ESGLI ESCMID STUDY GROUP FOR LEGIONELLA INFECTIONS

European Society of Clinical Microbiology and Infectious Diseases

ESGLI

European Technical Guidelines

for the

Prevention, Control and Investigation, of Infections Caused by *Legionella* species

June 2017

Foreword

These guidelines were originally produced with the assistance of funding from the European Commission prior to 2007, and the European Centre for Disease Prevention and Control (ECDC). Neither the ECDC nor the European Commission, nor any person acting on their behalf is liable for any use made of the information published here.

These guidelines were originally developed in 2001/02 by members of the European Surveillance Scheme for Travel Associated Legionnaires' Disease (EWGLINET) and the European Working Group for Legionella Infections (EWGLI). They were endorsed in 2003 by the Network Committee for the Epidemiological Surveillance and Control of Communicable Diseases in the Community, instituted by Decision No 2119/98/EC of the European Parliament and the Council of 24 September 1998 on setting up a network for the epidemiological surveillance and control of communicable diseases in the Community.

The following European experts in *Legionella* Infections are thanked for their input into these revised edition of the guidelines:

Dr Susanne Lee	UK (Chair)
Dr Sebastian Crespi	Spain
Dr Jaana Kusnetsov	Finland
Dr John Lee	UK
Dr Birgitta de Jong	ECDC
Dr Maria Luisa Ricci	Italy
Mr Wilco van der Lugt	Netherlands
Dr Enrico Veschetti	Italy
Dr Jimmy T Walker	UK

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If you notice any mistakes in these guidelines or have suggestions for improving them, please address them to susannelee@leegionella.co.uk

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- Prof Rodney Cartwright, Honorary Fellow The Royal Society for Public Health, UK
- Dr Esteban Delgado, Preverisk Group, Spain
- Ms Angie Hills, ABTA, UK
- Ms Lorraine Medcalf, Health & Safety Executive, UK
- Dr Claressa Lucas, CDC, USA
- Dr Maria Cristina Rota, Istituto Superiore di Sanità, Rome, Italy
- Mr Duncan Smith, Health & Safety Executive, UK

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Development and use of these guidelines

The European Working Group for Legionella Infections (EWGLI) was formed in 1986 and members of this group established a European surveillance scheme for travel-associated infections in 1987 (World Health Organization, 1990). In 2012 EWGLI was affiliated to the European Society for Clinical Microbiology and Infectious Diseases (ESCMID) and as a result the name changed to the ESCMID Study Group for Legionella Infections (ESGLI) (see https://www.escmid.org/research_projects/study_groups/esgli/).

The European surveillance scheme for Travel Associated Legionnaires' Disease, which was named EWGLINET in 2002, has grown in size and complexity since 1987, and now functions under an official EU Control of Communicable Disease programme with the name of European Legionnaires' Disease Surveillance Network (ELDSNet) (Commission Decision 2000/96/EC).

The first edition of this guidance document was produced in 2002 to describe the procedures for control and prevention of travel-associated Legionnaires' disease for participants in EWGLINET. It was produced by a small team from the surveillance scheme and the European Working Group for *Legionella* Infections and agreed by all collaborators in EWGLINET. The guidelines were submitted to the Network Committee for the Epidemiological Surveillance and Control of Communicable Diseases in the Community that operated under Decision No 2119/98/EC and Commission Decision 2000/96/EC. After some modifications, the EU Network Committee officially endorsed the document in June 2003. In 2005 the European Centre for Disease Prevention and Control (ECDC) was established through Regulation (EC) No 851/2004. As a disease-specific network, ECDC funded EWGLINET from January 2007 until April 2010.

Since 2010 the European surveillance of Legionnaires' disease has been carried out by ELDSNet and coordinated by ECDC in Stockholm. Data are collected by nominated ELDSNet experts for each European country and electronically reported to The European Surveillance System (TESSy) database.

The surveillance data are from two different schemes: the first scheme covers all cases reported from EU Member States, Iceland and Norway; the second scheme covers all travel-associated cases of Legionnaires' disease, including reports from countries outside the EU/EEA.

The aims of these two schemes differ. The main objectives of collecting annual data on all nationally reported cases of Legionnaires' disease are:

- to monitor trends over time and to compare them across Member States;
- to provide evidence-based data for public health decisions and actions at EU and/or Member State level;
- to monitor and evaluate prevention and control programmes targeting Legionnaires' disease at national and European level;
- to identify population groups at risk and in need of targeted preventive measures.

The daily surveillance of travel-associated Legionnaires' disease is primarily aimed at identifying clusters of cases that may not otherwise have been detected at a national level, and enabling the timely investigations and instigation of control measures at the implicated accommodation sites in order to prevent further infections. About 20% of all reported cases of Legionnaires' disease since 2005 are travel-associated.

ECDC annually publishes reports on the results of this surveillance. These reports can be found on the ECDC website http://www.ecdc.europa.eu/en/Pages/home.aspx

In this new edition, revisions to the technical guidelines have been prepared that reflect developments in clinical and environmental microbiology for the detection, control and prevention of *Legionella* infections and also from experience gained in investigating incidents and outbreaks of Legionnaires' disease as a result of *Legionella* contamination and colonisation in building water systems.

This edition also updates advice on risk assessments and the management of newly recognised sources of infection, and offers a standardised approach to procedures for preventing and investigating *Legionella* infections associated with travel taking into account the World Health' Organisations' approach to managing water safety within buildings.

These guidelines aim to further harmonise these procedures among Member States. However, national laws apply where advice on specific aspects of control and prevention differs between these European guidelines and regulations in force in Member States. The principles for investigation and control outlined in this document are not restricted to travel-associated infections but can also be applied to the prevention of *Legionella* infections in other situations.

Executive summary

Legionnaires' disease is a serious pneumonic infection caused by inhaling (or in rare cases aspiration of) the bacterium *Legionella pneumophila* or other *Legionella* species. Legionellosis is the term used for all forms of infections caused by *Legionella* and includes not only Legionnaires' disease but also a milder flu-like infection, commonly known as Pontiac fever. After the first recognition of Legionnaires' disease occurring in people attending a hotel conference in the USA in 1976 ("Epidemiologic Notes and Reports: Respiratory Infection – Pennsylvania", 1997), surveillance for the disease began in several countries and is now recognised as an infection which can be acquired worldwide wherever conditions allow legionellae to proliferate.

Community-acquired outbreaks of Legionnaires' disease are most commonly associated with aerosols generated by evaporative cooling towers. Wet cooling towers and evaporative condensers are used for comfort cooling in commercial buildings, hotels, etc., and for cooling industrial processes.

Legionella are also frequently found in building water systems, particularly in hot and cold distribution systems in large and complex buildings such as hotels, hospitals, office blocks, multi-occupancy accommodation buildings, commercial buildings, shopping malls and passenger vessels.

Legionella are also associated with causing infections from other systems such as spa pools and hot tubs including those on display. However, any system or equipment which contains, stores or recirculates non-sterile water[1] and has the potential to be aerosolised is a potential source of legionellosis. In rare cases legionellosis may also be acquired by aspiration.

Legionnaires' disease principally affects older adults. Those with risk factors including increasing age, smoking, immunosuppression and underlying diseases such as diabetes are at increased risk from the disease. The case fatality rate for community-acquired cases is currently around 10% and despite the availability of appropriate antibiotic treatment a certain number of deaths are recorded each year in otherwise healthy persons with no known underlying risk factors.

For a number of reasons people travelling to holiday destinations are particularly at risk, and such cases account for up to half of the cases reported from some European countries[2]. Through extensive media coverage, the public has become increasingly aware of Legionnaires' disease and the specific risks associated with travel, cruise ships and hotel stays. It is therefore important that early pan-European intervention and action should protect the public against the risks of infection. However, the acquisition of legionellosis is not limited to travel-associated buildings,

[1] Disinfected water is not sterile; disinfection reduces the number of microorganisms but does not eliminate them.

[2] Risk factors may include, but are not limited to, seasonality of holiday venues which can lead to an increase in the risk of stagnation and biofilms that support *Legionella* growth, and an increasing number of older travellers; holidaymakers are more likely to use spa pools and swimming pools with water features and to visit warmer climates where cold water temperatures are in excess of 20°C.

which include campsites, ships, etc. but may be acquired from any water system which is not maintained and controlled to minimise the risk of infection. These guidelines may be applied to all public and industrial sites with water systems which could produce aerosols of contaminated water.

The guidelines are in four parts (summarised below) and provide technical guidance for those involved in the design, installation, commissioning, risk assessment and management of building water systems. They are especially intended for those carrying out investigations following the reporting of cases of Travel Associated Legionnaires' disease, during the investigation of Legionnaires' disease outbreaks and the implementation of remedial works and control measures. It is important that these guidelines should be read in conjunction with the ELDSNet operating procedures (European Centre for Disease Prevention and Control, 2012).

Part 1: Procedures for the risk assessment, environmental investigation and the control and prevention of *Legionella* in water systems

This part summarises the factors to be considered in the risk assessment for both hot and cold water systems and evaporative cooling systems and includes:

- the responsibilities of the individuals concerned, assessment of their competence and training requirements;
- governance and management structure;
- factors promoting the growth of legionellae;
- the types of water system to be considered and associated documentation together with the systems for implementing and monitoring the control scheme.

It also details the items that should be included in the written scheme for the control of the risk and the need for regular review of the control measures including the role of microbiological sampling. The responsibilities of manufacturers, importers, suppliers and installers are also detailed. It includes useful checklists for inspections and the summary 15-point plan for managing *Legionella*, which can be used as a useful tool for assessing water safety management.

Part 2: Methods for the investigation and control of an outbreak of Legionnaires' disease in a hotel, other accommodation sites and other public buildings

This part briefly outlines the procedures for investigating an outbreak, with an emphasis on reviewing the risk assessment and monitoring results, sampling for *Legionella* and considering the emergency and long-term remedial measures for control. Note: investigators should carry out a personal risk assessment and ensure they have appropriate personal protective equipment for carrying out investigations. Fans within evaporative cooling towers, fountains and other devices producing an aerosol should be switched off before inspecting to allow time for aerosols to settle (this time can be usefully used to check paperwork).

Part 3: Technical guidelines for the control and prevention of *Legionella* in water systems

Since the publication of the WHO's *Water Safety in Buildings* in 2011 (Cunliffe et al., 2011), the Water Safety Plan (WSP) approach is being adopted worldwide as the most effective way to minimise risks from poor water quality from source to point of use. It is a preventive approach which aims to identify weak points in a system where waterborne hazards could enter and which might increase within the system to levels which pose a risk to users and anyone else who may be exposed. The WSP utilises a risk assessment to inform a multidisciplinary Water Safety Group (WSG), which uses the information to develop a management scheme to manage the hazards and mitigate the risks by implementing appropriate remedial works and control measures. The WSP approach also includes supporting programmes such as verification monitoring, appropriate documentation and record-keeping, training and communication.

This approach is not just limited to evaporative cooling and water in distribution in isolation but also includes all associated systems and equipment including pools and equipment used, for example, in leisure complexes including hair and beauty therapy.

The implementation of WSPs including the development of a WSG brings together all those who have an influence on how water is used and managed. This ensures good communication, facilitating a better understanding of factors which can adversely affect water quality (such as types of user and areas that are not being used or that have temperature restrictions, problems, etc). The WSP also includes:

- an up-to-date description of each system together with a schematic diagram;
- a risk assessment which includes identifying the types of water systems;
- an up-to-date management plan to control the risks which also identifies the monitoring programme to ensure the controls are effective;
- a review of governance procedures including the management structure, the responsibilities and accountabilities of the individuals concerned;
- training requirements and measurement of competence; and
- plans for dealing with foreseeable predictable events such as adverse results or a case (or cases) associated with critical failures in the system (e.g. major equipment failure such as a biocide dosing pump).

This part also provides the technical background to the control measures commonly applied to hot and cold water systems, cooling systems and spa pools, including:

- features of the design and construction;

- management of the systems during commissioning, recommissioning and normal operation and following adverse monitoring results.

These guidelines should be regarded as one example of good practice, which may not be entirely consistent with guidance produced in some other European countries because of legal requirements or constraints within individual countries. It is, however, a useful model to follow. National legislation should always be adhered to where relevant; but where legislation exists, these guidelines can also be used to enhance investigations.

This section also gives an overview of design, construction, operation and control of cooling systems with cooling towers or evaporative condensers, including the methods of cleaning and disinfection, biocide regimes and the use of chemical and microbiological monitoring. The design, construction, operation and control of spa pools are also detailed.

Part 4: Treatment methods for different water systems

This part emphasises the need for temperature control in hot and cold water systems along with good maintenance and where necessary, regular disinfection and cleaning. It also:

- describes the use of heat and biocides used for the disinfection and control of growth of *Legionella* in hot and cold water systems;
- describes treatment regimes for spa pools; and
- considers some alternatives.

