental confirmation.

Ultra violet (UV) radiation
Irradiation with ultraviolet light is an alternative method for the disinfection of drinking water. Ultraviolet light (254 nn) inactivates bacteria by producing thymine dimers in their DNA that inhibit replication. The application of ultra-violet light is a method of disinfection that has proven effective close to the point of use. The thermal shock and chlorination methods can be used prior to application of ultraviolet light to control Legionella present in the system. UV equipment is relatively easy to install and has no adverse effects on the taste or potability of the water and does not damage piping. The technique is not suitable as the only method for an entire building or water system because there is no residual effect, and Legionella remains in the biofilms, dead ends and stagnant areas of the system.

1.B3 Cold water systems
Oxidising biocides are the most widely used method of controlling Legionella in cold water systems. Chlorine, monochloramine and chlorine dioxide can all be used although chlorine has been most widely applied. If the water is to be used for drinking it is important to ensure that the national drinking water regulations are complied with. The maximum concentration permissible will usually be 0.5mg/l.

1.B4 Spa pools
It is imperative that spa pools are rigorously maintained. The water should be continuously filtered and treated continuously with chlorine or bromine to provide a residual concentration of 1 - 2 mg/l of chlorine or 2 - 3 mg/l of bromine. Public spa pools should be equipped with a sand filter of the type used for swimming pools and this should be back-washed each day. At least half the water should also be replaced each day. The water circulation and treatment system should be operated 24 hours a day. The residual concentration of chlorine or bromine should be measured several times a day. Spa pools on display should be treated in the same way as those used by bathers.