Brief information is also given on the use of biocides for the regular control of cooling systems.

This part also provides information on the use of alternatives such as chlorine, chlorine dioxide and chloramine and copper/silver ionisation. However, the use of some biocides and concentrations of biocide and disinfectant by-products may be regulated at European and/or national level and these must be adhered to.

Part 1: Procedures for the risk assessment, environmental investigation and the control and prevention of Legionella in water systems

Introduction

1.1 This part of the guidelines outlines the general principles of the procedures that should be followed in order to carry out a risk assessment including reviewing the effectiveness of control measures against the proliferation of legionellae in an establishment such as a hotel or other public building. It must be emphasised that, for the effective prevention of Legionnaires' disease, risk assessments and control measures must be implemented proactively and not merely in response to a case or cluster[3] of cases of Legionnaires' disease. If proactive management is in place and a single case is associated with the establishment, it should only be necessary to ensure that an adequate up-to-date risk assessment is in place and all the control measures are operating correctly and consistently. However, following a cluster of cases – or if proactive management cannot be demonstrated – it will be necessary to carry out a thorough review of the risk assessment and improve and validate control measures where indicated. It is important to note than in premises which have been associated with cases, merely complying with legislation and or guidelines may not be sufficient to mitigate the risk of further exposure, and more stringent controls may need to be implemented and validated to ensure they are effective with more frequent ongoing verification of control measures to ensure they remain effective.

Legal background

1.2 According to the European Agency for Safety and Health at Work (2011), most European countries have adopted public health policies against *Legionella* based on Directive 2000/54/EC on the protection of workers from risks related to exposure to biological agents at work. For management of *Legionella* risk on ships, the EU SHIPSAN ACT Joint Action (2016) has produced downloadable guidance that deals with the threat from biological agents including *Legionella*.

Scope

1.3 These guidelines apply primarily to the control of *Legionella* in premises likely to be associated with travel-associated cases of Legionnaires' disease (e.g. hotels, holiday apartments, campsites, cruise ships, leisure centres and trade shows and exhibitions). However, they may also be applied to any public buildings or building including where there is an undertaking involving a work activity and to premises in connection with a trade, business or other

[3] A cluster of travel-associated cases of Legionnaires' disease is defined as at least two cases being associated with the same accommodation site within two years.

undertaking where water is used or stored (e.g. manufacturing premises and commercial premises such as restaurants, shops and shopping malls). These guidelines should be read in conjunction with the technical notes in Part 3.

Identification of risk systems

1.4 A reasonably foreseeable risk of exposure to *Legionella* exists in buildings with:

- water systems incorporating an evaporative cooling tower and/or evaporative condenser;
- hot and cold water distribution systems;
- natural thermal springs and their distribution systems;
- spa pools (also known as hot tubs), whirlpool spas (they are also often referred to as Jacuzzis; however, this is a trade name and should not be used generically), water used in health and beauty treatments, etc.;
- other systems including humidifiers, fountains and water features, and industrial water systems (e.g. air washers, wet scrubbers, vehicle washers, wastewater treatment plants/systems, misting devices and horticultural sprinkler systems);
- any other plant, systems or equipment containing water that is likely to be between 20°C and 45°C which may release a spray or aerosol (i.e. a cloud of droplets and/or droplet nuclei) during operation or demonstration, or when being maintained;
- any plant or system which uses water from a non-potable source (e.g. river water for evaporative cooling systems).

Information note

Temperature is one of the most important environmental factors influencing the growth of legionellae in water systems with growth occurring between 20°C and 45°C. While it is acknowledged that in many countries incoming cold water temperatures below 20°C may not be achievable, the risk assessment should consider the potential risk of infection which increases as the rate of growth increases with increasing temperature.

In hot water if temperatures fall below 45°C, legionellae will grow and although above 40°C many heterotrophic bacteria found in water which support the growth of legionellae start to die, legionellae can still grow relatively quickly inside thermotolerant amoebae.

Proportionality

1.5 Not all of the systems listed above will require elaborate risk assessments and control measures. For smaller low-risk systems, the risk assessment may conclude that that there is no reasonably foreseeable risk or that the risks are insignificant and being managed properly. No further action may be required at this stage, but existing controls must be maintained. However, it is still advisable to make a record of the findings and review at regular intervals to make sure there have been no changes which could impact on the risk assessment findings.

Responsibility for *Legionella* control within buildings

1.6 The responsibility for ensuring that water systems are managed to reduce the risk of infection falls upon:

- the building owner/employer where there are risks from their business to their employees, visitors or others; or
- a self-employed person where there is a risk from their business to themselves or to others; or
- the person who is in control of premises or systems where there is a risk present from systems in the building (e.g. where a building is let to tenants but the landlord is responsible for its maintenance); or
- the person who is in control of premises used by visitors and the like for overnight accommodation (e.g. hotels, holiday apartments and campsites).

1.7 Where a risk assessment has identified there is a risk of legionellosis and it is reasonably practicable to prevent or control that risk, the person on whom the duty falls (see paragraph 1.6) should appoint a competent person or persons to take day-to-day responsibility for ensuring the systems are managed safely (i.e. the responsible person or appointed WSG (see paragraphs 1.9–1.11)).

1.8 In large buildings, especially where there are multiple and complex systems, one person may not have all the necessary skills to identify and manage the risks of waterborne infections including Legionnaires' disease; the WHO (Cunliffe et al., 2011) recommends a multidisciplinary WSG is appointed which includes, for example, a microbiologist, environmental health officer, water engineer and water treatment specialists depending on the systems and vulnerability of the users on each site.

1.9 The responsible persons should be senior enough with sufficient authority and access to funds and also the competence and knowledge of the installation to ensure that all operational procedures, responses to adverse results and remedial works are carried out in a timely and effective manner.

1.10 It is important that the responsible persons/WSG should be familiar with the systems under their management and have a clear understanding of their duties and the overall health and safety management structure, governance arrangements and policy in the organisation.

1.11 Where the necessary expertise is not available in-house, it may be necessary to appoint people with the necessary competence from external sources (see paragraphs 1.46–1.48). In such circumstances, all reasonable steps must be taken to ensure the competence of those providing advice and carrying out work that are not under the direct control of the responsible person. Good governance with clear lines of responsibilities and communication between the responsible person and any contractors/consultants appointed should be agreed, properly established and clearly documented.

Carrying out a risk assessment

1.12 To be able to carry out a risk assessment, the assessor should be competent and be familiar with the type of systems to be assessed and consider the system as a whole. They should be aware of the factors which increase the risk of legionellosis and the control measures appropriate for the individual systems in question. Both human and environmental risk factors need to be considered and these are discussed below.

Human susceptibility factors

1.13 The likelihood of acquiring Legionnaires' disease is greater in individuals who are more vulnerable because of age or underlying disease. Legionnaires' disease principally affects older adults; men are more likely to acquire Legionnaires' disease than women with a ratio of approximately 3:1. Those who are most at risk include:

- smokers;
- those over 50 years of age – the risk increases with increasing age;
- those who have depressed immune systems as a result of illness or treatment;
- those with underlying chronic diseases such as diabetes and chronic lung and heart disease (European Centre for Disease Prevention and Control (ECDC), 2016).

1.14 The case fatality rate for community-acquired cases is currently 10% and despite the availability of appropriate antibiotic treatment a certain number of deaths are recorded each year in otherwise healthy persons with no known underlying risk factors.

Environmental risk factors

1.15 The risk of legionellosis associated with a water system or piece of equipment utilising water is dependent on its design, installation, commissioning, operation, management and maintenance. The more complex the system, the greater the likelihood of colonisation either within the system or within areas and/or components in, or attached to, the system.

1.16 Where water is present, which can, at any time, be within the range of 20°C to 45°C, there is the potential for *Legionella* to be present and grow unless there are precautions in place to prevent or control its growth. Infection most commonly occurs when *Legionella* are disseminated in aerosols derived from sprays and inhaled deep into the lungs. In rare cases Legionnaires' disease can be acquired by aspiration[4], usually in hospital patients, but can also occur in certain vulnerable groups who have swallowing defects such as those with motor neurone disease, stroke patients and very elderly people.

1.17 The risk of legionellosis is present when:

- there are conditions suitable for microbial growth to levels which may cause infection, for example:
  - a suitable temperature for growth (20°C to 45°C),
  - poor or no flow,
  - where they may be ingress from cross-connections especially during maintenance,
  - where there is inadequate backflow protection,
  - where there are inappropriate materials providing a source of nutrients for growth and biofilm formation including sludge, scale, rust, algae and other organic matter,
  - where there is a means of creating and disseminating inhalable droplets such as the aerosol generated by an evaporative cooling tower, operating a tap, showering, operating a spa pool or indoor fountain, or flushing a toilet,
  - where there is the potential for contamination from poor source water quality and absence of point-of-entry (POE) treatment, for example where supply quality is:
    - not from a public utility
    - not of consistent potable quality
    - intermittent or through a bowser or other supply method.

Information note

It is important to recognise that while *Legionella* may have been expelled from the source within a water droplet, by the time they are inhaled deep into the lungs the liquid component will have largely evaporated, leaving very small particles of between approximately one and three micrometres (1–3 μm) which are not visible to the naked eye.

Assessment of risk

1.18 The following paragraphs provide a summary of risk factors for typical systems. These factors should be considered, when applicable, when carrying out the technical risk assessment for typical systems. More detailed checklists of items

[4] Aspiration occurs when water enters the lungs instead of the gullet when swallowing commonly referred to as "going down the wrong way"

to be considered for different systems and the inspection frequency checklists for the different systems are given in this part and at the end of Part 3.

1.19 The risk assessment should cover all aspects of operation and ensure that the system is working efficiently and safely by checking:

- **Design**: good design can minimise the risk of causing Legionnaires' disease by:
    - ensuring systems such as evaporative cooling systems are enclosed as much as possible to prevent aerosol egress;
    - ensuring that the system design limits the potential for heat transfer and ensures good flow to **all** parts of the system;
    - ensuring that there is sufficient space and access for cleaning and maintenance.
- **Potable quality water at point of entry and during storage:** having a continuous, good quality potable supply entering the system. Point-of-entry treatment may be necessary where supplies are intermittent, high in particulates or not of consistent drinking water quality. Stored water should be held for the minimum time, ideally less than 24 hours, to avoid microbial growth and temperature gain and there should be cross-flow within the tanks so there are no stagnant areas. However, in areas where there are water shortages, this may not be achievable. In such cases other control measures (e.g. chlorination) should be put in place.
- **Good hygiene practices to minimise the risk of contamination during installation and commissioning:**
    - ensuring systems are installed and commissioned to minimise the potential for microbial colonisation and growth;
    - minimising the potential for ingress of dirt by ensuring components and pipework is suitably protected and capped as appropriate;
    - ensuring that new components and equipment (including spa pools/hot tubs) which have been tested with water without adequate precautions to prevent colonisation are disinfected before installation or alternative testing regimes are used where safe to do so (e.g. pressure-tested with gas or sterile water, or disinfected following testing).
- **The timing of commissioning and occupation to ensure that the length of time the building was unoccupied was minimised following system filling:** ensuring that during commissioning the system is filled with water as close to occupation and normal use as possible, flushed to remove nutrients which may be present following construction and/or installation, and disinfected will minimise the risk of colonisation. In large buildings, especially those requiring extended fit-out times, the systems and any attached equipment should be flushed regularly (at

least weekly) to keep water moving as though the building was in normal use.

- **Water flow in all parts of the system**: avoiding water stagnation and low flow. Stagnation may encourage the growth of biofilms (slimes that form on surfaces in contact with water) which can harbour *Legionella* and provide local conditions that encourage its growth. Areas which encourage stagnation include:
    - areas with low or no flow such as oversized storage tanks;
    - dead-legs including outlets not used for longer than a week;
    - blind ends (capped off lengths of pipework with no flow);
    - equipment attached to the system which is infrequently used.
- **Materials and components:** avoiding the use of materials and components in the system that can harbour or provide nutrients for bacteria and other organisms – e.g. natural compounds such as rubber washers, and jointing compounds including hemp and flexible hoses lined with materials that support growth and which may become constricted when fitted.
- **Management and maintenance:** keeping the system clean to avoid the accumulation of sediments which may harbour bacteria (and also provide a nutrient source for them) and ensuring that the system operates safely and correctly and is well maintained.
- **Implementation of an effective scheme of control:**
    - **suitable temperature control** – avoiding water temperatures of between 25°C (ideally 20°C if achievable) and 50°C (preferably 55°C) in any part of the system for any period of time is a particularly important factor in controlling the risk.
    - **validated water treatment regime** – if the temperature regime cannot be achieved in all parts of the system, installing a suitable and validated water treatment programme where it is appropriate and safe to do so.
    - **monitoring** – ensuring that appropriate parameters are being monitored, that target levels are consistently reached and that timely and effective remedial actions are carried out.

For the risk assessment of evaporative cooling systems, see also paragraph 1.56.

Risk assessor requirements

1.20 Those carrying out risk assessments should have an understanding of the factors which lead to the colonisation and growth of waterborne pathogens, including *Legionella*, and how these can be prevented or controlled. The person conducting the risk assessment should therefore be familiar with the type of system to be assessed and be competent to assess risks present of exposure to *Legionella* in all systems on the site and the effectiveness of control measures. If microbiological samples are to be taken as part of the risk assessment process, the assessor should have been trained to know how and when to take samples and where to take them from.

Scope of risk assessment

Information note

While *Legionella pneumophila* serogroup 1 is the strain most associated with causing community-acquired cases, the detection of other strains of *Legionella* in routine testing does not necessarily mean the risk is reduced. This is because during routine testing only a minority (maybe as few as one or two colonies on a culture plate) will be tested. For outbreak investigations public health laboratories will take multiple picks, but to be sure that the outbreak strain has not been missed around 30 picks for confirmation will be necessary.

1.21 The risk assessment should also include a check of the governance arrangements to ensure that appropriate chains of accountability and communication are in place for the organisation with a clear definition of roles and responsibilities to appropriately manage risks associated with all water use on site.

1.22 The risk assessment should take account of all plant/equipment and components and any equipment associated with, or connected into, the system (all associated pipework, pumps, feed tanks, valves, showers, heat exchangers, quench tanks, expansion vessels, chillers, pools, whirlpool baths, recreational hair and beauty equipment, etc.).

1.23 It is important that the functioning of the system and associated equipment is considered as a whole and not in isolation (e.g. considering a cooling tower without taking the supply water quality into account). A risk assessment of a water system cannot be completed if access is not available to all areas of the system including plant rooms, rooftop cooling towers and balance tanks. An assessment which excludes part of the system is not valid, suitable or sufficient.

1.24 Within distribution systems used on a seasonal basis such as in hotels, cruise ships, campsites, leisure complexes, etc., dead-legs, blind ends and parts of the system used intermittently, including sections of buildings that are closed in low season, also need to be included as part of the system since they can create particular problems with microbial colonisation and growth going unnoticed. There should be a procedure for safe decommissioning and recommissioning. Once brought back on-line, mothballed systems can release high levels of contamination which might overload the water treatment regime and result in dissemination of *Legionella* throughout the system.

Risk assessment requirements

1.25 The risk assessment should provide adequate information for the user and the investigator about the risks from each system and the measures necessary to ensure that the water systems are safe and without risks to health. The risk assessment is a critical component of a WSP (see paragraphs 3.3–3.6) and should be regularly reviewed and updated. Checks should be made to ensure it includes consideration of:

- the identification of all the water systems and associated equipment and components to be considered (asset register);
- the temperature of the incoming water (at the warmest time of the year) and throughout all parts of the system including an assessment of the potential for thermal transfer;
- the potential for aerosol generation;
- an up-to-date and valid schematic diagram;
- an assessment of the vulnerability of persons likely to be exposed, especially when there may be exposure sources which cannot be treated (such as natural spas in some countries);
- identification of areas which may not be used consistently (e.g. seasonal occupation or use in hotels rooms, sports pavilions and changing rooms or where water storage vessels have no or low turnover);
- assessment of each system for points where contamination could enter/occur including during maintenance;
- assessment of factors and or materials present which could promote the growth and dissemination of legionellae and other waterborne hazards;
- assessment of the effectiveness of the current control measures and the monitoring programme put in place to verify ongoing control, including:
    - the results of on-site monitoring such as biocide levels, pH, temperature, turbidity, dissolved solids and dip slides (for cooling towers) together with the results of laboratory-determined microbiological and chemical parameters (e.g. *Legionella* and heterotroph counts (TVC), chlorine dioxide, and copper and silver concentrations (where used)),
    - recommendations for improvement where needed,
    - whether remedial actions have been taken as recommended in the risk assessment,
    - appropriate and timely actions taken follow an adverse monitoring result;
- a review of governance procedures and the chains of communication are in place and up to date, including the management structure, the

responsibilities and accountabilities of the individuals concerned, their training requirements and measurement of competence.

Survey

1.26 A site survey should be carried out to identify and assess all potential sources and the risk of exposure to *Legionella* in all premises. For example, a hotel risk assessment may include:

- all hot and cold distribution systems;
- any evaporative cooling;
- water in leisure facilities including pool water systems;
- water features and the like;
- water associated with health and beauty salons such as hairdressing stations and hydrotherapy treatments.

1.27 The assessment (see paragraphs 1.18–1.19) should include a full inspection of each relevant system to identify and evaluate potential sources of risk and how exposure to *Legionella* is to be prevented (e.g. replacing an evaporative cooling tower with a dry system or the closure of non-critical systems such as a spa pool or fountain).

Note

Those inspecting systems and taking samples should be familiar with all aspects of the system to be assessed and appropriate systems of control. It is particularly important that the hydraulics of all the circulating systems are understood and fully investigated. Adequate flow throughout all parts of a system is an essential component of water system control, and each system should be checked to ensure there are no areas where flow is not maintained so that the temperatures and biocide levels required for effective control cannot be achieved throughout the system.

1.28 The individual nature of each site should be taken into account. The site survey should include an asset register of all associated plant and equipment (e.g. pumps, strainers, thermostatic mixing valves (TMVs) and other relevant items). It should then be decided which parts of the water system's specific equipment and services are likely to pose a risk to those exposed. The effectiveness of the precautionary measures to reduce the risk should be also assessed for each system – i.e. is the risk from exposure to *Legionella* effectively controlled?

Documentation review

1.29 The fully documented record of the risk assessment should be kept and linked to other relevant health and safety records together with all records of monitoring and should also include records of any remedial work carried out on each system and who carried out the work. This can be maintained in the form of a system logbook. The assessment of the documentation should include:

- A review of the documentation of the risk assessment and the systems for implementing and monitoring the control scheme and detail which items should be included in the written scheme for the control of the risk.
- The timing and triggers for regular review of the control measures, including the role of real-time system monitoring and microbiological sampling.
- An assessment of the training and competence of staff and contractors to carry out their task effectively.
- Checks on the procedures in place to deal with foreseeable predictable events.
- Assessment of cleaning and disinfection procedures. with a description of the operation of the water system plant to ensure that adequate control is maintained including checks of warning systems and diagnostic systems in the event of system malfunction together with remedial measures to be implemented.
- Commissioning and recommissioning procedures.
- Shutdown procedures and opening procedures following temporary shutdown (e.g. during winter).
- Maintenance requirements and frequencies.
- Operating cycles – to include when the system plant is in use or idle.
- Foreseeable breakdowns in key components (e.g. a chemical dosing pump).
- Actions when a case of Legionnaires' disease is associated with the building.
- Foreseeable predictable events likely to result in poor water quality (e.g. areas which are prone to flooding, drought and intermittent water supplies).
- The implementation of the water system control scheme should be regularly and frequently monitored and all persons involved in any related operational procedure should be properly supervised. Staff responsibilities and lines of communication should be properly defined and clearly documented.
- Arrangements have been made to ensure that appropriate staff are available during all hours when complex water systems are in operation. The precise requirements will depend on the nature and complexity of the water system. Appropriate provision should be made to ensure that the responsible person or an authorised deputy can be contacted at all times.

Note

Communication and management procedures are particularly important where several people are responsible for different aspects of the operational procedures. For example, responsibility for applying precautions may change when shift work is involved, or the person who monitors efficacy of a water treatment regime may not be the person who applies it. In such circumstances responsibilities should be well-defined in writing and understood by all concerned. Lines of communication should be clear, unambiguous and audited regularly to ensure they are effective. This also applies to outside companies and consultants who may be responsible for certain parts of the control regime.

- Call-out arrangements for persons engaged in the management of water systems that operate automatically are maintained. Details of the contact arrangements for emergency call-out personnel should be clearly displayed at access points to all automatically or remotely controlled water systems and control equipment. These should be regularly reviewed to ensure they are up to date.

Low risk systems

1.30 In buildings where the assessment has demonstrated that there is no reasonably foreseeable risk or that risks are insignificant and unlikely to increase, no further action may be required. However, there should be available a written record of reasons leading to this conclusion, which should be kept. There must also be a regular review to ensure there have been no significant changes/alterations or additional water sources brought on to the site which may change the assessment. If the situation changes, the assessment should be reviewed and any necessary changes implemented.

Managing the risk: management responsibilities, training and competence

1.31 Inadequate management, lack of training and poor communication have all been identified as contributory factors in outbreaks of Legionnaires' disease. Management and communication procedures should be regularly reviewed and appropriate checks should be made of those who have been appointed to carry out the risk assessments and any control measures to ensure they are suitably informed, instructed and trained and that their suitability has been assessed. The assessment should include the following:

a. To check whether staff have been properly trained to a standard that ensures that tasks undertaken are carried out in a safe and technically competent manner.

b. To check whether regular refresher training has been undertaken and records of all initial and refresher training are up to date and have been maintained. It is recommended that an understanding of the system is established through dialogue and reliance is not put solely on certificates. Merely proof of attending a course is not sufficient to establish competence. Training is an essential component of competence; it is not the only component – it is also essential to have sufficient experience, knowledge and other qualities that are required to undertake a job safely.

c. Competence assessments: competence is dependent on the needs of the situation and the nature of the risks involved, but it is essential that those carrying out key tasks in water system management, including any operational tasks and monitoring, understand the reasons for monitoring, what the target levels should be and what action to take when results are out of the target range. Periodic checks should be made to ensure competence is maintained.

Risk assessment review

1.32 The risk assessment should be reviewed regularly (at least every two years) or whenever there has been a significant change which means there is reason to suspect that it is no longer valid, such as:

- changes to the water system;
- changes to the frequency of use of water systems or associated equipment or the type of use;
- the availability of new information about risks or control measures;
- if the results of checks indicate that control measures are no longer effective;
- changes to key personnel;
- a case or cases associated with the premises.

Preventing or controlling the risk: the scheme of control

1.33 Once the risk has been identified and assessed, a written scheme should be prepared for preventing or controlling it. In particular, it should contain such information about the system as is necessary to ensure the risks from exposure are minimised as far as reasonably practical. The written scheme should specify the measures to be taken to ensure that it remains effective, together with procedures for remedial action in the event that the control scheme is shown to be ineffective. The primary objective should be to avoid the conditions that permit legionellae to proliferate and to avoid creating a spray or aerosol. If it is practicable to prevent a risk by replacing a piece of equipment that presents a risk with one that does not, this should be done.

1.34 The written scheme of control should give details on how to use and carry out the control measures and water treatment regimens including:

- the physical treatment programme (e.g. the use of temperature control for hot and cold water systems);
- the chemical treatment programme, including a description of the manufacturer's data on effectiveness, the concentrations and contact time required; the management of breakdown products, and data verifying that these measures are effective in the system being considered;
- health and safety information for the storage, handling, use and disposal of chemicals;
- system control parameters (together with allowable tolerances): these parameters may be physical, chemical and microbiological, together with measurement methods and sampling locations, test frequencies and procedures for maintaining consistency;
- remedial measures to be taken in the event that the control limits are out of the acceptable target range, including lines of communication to be followed;
- cleaning and disinfection;
- emergency procedures.

Review of control measures – monitoring and routine inspection

See also paragraphs 1.58–1.60 on inspecting hot and cold water systems.

1.35 If precautions are to remain effective, the condition of the system and performance of the control measures will need to be monitored. This should be the responsibility of the responsible person/WSG or, where required, a competent external contractor or an independent third party and should involve a system for:

- checking the performance of the system and its component parts;
- inspecting the accessible parts of the system for damage and signs of contamination, scale and corrosion;
- reviewing monitoring results to ensure that the treatment regime continues to control the system to the required standard. The frequency and extent of routine monitoring will depend on the operating characteristics of the system, but some should be carried out at least daily – e.g. checking that there is sufficient biocide available and that the usage is within normal limits;
- testing of water quality, which is an essential part of the verification of the treatment regime, especially in cooling towers and spa pools. This may be carried out by a service provider (e.g. a competent water treatment company or consultant) or else by the operator, provided they have been

trained to do so and are properly supervised. The type of tests required will depend on the nature and usage of the system;

- the routine monitoring of background bacterial counts (total viable count (TVC)) in evaporative cooling towers and spa pools. This is also appropriate as an indication of whether microbiological control is being achieved and whether a disinfection procedure has been effective. This can also be useful for verifying that a system or tank disinfection has been effective if samples are taken before disinfection and then again at least 48 hours after disinfection[5];
- periodic sampling and testing for the presence of *Legionella* based on the risk assessment. This may also be appropriate as an indication that the control measures are effective.

Microbiological monitoring

1.36 It is important to understand a sample taken from a water system is only a small proportion of the total system volume and that a negative *Legionella* result does not necessarily mean the entire system is safe and under control. Microorganisms are not uniformly distributed throughout the water system all of the time, especially in areas of poor flow and stagnation or where controls are not effectively maintained. Generally, water samples should be taken for routine sampling as the results are comparable over time and are therefore useful for trend analysis. However, in investigations, or when following up adverse results, swab samples may be a useful addition. There are many published methods for the detection of *Legionella* from water samples including those in both international and national standards. The International Standardization Organization (ISO) produces standard methods including for the detection of *Legionella* by culture (ISO 11731). Within Europe, CEN – the Committee for European Standardization (Comité Européen de Normalisation) – is recognised as competent in the area of voluntary technical standardisation and is listed in Annex I of European Directive 98/34/EC. CEN has adopted these ISO standards for use within the EU. This means that standards bodies in countries within the EU must adopt them for use. Most published methods are optimised for the growth of *Legionella pneumophila* serogroup 1 as this was the first species to be recognised and is the type species which accounts for approximately 90% of all outbreaks. Any methods used which deviate from EN ISO 11731 (International Organization for Standardization, 2017) should be validated using ISO 17994 (International Organization for Standardization, 2004).

1.37 Samples should be taken in accordance with nationally and internationally accepted methods (e.g. the international standard ISO 19458 (International Organization for Standardization, 2006)) or national guidance (e.g. in the UK, BS

[5] Samples should not be taken before 48 hours following disinfection as this may lead to a false negative result. Injured microorganisms may not grow if the tests are carried out immediately but may recover and continue to grow after a period of recovery.

7592 (British Standards Institution, 2008); BS 8554 (British Standards Institution, 2015)) and sent to laboratories which hold ISO 17025 accreditation (International Organization for Standardization, 2005) for the tests required within the scope of accreditation (e.g. for *Legionella* by culture ISO 11731 (International Organization for Standardization (2017)).

1.38 The sensitivity of the method should be such that the laboratory can reliably recover 100 cfu/ litre or less. The laboratory's ability to recover viable cells is critically dependent on the time delay between sampling and culture, and care should be taken to avoid exposure of samples to adverse temperature conditions (e.g. freezing or overheating).

1.39 Accredited laboratories should take part in a nationally or internationally approved external quality assurance scheme for *Legionella* testing from water samples. Where oxidising biocides are used (e.g. chlorine, bromine and chlorine dioxide), the sample bottles should contain an effective neutraliser such as 18 mg/l sodium thiosulphate to prevent the biocide present at the time of sampling from continuing to work until the samples are processed in the laboratory (for sampling advice, see paragraphs 2.3–2.26). When non oxidising biocides are used it is important to inform the laboratory so that it can ensure the samples are processed as soon as possible after receipt in the laboratory because non-oxidising biocides cannot be effectively neutralised. Samplers should also make a note on the sample submission form when non-oxidising biocides are used. The microbiologist interpreting the results of samples from systems with non-oxidising biocides should take into account the timing of the last dose of biocide and the time interval from sampling to testing.

Alternative methods

1.40 For culture methods, laboratories should use the current ISO method; EN ISO 11731:2017. Molecular methods such as quantitative polymerase chain reaction (q-PCR) can give a same-day result, which is valuable in investigations, especially when used to exclude potential sources. ISO/TS 12869 has been developed for the use of q-PCR with water samples (International Organization for Standardization, 2012). Where it is proposed to use alternatives, these should be validated to show they perform at least as well as the culture method. Reliably detecting the presence of *Legionella* is technically difficult whether by traditional culture methods or molecular detection, especially where the methods require specialist laboratory facilities. The interpretation of results is also difficult; a negative result is no guarantee that legionellae are absent and does not mean that the water is safe. Conversely, a low local count may not indicate a failure of system controls.

1.41 The use of q-PCR for the detection of *Legionella* has posed some difficulties for interpreting results in the context of compliance with guidelines. Within legislation and guidelines, target levels are based on culture which are normally expressed in terms of colony forming units per litre (cfu/l) while those of q-PCR are expressed as genome units per litre (GU/l). This difference has sometimes led to confusion as these results are not interchangeable for a variety of reasons (see paragraphs 2.27–2.28).

Interpretation of results

1.42 It is essential, therefore, that a suitably experienced and competent person should interpret the results of monitoring and testing in the context of where and when the sample was taken, taking into account the levels and timing of any biocide treatment and the temperature of the water at the time of sampling. Where necessary, any remedial measures should be carried out promptly and verification obtained that they have been effective.

External audit

1.43 An external competent person should audit the risk assessment and operation of the control measures regularly (at least every two years) and also if there has been a case or cluster of cases linked to the system.

Record-keeping

1.44 The responsible person(s) should ensure that appropriate records are kept, including details of:

- the person or persons responsible for conducting the risk assessment and managing and implementing the written scheme;
- the findings of the risk assessment;
- the control scheme and details of its implementation;
- details of the state of operation of the system – i.e. in use/not in use;
- the results of any validation, monitoring, inspection, test or check carried out, and the dates;
- all personnel concerned with the running and maintenance of the system and their training records.

1.45 Records should be retained throughout the period for which they remain current and for at least two years after that period except for records relating to monitoring and inspection which should be kept for five years.

Contractor obligations

Competence of risk assessors

1.46 Persons who are contracted to give advice pertaining to system water safety, carry out system risk assessments and who draw up, implement and monitor precautionary measures should have the ability, experience, instruction, information and training on the specific systems to be assessed. They should also possess the required resources to allow them to carry out their tasks competently and safely. In particular, they should know about:

- the systems to be assessed and the risks they present;
- the appropriate measures to be implemented to control the risks, including precautions to be taken for the protection of people who may be exposed, and the relative effectiveness of the measures;
- the actions to be taken to ensure that controls remain effective and the significance of the controls.

1.47 The person(s) conducting the assessment must be competent to assess the risks of exposure to *Legionella* in building water systems, and have sufficient knowledge of the necessary control measures to assess their appropriateness and effectiveness in the system being assessed (e.g. a microbiologist, environmental health officer or water engineer with this specific expertise). Where outside contractors are used to carry out risk assessments and advise on control measures (e.g. where there is insufficient in-house competence), the responsible person must ensure they are competent and have the resources to carry out the tasks effectively (see paragraph 1.20 and paragraphs 1.46–1.48).

1.48 The employment of contractors or consultants does not absolve the owner/person responsible for health and safety of staff and visitors on the site of the responsibility for ensuring that control procedures are carried out to the standard required to prevent of the proliferation of *Legionella*. It is important that those employing contractors (and subcontractors if applicable) make every effort to ensure they have the necessary training and competence in the area of work before entering into contracts for the treatment, monitoring and cleaning of water systems, and other aspects of water treatment and control. Where a site has several systems (e.g. a hotel and leisure complex where the hotel has an air conditioning system cooled by a water tower, and the leisure complex has swimming and spa water systems, hair and beauty salons, etc., together with domestic hot and cold water systems), it may be necessary to assemble a team of assessors with appropriate expertise in each of these areas.

Suppliers of services

1.49 Suppliers of products and services, including those who supply consultancy and water treatment services aimed at preventing or controlling the risk of exposure to *Legionella*, should, so far as is reasonably practicable:

- ensure that measures intended to control the risk of exposure to *Legionella* are so designed and implemented that they will be effective, safe and without risks to health when used at work;
- provide adequate information on the correct and safe use of products, taking into account the circumstances and conditions of their use;
- ensure that any limitations on their expertise or on the products or services they offer are clearly defined and made known to the person(s)

who is defined as having the duty of care/managerial responsibility in national legislation or guidelines;

- ensure that any deficiencies or limitations which they identify in the building systems assessed or in the written scheme to control the risk of exposure to *Legionella* are communicated to the person defined as having the duty of care/managerial responsibility in national legislation or guidelines;
- ensure that their staff have the necessary ability, experience, instruction, information, training and resources to carry out their tasks competently and safely.

Installers of systems and equipment

1.50 Outbreaks of Legionnaires' disease have been associated with faulty installation of equipment used in buildings including hotels. Whoever designs, manufactures, imports or supplies water systems that may create a risk of exposure to *Legionella* should, so far as is reasonably practicable:

- specify the usage and conditions under which the system has been designed and its intended use;
- ensure that the water system is so designed and constructed that it will be safe and without risk to health when used as intended;
- provide sufficient documentation so that when installed and commissioned according to the manufacturer's instructions it is safe and without risk to health if used and maintained as intended.

1.51 All water systems should be properly installed and commissioned as appropriate. New systems may contain high nutrient levels derived from the surfaces of some new materials and dirt entering the system while under construction. Consequently they should not be left with water in for prolonged periods before opening, but be filled as late as possible and disinfected and flushed with fresh water within two weeks before opening. Failure to ensure that the systems are commissioned safely could lead to long-term system management problems and ongoing costs.

1.52 Where it is anticipated that the building will not be fully occupied for some time, consideration should be given to only partially filling the system in those areas to be used. Each new system should have a risk assessment carried out before commissioning, which should be reviewed after a few months of normal use.

Inspecting evaporative cooling systems

1.53 Evaporative cooling of water within cooling towers and evaporative condensers are widely used to dissipate heat from air conditioning, refrigeration and industrial process systems. They use the evaporation of water to achieve the cooling effect. They include open-circuit cooling towers which are the most common and can range in size from small packaged towers (used in air conditioning and light industrial applications) up to large towers (including hyperbolic towers) for heavy industrial, petrochemical and power generation applications.

1.54 All evaporative cooling systems, except for large natural draught towers, have a fan system to force or induce airflow through the unit. The UK Health & Safety Executive guidance HSG274 Part 1 (Health & Safety Executive, 2013b) contains much useful information on the various designs and types of cooling towers and good guidance and management practice.

1.55 Evaporative cooling systems are the cause of the largest outbreaks of legionellosis and the highest number of cases, as those located on the roofs of buildings have the potential to produce contaminated aerosols which may spread over large distances and infect large numbers of people. It is imperative that they are managed to prevent the colonisation and growth of microorganisms, including *Legionella*, and the potential release of contaminated aerosols.

Risk assessment of evaporative cooling systems

1.56 Factors the risk assessment for evaporative cooling systems should take into account include:

a. The location/position of the evaporative cooling system in relation to air intakes and surrounding buildings (e.g. towers close to food manufacturing premises are more likely to accumulate nutrients and make control more difficult).

b. The vulnerability of the population to be exposed (whether the towers are close to healthcare facilities for example).

c. Whether the release of water spray from the tower is properly controlled by having tight-fitting high-performance drift eliminators in place which are in good condition.

d. Whether there are conditions (such as sludge, rust, scale or organic matter) that support the growth of microorganisms including *Legionella*. (if possible look inside the pack to see if there is scale or sludge).

e. Whether there are any areas where water can stagnate in the system. (Stagnation can be avoided by ensuring there is regular movement of water in all sections of the distribution system and pond, by keeping pipe lengths as short as possible, and/or removing redundant pipework and dead-legs and ensuring there is good water circulation.)

f. The materials used should not encourage the colonisation and growth of bacteria and other microorganisms or provide nutrients for microbial growth.

g. Whether all parts of the system can be kept clean. For example, are the distribution channels free from dirt and debris (uneven accumulation of dirt and debris in the distribution channels may indicate poor water management).

h. Whether the water is effectively treated to either control the growth of microorganisms, including *Legionella*, or limit their ability to grow (check the monitoring results).

i. Whether there is an up-to-date written control regime and whether it has been validated.

j. When microbiological samples are taken, whether they are taken at a time which represents the highest risk (worst-case scenario) – i.e. just before a biocide dose is due – and whether the sampling location represents the highest risk in the system (usually the warmest places or areas with low flow). If samples are taken from the pond of the cooling tower, they should be taken as far away as possible from the incoming make-up water supply and biocide dosing point.

k. Whether the personnel managing and sampling the system are trained and competent (don't just rely on certificates; check they understand the system).

Checks on documentation

1.57 Checks should be made on any associated reports and certificates and other actions taken, such as maintenance, remedial actions and repair work. Records should be readily available and up to date and include:

- training and competence checks on all operational personnel;
- records of inspections and checks on the cooling system components and water treatment equipment carried out to confirm correct and safe operation;
- checks on:
    - regular chemical and microbial analysis of the water,
    - the remedial actions taken for out-of-specification results and whether they are timely and appropriate and whether there is evidence that they have been effective,
    - water treatment chemical usage,
    - regular maintenance to the cooling system and components, equipment and the water treatment system together with calibration of measuring devices/probes and the like,
    - cleaning and disinfection procedures and when they were carried out and by whom;
- an up-to-date schematic diagram.

See Figure 1 and Table 1 on the following pages.

Figure 1 Schematic example of installation with cooling towers and the key components to review during risk assessments (see Table 1 on next page)

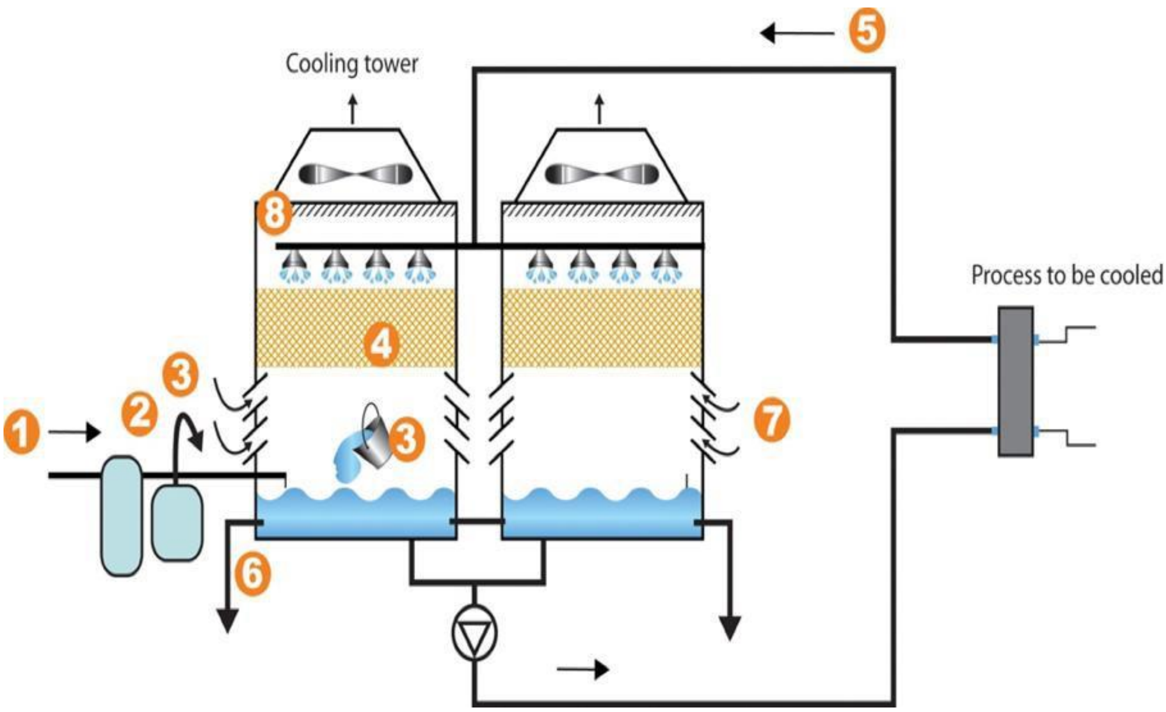


Table 1 Key points for auditing a cooling tower system (see Figure 1 on previous page)

1.	**Supply water**	Check the source and quality. Review any testing results and the incoming temperature.
2.	**Treatments against scaling and corrosion**	• Check the system is working and dosing correctly (for further information see Part 3 and HSG274 Part 1 (Health & Safety Executive, 2013b, paragraph 1.40). • Check the surfaces for scale and the tower fabric for corrosion.
3.	**Treatments against microbial growth (biocides and biodispersants)**	• Check the dosing regime. • Are there regular checks to ensure the biocide is being used as expected on a daily basis (visual check on volume used)? • Check dip slide results and how these are done (e.g. are they incubated and read correctly?).
4.	**Tower fill or pack**	• Check for slime, scale and corrosion (gently pull the pack apart; if available, check with a borescope inside the pack). • Check when the pack was last removed and cleaned.
5.	**Circuit of water cooled by cooling towers (exposed to air within tower)**	• Check the distribution channels for debris, sludge and slime. • Is there evidence of uneven distribution? • Are the pumps working effectively? • Check the pond for clarity, debris, slime and sludge.
6.	**Blow-down/discharge network**	• Check the number of concentration cycles before blow-down. • Check total dissolved solids (TDS) results
7.	**Air inlet**	Check for dirt and debris.
8.	**Drift eliminator**	Check these are tightly fitting and not damaged.
Documentation		• Check there is an effective up-to-date written scheme for controlling exposure to *Legionella* which includes instructions for start-up, normal operation and shut down. • Is there an up-to-date schematic diagram? • Is there a logbook with up-to-date monitoring data, and are there any anomalies? • Have anomalies in results been addressed in a timely and effective manner?

Useful checklists are given in the Health & Safety Executive's (2003) *Control of Legionella Bacteria in Water Systems: Audit Checklists*

Inspecting hot and cold water systems

1.58 The frequency of inspecting and monitoring hot and cold water systems will depend on their complexity and the susceptibility of those likely to use the water. The risk assessment should define the frequency of inspection and monitoring, depending on the type of use and user, taking account of where there are adjustments made by the assessor to take account of local needs. Within hot and cold water systems, the risk areas that support growth of microorganisms, including *Legionella*, are controllable with good design, operation, maintenance and water system management. Areas which pose an increased risk of contamination and colonisation if not properly managed include:

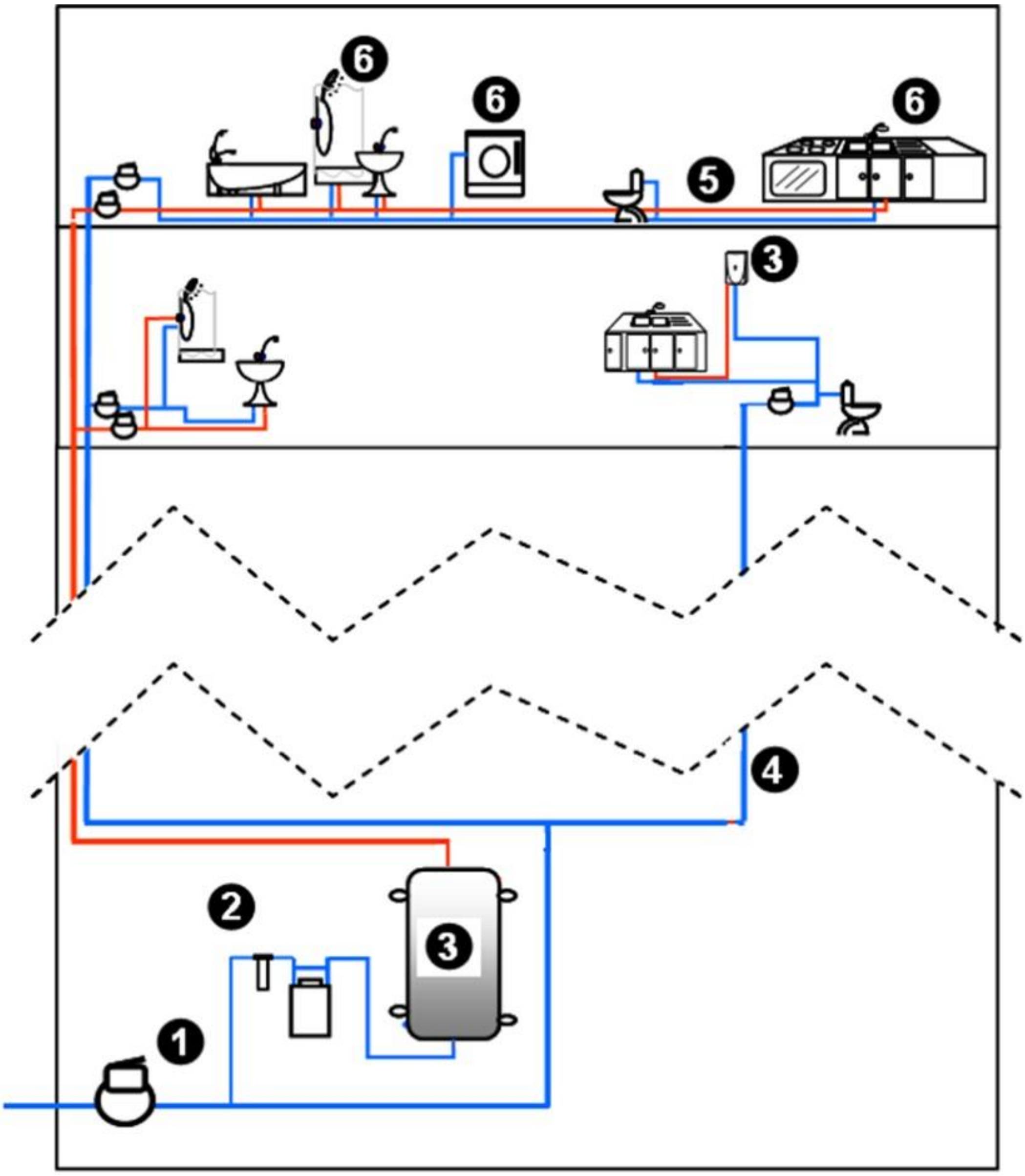
- the base of the water heater and storage vessel, particularly where incoming cold water reduces the temperature of the water within the vessel and where sediment collects and is distributed throughout the system;
- where optimum temperatures for microbial growth and stagnation occur (e.g. dead-legs, capped pipes (dead ends), infrequently used outlets and any areas of the system where there is poor circulation);
- where incoming cold water temperatures are above 20°C or there are areas within the cold water system that are subject to heat gain (hot and cold pipes running together or over heating panels, adjacent to pumps, etc.) and areas of stagnation where there are biofilms and deposits to support growth;
- where there are cool areas of the hot water system so temperatures fall within the range 20°C to 45°C.

1.59 Table 2 provides a checklist for hot and cold water systems with an indication of the frequency of inspection and monitoring. Further information on types of hot and cold water system and monitoring requirements can be found in Part 3 and in the UK Health & Safety Executive guidance HSG274 Part 2 (Health & Safety Executive, 2014).

Table 2 Key points for managing hot and cold water systems (see Figure 2 on next page)

1. **Incoming supply water and associated storage tanks**	• Is the incoming water consistently supplied and of wholesome potable quality? If not, is point-of-entry treatment implemented and effective? • Review any testing results and if any adverse results detected, is the remedial action carried out in an effective and timely way? • Are the incoming temperature and temperatures of storage tanks (including records for preceding 12 months) ≤25°C (preferably 20°C)? If not, is there a biocide dosing regime? • Check ambient air temperatures and insulation to assess the risk of increasing the stored water temperatures. • Check tanks for water and surface clarity, intact liners: is there slime, sludge and debris in the base of tanks? • Check if there are tight-fitting lids, insect screens, etc. • Check for areas of stagnation; if more than one tank is there adequate cross flow?
2. **Treatment systems (can be collective or individual)**	• Check the system is working and dosing correctly (for further information, see Part 3 and HSG274 Part 2 (Health & Safety Executive, 2014)). • Check the target concentrations are consistently achieved at the furthest outlets. • Check the dosing system, chemical probes and monitoring equipment have been calibrated within the last year.
3. **Water heater (can be combined, serving several outlets or individual serving one outlet)**	• Check the flow and return temperatures. • Check the return temperatures on each return loop. • Check the anti-stratification pump (if present) to ensure it is fitted so that flow is from top to bottom and only operated when there is little use (e.g. in the early hours of the morning for 1–2 hours). • Check the recovery time from periods of high use (e.g. following the morning bath/shower run).
4. Distribution pipes (mains, including eventual recirculation pipes)	• Check for slime, scale and corrosion. • Check that, where fire risers are in place, these are not off the distributed drinking water supply and there is adequate backflow protection.
5. Distribution pipes (secondary spurs)	• Check for dead-legs and blind ends. • Outlet usage (e.g. are there rooms that are rarely used?). • Decommissioning and recommissioning procedures are in place especially when systems are used on a seasonal basis.
6. Point of use	• Are sentinel outlets identified for routine monitoring of temperature, biocide levels (if required) and microbiological monitoring (if required)? • Are checks carried out to determine if hot and cold temperatures at representative outlets are: ○ for hot water, ≥50°C (preferably 55°C) within one minute of turning on the tap; ○ for cold water, ≤25°C (preferably 20°C) within 2 minutes?

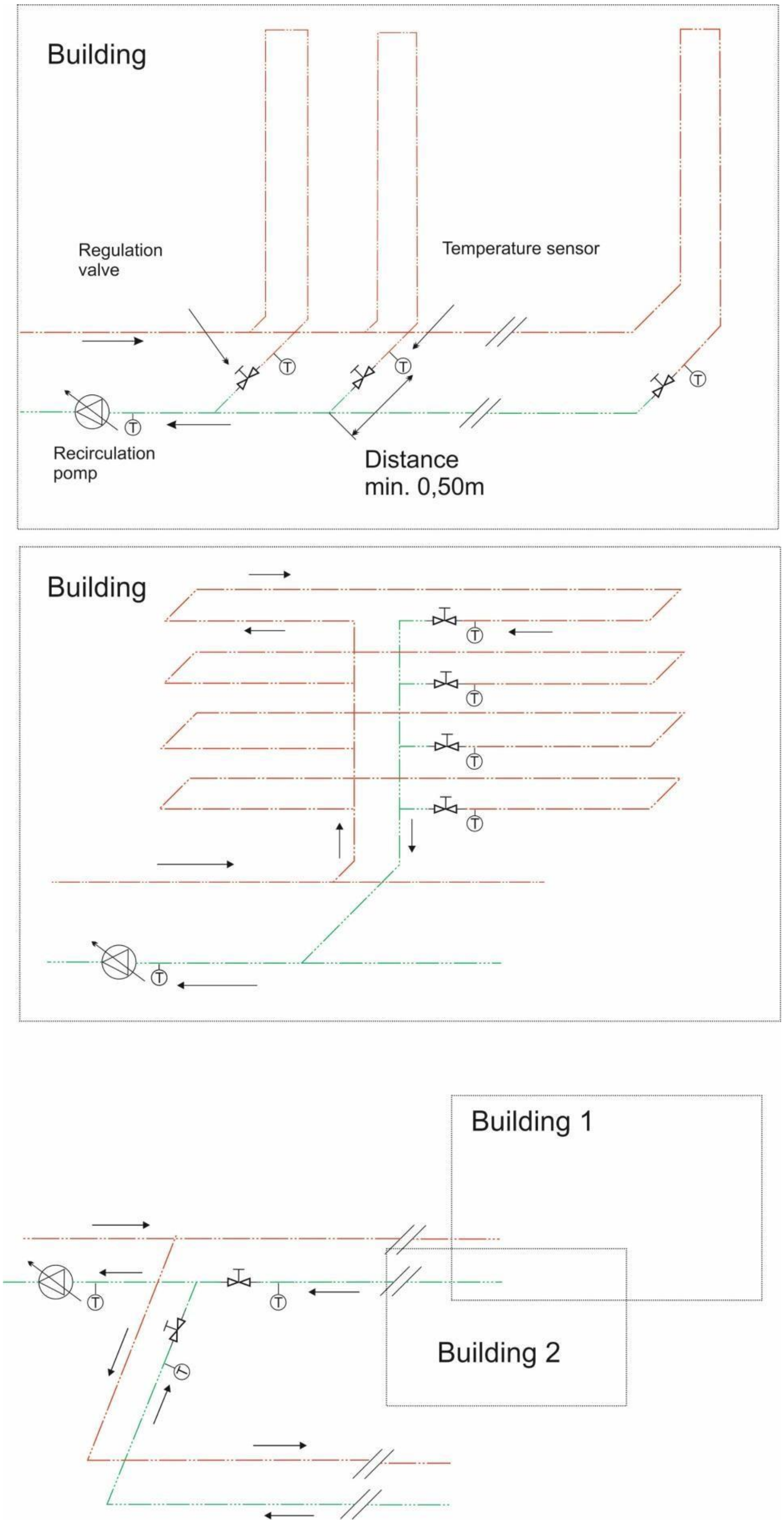
Figure 2 representation of water system with centralised and local water heating (see Table 2 on previous page)



Key components requiring consideration during risk assessments:
1. Incoming supply water and associated storage tanks
2. Treatment systems (can be collective or individual)
3. Water heater (can be combined serving several outlets or individual serving one outlet)
4. Distribution pipes (mains, including eventual recirculation pipes)
5. Distribution pipes (secondary spurs)
6. Point of use

1.60 Large buildings may have complex water systems with more than one loop. It is important that the whole system is balanced and the return of each loop to the calorifier is at a minimum of 50°C (see Figure 3).

Figure 3 Examples of hot water recirculation schemes



Checklist for conducting the risk assessment of legionellosis

Objective: To provide a simplified guide, for example, for public health authorities, investigating possible sources of Legionnaires' disease cases. This list assists with the completion of Form A for reporting travel-associated Legionnaires' disease cases to ECDC (http://ecdc.europa.eu/en/publications/Publications/1202-TED-ELDSNet-operating-procedures.pdf).

Method: The checklist below is a simple working tool devised to help the health officers to conduct the pertinent risk assessment at a determined establishment. The checklist is a simplified 15-point programme for reducing the risk. However, investigators should be familiar with the contents of the technical guidance within this document and if there are items of concern not on this checklist, then they should be assessed for their possible contribution to the acquisition of Legionnaires' disease.

The final evaluation and relevant recommendations should be based on the results of the checklist below and on other evidence gathered during the inspection of the premises, and should take also into consideration these Guidelines and any relevant local regulations.

Facility identification data:

____

Address:

____

: ____

: ____

: ____

Item to check	Yes	No	Comment/Action required
1. Assessment of the ability of premises personnel to control risk			
Is there a person or persons appointed with responsibility for *Legionella* control?			
Is this person(s), and other concerned relevant staff, properly trained in the control of *Legionella* and able to demonstrate they understand the system(s), risk factors and control measures?			
If an external firm is providing help and advice, have efforts been taken to ensure the contractors and operatives on site are trained and competent in this task and there is adequate supervision?			
2. Assessment of the control measures (domestic cold and hot water temperatures and biocide levels)			
Is there a continuous supply of source water of potable quality from a public utility?			
Is there a private water supply used for source water (e.g. well, spring or bunkered water)?			
If there is a private supply, is there adequate point-of-entry treatment?			
Is there evidence (e.g. monitoring of appropriate sentinel points throughout the year) that the hot water temperatures of the **entire** hot water system are kept all times between 50ºC and 60ºC?			
Is there evidence that the cold water temperatures of the **entire** cold water system are below 25ºC?			
Are there other preventive methods in place (chlorine, chlorine dioxide, copper/silver ions, etc.)?			
Is there evidence that there is adequate monitoring and effective biocide levels maintained in the entire circuits and up to the outlets?			
3. Assessment of other factors that may promote *Legionella* growth (low flow /stagnancy, scale, sediments, corrosion, etc.)			
Is there evidence that all taps, showers and any other points of water use in all buildings are flushed for several minutes (sufficient to remove any stagnant water) on a weekly basis?			
Are showerheads, hoses and tap filters, aerators etc., TMVs and sieves cleaned, descaled and disinfected on a regular basis as advised in the risk assessment? (The frequency will depend on scale deposition and usage.)			
Is there pipework with intermittent or no water flow (bypasses, dead-legs, blind ends, areas not used or used intermittently, etc.) in any part of the water network?			
Is there any visible or significant sediment, biofilm/slime, dirt, corrosion or scale deposit in any part of the water network?			
4. Assessment of the cleaning and disinfecting practices			
Are the calorifiers inspected, drained, cleaned and disinfected at least annually, and when a building is not used throughout the year, before the beginning of every season and after any maintenance?			

Item to check	Yes	No	Comment/Action required
Are cold water tanks inspected, cleaned and disinfected annually, and when a building is not used throughout the year before the beginning of every season?			
Is the entire water network disinfected when a building is not used throughout the year before the beginning of every season?			
Are water filters (sand filters, multimedia filters, etc.) and softeners disinfected regularly, at least every three months? Are carbon filters (where used) replaced according to the manufacturer's instructions and before the beginning of each season?			
Are there adequate written procedures for cleaning and disinfecting the water systems (e.g. 50 ppm chlorine for an hour)?			
5. Assessment of the surveillance and monitoring practices and associated documents			
Is there a written *Legionella* control programme in place for each system which could pose a risk?			
Is this programme suitable and sufficient for all the systems which could pose a risk of Legionnaires' disease in the premises?			
Are there regular records (logbook for example) of the critical monitoring activities kept on site (temperatures, chlorine levels, etc.)? Are appropriate actions taken to out-of-target results? Are these records reviewed by the responsible person(s)?			
Is a risk assessment review of the premises' water systems carried out regularly (at least every two years) or when there have been changes which may affect the risk assessment (e.g. change of frequency and type of use, key personnel)?			
Are both the risk assessment and operation of the control measures periodically audited by an independent and competent person?			
6. Assessment of particular water systems (spa pools, wet cooling towers) present at the premises			
If there is a spa pool, are there records to show that: • there are trained competent operatives on site? • there is continuous treatment with chlorine or bromine and pH adjustment (3-5 mg/l chlorine or bromine and pH at 7.0–7.6)? • chlorine/bromine and pH is monitored at least three times/day? • the dosing system is checked on a daily basis to check pumps are working and the expected amount of chemicals has been used? • half the water is replaced each day? • sand filters are backwashed at the end of every day after the last person has left the pool? • the whole system, including the balance tank, is cleaned and disinfected once a week? • daily records are kept of the temperature and all water treatment readings (chlorine/bromine, pH)?			

Item to check	Yes	No	Comment/Action required
• there has been an appropriate response to out-of-target results? • there is evidence to show they are checked regularly by responsible persons?			
If there is an evaporative cooling tower, ensure that: • there is evidence that a trained and competent person has carried out a risk assessment; • there is a trained and competent person in charge of the cooling tower treatment and monitoring regime; • there is evidence that there is an adequate water treatment regime implemented (with effective biocides, corrosion inhibitors and adequate bleed-off rates as a minimum); • there is a daily check to ensure the dosing systems are working effectively and the expected volume of chemicals is being used; • entire cooling tower and associated pipes are cleaned and disinfected at least twice a year (and where a building is not used throughout the year and before the beginning of every season); • the system is inspected monthly for ensuring that drift eliminators are intact and firmly in place; • a microbiological monitoring system and a chemical one (e.g. chlorine or bromine treatment) is in place; • samples are taken to represent the worst-case scenario i.e. just before dosing (if intermittent) and at the furthest point from where the biocide enters the system.			
Check and list other at-risk water systems present at the building within the near vicinity with indication of their hygienic status, for example: • beach/outdoor pool showers • irrigation systems; • misting devices (e.g. in food display cabinets); • ornamental fountains/water features (indoor); • ornamental fountains/water features (outdoors); • humidifiers (air conditioning); • natural thermal springs; • vehicle washers; • solar systems; • grey water and rainwater recovery systems. Are there any other systems in the vicinity which may pose a risk (e.g. wet scrubbers, industrial water systems, wastewater treatment plants/systems)? Others:			

1.61 For certain basic systems, a simple risk assessment may show that the risks are low and that no further action will be necessary. Some other water systems may need more elaborate approaches for a correct assessment, depending of the different circumstances (size, type, location, number and connections, etc.). See Part 3 for more detailed information.

Managing the *Legionella* risk: the 15-point WSP

1.62 In summary building owners should manage systems to ensure they are effectively managed by following the 15-point plan.

1.63 In complex sites such as hotels with leisure and beauty facilities, pools, etc., the *Legionella* management plan will form only a part of an overall WSP and this should be expanded to take account of all potential waterborne pathogens including the risk of *Cryptosporidia* and *Pseudomonas aeruginosa* contamination in pools and hot tubs. It is recommended that the WSP is audited both internally and externally to ensure it adequately covers all areas of the water systems which may pose a risk of infection.

The 15-point plan

1. Have at least one named appointed competent person or a WSG responsible for *Legionella* control.
2. Ensure the named persons have sufficient training and experience to be able to carry out their role competently and other staff are trained to be aware of the importance of their role in controlling *Legionella*.
3. Ensure that the source water quality meets the requirements of the EU Drinking Water Directive (Council Directive 98/83/EC) by:
    - ensuring that the water supply is continuous (intermittent supplies result in depressurisation of water supply pipework which is likely to result in the release of nutrients (biofilms, scale and corrosion) into the system) and that cold water is kept cold at all times. It should be maintained at temperatures below 25°C (ideally below 20°C) throughout the system to all outlets (this may not be possible when the ambient temperature is high, but every effort should be made to ensure that cold water entering a building and in storage remains as cold as possible). See Note below.
    - checking that there are appropriate backflow protection devices where there are connections from the drinking water system to non-potable water systems (such as fire suppression systems) and or equipment and that these have been checked on an annual basis.
4. Inspect the inside of cold water tanks at least once per year and disinfect with 50 mg/l chlorine and clean if they contain a deposit or are otherwise dirty.

5. Keep hot water hot and circulating at all times: at least 50°C at the outlets (too hot to put hands into for more than a few seconds) throughout the entire hot water system (ensure there are hot water warning signs so users are aware of the scalding risk).
6. Run all taps and showers in guest rooms and other areas for several minutes to draw through water (until it reaches the temperatures stated in points 3 and 4 (or target biocide levels where target water temperatures cannot be achieved)) at least once a week if rooms are unoccupied and always prior to occupation.
7. Keep showerheads, hoses and taps clean and free from scale and biofilm.
8. Clean, drain and disinfect water heaters (calorifiers) once per year.
9. Disinfect the hot water system and water heaters with high level (50 mg/l) chlorine for 2–4 hours after work on the system and before the beginning of every season.
10. Clean and disinfect all water treatment filters regularly as directed by the manufacturer, at least every one to three months. Note POU filters should not be replaced if removed but a new one fitted according to the manufacturer's instructions.
11. Inspect water storage tanks, cooling towers and visible pipework monthly. Ensure that all linings and coverings are intact and firmly in place.
12. Clean and disinfect cooling towers and associated pack and pipes used in evaporative air conditioning systems regularly – at least twice per year.
13. Ensure that when carrying out system modifications or new installations they do not create pipework with intermittent or no water flow, and disinfect the system following any work.
14. If there is a spa pool (also known as hot tubs, whirlpool spas and spa baths) ensure that:
    - it is continuously treated with 3-5 mg/l chlorine or bromine and the levels and pH (7.0–7.6) are monitored at least three times per day including at the beginning of each day;
    - any adverse monitoring results have been appropriately dealt with in a timely manner;
    - *Legionella* testing has been carried out by an accredited laboratory;
    - at least half of the water is replaced each day;
    - sand filters are backwashed daily **after** the last user has left the pool;
    - the whole system is cleaned and disinfected once per week.

15. Daily records are kept of all water treatment readings, such as temperature, pH and chorine concentrations and ensure they are checked regularly by the manager as being satisfactory.

Note

Where target temperatures cannot be achieved due to local conditions, suitable alternative residual disinfection procedures must be used and verified by regular testing for *Legionella*. Disinfection procedures that have been used successfully include chlorine, chlorine dioxide and copper/silver ionisation. If chlorine is used in the mains water supply, it may be still necessary to use a supplemental source of chlorine at the site in order to achieve a sufficient chlorine concentration at the terminal points (e.g. >0.2 mg/l). However, the efficacy of a biocide dosing system depends on the system conditions and water chemistry; any treatment system must be validated to ensure it is effective in each system and a monitoring plan put in place to ensure ongoing verification. It should also be noted that chlorine disinfection is more efficient when close to pH 7-0 and this should be the target.

1.64 Further advice about specific controls should be sought from experts in this field who can carry out a full risk assessment of the premises.

Part 2: Methods for the investigation and control of an outbreak of Legionnaires' disease in a hotel, other accommodation sites and other public buildings

General – competence

2.1 The appropriate health authorities, in accordance with national arrangements for communicable disease control, should investigate each outbreak. Sampling and microbiological analysis should be carried out by a laboratory that is accredited to ISO/IEC 17025 (International Organization for Standardization, 2005) or equivalent and includes detection of *Legionella* species from environmental samples within the scope of its accreditation. The laboratory should be capable of the recognition of *Legionella* species and serogroups and perform satisfactorily in an appropriate accredited external quality assurance scheme. It is recommended that samples are taken on a risk assessment basis with the engineer responsible for maintenance and operation of the water systems assisting in determining the appropriate sites to be sampled. The laboratory findings should be interpreted by a microbiologist experienced in the microbiology of water systems and the detection and ecology of *Legionella* species.

Temperature testing

2.2 Temperature testing of hot and cold water systems is an essential part of risk assessment and should always be undertaken in conjunction with sampling for legionellae. The measurement of temperatures in different parts of a system is also an essential aid to deciding where samples should be taken. It is important to determine the temperature of water coming out of outlets or entering a TMV and also within the flow and return pipes in the different loops of the system. This can be done by the use of an electronic thermometer with a contact probe placed on the surface of the pipe. For metal pipes the difference in temperature between the water within the pipe and the external surface temperature is small (<1°C) but for plastic pipes it is larger, depending upon the type and thickness of the plastic. The difference should be checked near an outlet by determining the temperature of the water flowing from the outlet while measuring the pipe's surface temperature.

Sampling water systems

Aims

2.3 To establish if a building such as an accommodation site or other building associated with legionellosis cases could be a source of infection and to ensure appropriate controls are in place to eliminate or control any risk.

Objectives

2.4 It is not sufficient to simply collect samples. It is essential to carry out the following actions:

a. Carry out a risk assessment of **all** water systems which may pose a risk of causing Legionnaires' disease.

b. Distinguish between local and systemic colonisation of the water systems.

c. Identify sites of highest risk.

d. Check the regulation of the temperature, pressure and flows in the plumbing system.

e. Select a strategy for the immediate short-term control of *Legionella*.

f. Develop proposals for the long-term control strategy for the whole facility.

2.5 In addition to areas where patients have stayed or thought to be exposed, sample sites should also be chosen to be representative of the water system. The water storage and piping plans should be consulted prior to selecting the sample points. Temperature profiling of the hot and cold outlets (and feeds to TMVs where accessible) is a relatively quick and easy way to identify where controls may not be effective.

Note

As temperature measurements may be used as evidence of control, it is important that temperature probes are calibrated by an accredited laboratory or against a primary reference thermometer that has been calibrated by an accredited laboratory.

Sampling: safety measures

2.6 The responsible person should ensure that persons taking the samples have the appropriate competence, training and equipment, that they are trained to take samples from the systems requested, that they carry out a personal risk assessment before sampling and that they wear appropriate personal protective equipment if the risk assessment determines it is necessary. The fans in evaporative cooling towers should be switched off and the aerosols allowed to dissipate before sampling. Appropriate training is especially important if sampling from difficult-to-access places such as storage tanks in elevated positions or in confined spaces, and from hot water calorifiers and buffer vessels which may be under pressure.

Distribution of sites to be sampled

2.7 Systemic:

- incoming cold water to the facility including any stored water in cisterns/tanks;
- hot water leaving the water heater or hot water storage vessel;
- circulating hot water returning to the heater.

2.8 Basic:

- the outlet nearest to the entry of the hot water into the facility;
- the most distal sites within the hot and cold distribution systems;
- the hotel room(s) where the infected guest(s) was accommodated;

- the samples points in the leisure complex/swimming/spa pool area.

2.9 Risk-based:

- guest rooms on different floors to be representative of the different loops of the distribution systems;
- temperature monitoring is an important factor in the risk assessment process to determine appropriate sampling points. For example, samples taken from the warmest point in a cold water system, or the coolest part of a hot water system, are likely to pose the greatest risk of *Legionella* growth and survival;
- areas where there has been stagnation – e.g. a room rarely occupied or a closed floor of rooms (little used areas often include sinks in cleaners' cupboards, chambermaids' pantries, etc.).

How to sample hot and cold water systems

Sample containers

2.10 Collect 1 litre samples in sterile containers containing sufficient sodium thiosulphate pentahydrate to neutralise any chlorine or other oxidising biocide (35 mg of $Na_2S_2O_3{\cdot}5H_2O$ in 1 litre will reduce up to 1 litre of 5 mg/l chlorine). Measure the temperatures using a calibrated thermometer placed in the middle of the water stream after the sample has been collected.

Systemic points

2.11 If possible, samples are collected:

- from the water softener, if fitted;
- in the boiler room from the base of the calorifier if safe to do so (great care is needed as this may be under pressure);
- the discharge valves of the hot water flowing from the heater to the building;
- from the return water; and
- from the cold water feed to the heater.

2.12 If hot water storage heaters/buffer vessels are installed, samples from the sludge drain valves should also be collected but with care as these may be under pressure. If there are no suitably representative sample points of the water in the heater – i.e. the water flowing from the heater and the flow returning to the heater – this fact should be recorded. If expansion vessels are incorporated, these should be sampled if possible.

Basic and risk-based points

Hot water

Immediate sample

2.13 Turn the tap on gently to minimise aerosol production. Immediately after it has been turned on, collect the water discharging from the tap into a sterile sample bottle containing sufficient sodium thiosulphate to neutralise any residual biocide.

This "immediate" sample will be representative of the colonisation of the outlet and most representative of the risk to the user. Continue to run the tap until 60 seconds has passed and then measure the temperature.

Post-flush sample

2.14 To determine whether the water feeding the outlet from the main cold water feed or circulating hot water system is colonised (i.e. to monitor hygiene conditions in the water system):

- Run the water and measure the temperature (by placing the thermometer in the water flow) for the time necessary for it to reach a constant value (note this time and temperature); continue to let the water run for at least one minute and note the temperature after one minute.
- Close the tap and disinfect with 1% sodium hypochlorite or 70% ethanol; leave it for at least one minute and then flush the outlet to remove residual disinfectant from inside the outlet
- Collect the post-flush sample.

Swabs

2.15 Swabs may be useful in outbreak investigations especially where it is difficult to take water samples; they may yield legionellae even when the system has been drained.

2.16 Samples can be taken, for example, from the inner walls of showerheads and their handles and spa pool jets etc. with a damp sterile cotton swab using a rotating motion. If the area to be swabbed is dry, moisten the swab in the residual water, sterile Ringers solution or 1/40 Ringers. Sample shower hoses at the point where they are attached to the fitting. Swabs can also be taken from biofilms on the surfaces at the air–water interface in tanks, toilet cisterns, etc. sterile templates such as those used in food premises, (e.g. 10cm by 10cm) can be used on flat surfaces to give a semi - quantitative count. Swabs should be transported in 0.5–1.0 ml of the same residual water, sterile water, 1/40 sterile Ringers solution or sterile Page’s saline solution.

2.17 With regard to sieves on mixer valves, remove the sieves and swab and culture any deposit within them.

Cold water

2.18 Collect the sample following what has been described for hot water (pre-flush (immediate) sample and post-flush sample). Take samples from areas where cases have stayed/thought to have been exposed; take these from the places of highest risk – i.e. where the water temperature is above 25°C, from little or unused outlets, etc. When the water temperature in the system is ≤20°C, the number of samples can be reduced.

Water closet cisterns

2.19 These should not be overlooked as potential sources of infection as they can become heavily colonised if the ambient temperature is high, the cold water feed is not directly off the municipal mains supply or the water closet is used infrequently (e.g. accessible toilets often have restricted use, which is not recommended as they become dead-legs). Collect water samples directly from the cistern using a clean sterile container. Swabs from the cistern from the biofilm at the water line are also useful.

Evaporative cooling towers

2.20 If suitable sample points are available, collect a sample from the water returning to the cooling tower in addition to a sample from the cooling tower pond, as far away from the fresh water inlet and dosing point as possible. Collect samples of 200 ml to 1000 ml. If the tower is implicated in an outbreak, samples of sediment are also useful.

Spa pools

2.21 Collect water samples of 1 litre from the pool and, where fitted, the balance tank. In some investigations water from the pool has yielded few legionellae at the time of sampling although filter material and biofilm from inside the pipes contained large quantities of *Legionella*. This probably reflected the type and positioning of the biocide treatment and zones within the piping where the biocidal effect did not penetrate adequately. Therefore, it is also important to inspect the air and water circulation pipes and hoses for the presence of biofilm containing legionellae.

2.22 Biofilm samples should be collected with swabs from the inside of the jets and some sections of these pipes. It is sometimes possible to do this by removing a jet but quite often sections of pipe will have to be cut out to gain adequate access.

Air washers and humidifiers

2.23 Collect samples of at least 200 ml directly from the source.

Decorative fountains, water features and irrigation systems

2.24 Collect samples of at least 1 litre, if possible, from the warmest part of the system. Swabs may also be useful from the inside of jets and the like.

Sample transport and laboratory processing

2.25 Keep and transport hot and cold samples separately; samples must be kept at cool ambient temperature and protected from direct light. Water and swabs should be processed on the day of collection or within 24 hours of collection. Do not freeze samples.

2.26 During the sampling, all details that may help the implementation of possible remedial measures should be recorded; photographs can be a useful aide-memoire. For example, the appearance of the water, obvious pressure and temperature drops or rises in the water circuits, the presence of rust / iron sediment or sludge, the condition of aerator and taps, the occurrence of scale, and the presence of various rubber and plastic attachments. The presence of biocide (note time and date dosed), type of biocide and other control factors dependent on the system (e.g. pH levels, appearance of the water) should be recorded. Also note any significant control failures including equipment (e.g. heater/boiler breakdowns, dosing system blockages, pump failures, unusual chemical use or running out of chemicals).

Warning note

It is important to follow the sampling procedure. Incorrectly collected or labelled samples may invalidate the analysis, make interpretation of the results difficult and may result in a failure to identify the source of infection.

Use of PCR for detecting *Legionella* in water samples

2.27 In these guidelines the referred standard method for enumeration of *Legionella* in environmental samples is a culture technique which is performed in accordance with the ISO standard 11731 (International Organization for Standardization, 2017). Legionella can however be detected by other methods. One of the newer and now widely used techniques to detect and enumerate *Legionella* is polymerase chain reaction (PCR) in accordance with ISO/TS 12869 (International Organization for Standardization, 2012). It is possible to render the PCR technique quantitative by incorporation of standards with known amounts of bacteria (genomes), and quantitative real-time variants of PCR (q-PCR) are often used today. Several commercial kits are available, and several laboratories offer this analysis within their scope of accreditation. Although q-PCR can be useful in investigating potential sources of infection and in monitoring remedial actions, there is still no consensus on how and when q-PCR should be used and how the results should be interpreted.

2.28 The results for q-PCR are expressed as genome units (GU) per ml or litre, but it is clear from several studies that these q-PCR results often have a very poor correlation with the results of culture (cfu/litre) and often are several times higher than the culture results. This is in part due to the fact that PCR can also detect viable but non-cultivable and dead bacteria. The discrepant results are especially pronounced for *Legionella* non-*pneumophila* species. The action levels given in Table 6 in Part 3 refer only to culture and cannot be adapted for q-PCR results. Studies are ongoing to establish the most appropriate interpretation of q-PCR results. However, whereas a negative result in q-PCR is almost certainly negative by culture also (as long as the controls are as expected), at the moment this method can be recommended for a rapid analysis of numerous samples taken from sites likely associated with a case or a cluster/outbreak of Legionnaires' disease in order to quickly rule out the negative sites and identify the positive ones. In this case, kits used should have been validated according to ISO/TS 12869 (International Organization for Standardization, 2012). Nevertheless the results must be confirmed by the culture method, which for the moment remains the gold standard.

Emergency action

2.29 Emergency control measures must be carried out as soon as possible after the outbreak has been recognised but not before samples have been collected. Non-essential equipment such as spa pools, fountains/water features and cooling towers associated with air conditioning systems can be rendered safe by switching them off until samples can be collected and remedial measures implemented.

2.30 For essential systems such as distributed hot and cold water, a risk assessment should be carried out and emergency control measures implemented.

2.31 The exact choice of measures will depend on the type of system, the risk assessment and any available epidemiological evidence. The measures will usually involve:

- disinfection of potential sources by high levels of chlorine or another oxidising biocide compatible with the current biocide regime;
- cleaning and disinfection of tanks and water heaters; and
- in circulating hot water systems, raising the hot water temperature if this is below 60°C.

2.32 The potential control measures are discussed more fully elsewhere in this document. If immediate disinfection equipment is not available, pasteurisation may also have a short-term benefit until other arrangements can be made. Care must be taken to ensure the heating system has the capacity to maintain target temperatures of >60°C at every outlet and measures put in place to avoid scalding staff and users. Validated point-of-use microbiological grade filters fitted to outlets and showers may also be a short-term measure but these may reduce flow especially if water pressure is low or there are high levels of particulates in the system.

Long-term remedial measures

2.33 The selection of the long-term remedial measures must be based on a thorough up-to-date review of the risk assessment combined with any monitoring and epidemiological information available. Effective long-term control depends on rigorous adherence to the control measures. The measures will probably be a combination of those described elsewhere in this document. They are likely to require engineering modifications to the existing water systems to improve flow and remove stagnant areas as well as improvements in monitoring controls, management and staff training.

Note

Control measures in premises such as hotels that have been colonised with *L. pneumophila* and which have caused outbreaks must be continued **indefinitely** in conjunction with a monitoring programme to verify their ongoing effectiveness. There are many examples of further cases resulting from the deliberate or accidental discontinuation or relaxation of control measures.

Investigating evaporative cooling tower systems

2.34 See paragraphs 1.53–1.57 in Part 1.

Part 3: Technical guidelines for the control and prevention of *Legionella* in water systems

3.1 These technical guidelines provide the background to the control measures commonly applied to evaporative cooling systems, hot and cold water systems spa pools and other systems and include features of the design and installation, management of the systems during commissioning and re-commissioning and normal operation.

3.2 These guidelines include reference to the WHO's publication *Water Safety in Buildings* (Cunliffe et al., 2011), which advocate the move towards holistic Water Safety Plans. They are mainly based on technical recommendations contained in the freely available UK Health & Safety Executive's *Legionella* technical guidelines Parts 1–3 published in December 2013 and 2014 (Health & Safety Executive, 2013b, 2013c, 2014). They should therefore be regarded as one example of good practice. These may not therefore be entirely consistent with guidance produced in some other European countries because of legal requirements or constraints within those countries. They are, however, a useful guide to follow.

Water safety plans

3.3 The Water Safety Plan (WSP) (Cunliffe *et al*., 2011) approach is advocated by the World Health Organisation to ensure the safety of all water to which staff and the public may be exposed within a building from its source to the point of use. This approach is particularly recommended:

- where water is supplied from a source other than a public potable water supply; and
- for large complex buildings (or ships) where there may be multiple and complex systems which could pose a risk of waterborne infection if not managed effectively (e.g. evaporative cooling systems, hot and cold water distribution systems, leisure facilities including swimming and spa pools, water features and the like, together with spas and hair and beauty salons that use water for treatments).

3.4 Implementation of WSPs ensures that not only is the water quality for each type of use identified but also a management system is put in place for all systems and associated equipment to ensure the risks are adequately controlled so that all water is safe for all types of use and all users.

3.5 The WSP approach is preventive and includes:

- the appointment of a multidisciplinary water safety team; this is particularly important where there are multiple buildings/systems and complex sites;

- an up-to-date description of each system and associated equipment including all relevant components such as storage tanks, pumps, blending valves and flow restrictors (i.e. an asset register);
- an up-to-date schematic diagram of each system showing the layout of the plant or system, including parts temporarily out of use. This is not an as-fitted scale drawing but a simplified plan showing all relevant components, connections, etc. which can be easily understood by a non-technical person;
- a risk assessment which is carried out on each system and associated equipment that uses water;
- a water management plan to minimise the risks from *Legionella* and other relevant waterborne pathogens;
- supplementary programmes to support the WSP including surveillance, audit, training and communication.

3.6 The WSP should also include a plan for dealing with foreseeable problems including the remedial actions to be taken in the event of such occurrences (e.g. the breakdown of a critical piece of equipment such as a circulation pump which can be predicted to occur sometime in the lifetime of a system, or failure in delivery of treatment chemicals). There should also be a list, with contact details, of those to be informed if such an event occurs.

Water Safety Group

3.7 The team approach to managing water is an important component of the WSP. The WSG ensures all the skills necessary are available and there is cross-communication between professionals to assess and manage water safely for all types of use and user. Typically a WSG for a hotel complex, for example, could include:

- a competent water system engineer/technician who is familiar with each of the water systems on site;
- a representative from water treatment professionals who provide services such as risk assessment, disinfection and cleaning services, and/or monitoring and sampling;
- a consultant(s) who understands how to interpret water monitoring results, give advice on appropriate remedial measures and carry out independent audits
- a member of senior management; and
- a representative from users of any specialised systems such as leisure pools, hairdressing, and beauty and spa treatments.

3.8 The exact composition will vary depending on the number and complexity of systems on site.

Responsibility

3.9 One advantage of a WSG is that responsibility for day-to-day management is shared between those with the appropriate expertise. However, the group should report up to the person who has overall legal responsibility for health and safety within the building; in a hotel, for example, this would normally be the owner/manager, chief executive officer or equivalent. The WSG would have overall day-to-day responsibility for the WSP (e.g. agreeing designs for water systems in new builds and refurbishments to ensure they minimise the risks from waterborne infections, developing and implementing WSPs, reviewing risk assessments, documentation and monitoring results and any remedial actions).

Cooling towers and evaporative condensers

3.10 These guidelines for evaporative cooling systems are based on the UK Health & Safety Executive Guidelines HSG274 Part 1 published in 2013 (Health & Safety Executive, 2013b), which gives further information on types of towers (with illustrations) together with further guidance.

3.11 This section gives an overview of the characteristics of each type of system, the design and construction of evaporative cooling systems and their safe operation, commissioning, management and maintenance.

Introduction

3.12 Air conditioning is the process of treating air to cool its temperature, humidity and air cleanliness and distributing this are to meet cooling requirements. Evaporative cooling of water within cooling towers and evaporative condensers is widely used to dissipate heat from air conditioning, refrigeration and industrial process systems by using water as a heat exchange medium. Heat from the cooling cycle is removed by a condenser which is often cooled by water from an evaporative cooling tower. During heat exchange, the cooling water is heated to around 30°C, and with the potential for scale formation, corrosion and fouling, this may provide an environment for the proliferation of legionellae.

3.13 They come in a variety of designs and sizes including open-circuit cooling towers, which are the most common. They can range in size from small packaged towers used in air conditioning and light industrial applications, up to large towers, including hyperbolic towers, for heavy industrial, petrochemical and power generation applications – all have the potential to cause Legionnaires' disease if not adequately maintained and controlled.

3.14 For further information and diagrams, see the UK Health & Safety Executive's HSG274 Part 1 (Health & Safety Executive, 2013b, pp 9–12).

3.15 An evaporative cooling system consists of a cooling tower, evaporative condenser or other cooling equipment, together with pumps, recirculation pipework and valves and usually the heat exchanger or condenser and a pond. It may also include ancillary items, such as make-up supply tanks, pre-treatment plant and chemical dosing plant. These items all need to be considered and included in the management and control scheme of the system.

3.16 All evaporative cooling systems, except for large natural draught towers, have a fan system to force or induce airflow through the unit.

3.17 In buildings such as hotels, apartment blocks, leisure complexes, offices, shopping malls, etc., cooling towers and evaporative condensers are primarily used for comfort cooling. In industrial settings they may be used to cool processes and recover heat. Industrial cooling towers may also be used to cool contaminated process water with high microbial counts and pose a significant risk of transmitting contaminated aerosols. These will require additional treatment regimes validated for use in the specific system, and more extensive monitoring programmes will be needed to verify the treatment regimes. The risks from disposing of highly contaminated process water from these into rivers or wastewater treatment plants should also be assessed and the water treated before disposal where indicated.

3.18 Those who own or manage buildings with evaporative cooling towers should consider as part of the risk assessment process whether replacing these with dry systems is a viable alternative. Where this is not reasonably practicable and a wet cooling system is the only realistic option available, a cooling system should be designed with safe operation and maintenance in mind.

3.19 Both cooling towers and evaporative condensers have been associated with cases of Legionnaires' disease, so they should be regarded as presenting a similar risk and requiring similar precautions. Dry/wet cooling systems (adiabatic)[6] are increasingly being used but if used intermittently, as with other towers, they may pose a risk of infection especially where water is recycled and stored or if a poor-quality water source is used, which increases the risk of microbial growth. Because of their potential to cause large outbreaks, all evaporative cooling systems should be rigorously risk-assessed and actively managed and monitored.

Design

3.20 The design should minimise the potential for microbial colonisation, growth and dissemination of aerosols. Factors which should be taken into account during the design, selection of location and installation include:

a. Ideally, towers should not be located near any air conditioning or ventilation inlets nor close to openable windows; this is particularly important where healthcare building intakes are close by.

b. The air inlets should be designed and protected so as to minimise splash-out or windage losses and to avoid leaves and other contaminating debris being drawn into the tower. This is especially important on industrial sites with a high-nutrient environment (e.g. in food manufacturing).

c. Towers should be located in such a way that there is an unimpeded supply of ambient air for cooling and no obstruction to the exhaust stream from the tower.

[6] For further information see the UK Health & Safety Executive's HSG274 Part 1 (Health & Safety Executive, 2013b).

d. It should be ensured that all areas are easily and safely accessible for inspection. There should also be adequate space around the tower for routine maintenance, including cleaning and disinfection and pack removal, with gantries or platforms and access doors and hatches so that all parts of the equipment that require inspection and maintenance can be safely accessed.

e. Cooling towers and evaporative condensers should be made of materials that do not support microbial growth and which are resistant to corrosion and easy to descale, clean and disinfect. Construction components made from materials which support microbial growth such as natural rubber and untreated timber should be avoided.

f. The base tank or pond of cooling towers should be fully enclosed to prevent direct sunlight onto the water and therefore the growth of algae which can support legionellae growth. The bottom of the tank or pond should be designed to facilitate draining, with a suitably sized drain at the lowest point.

g. The water pipework including balance pipes should be as simple as practicable, avoiding dead-legs and sections that can hold stagnant water and cannot be drained, allowing microbial growth. It should be constructed from materials compatible with the fabric of the evaporative cooling equipment to reduce the possibility of corrosion.

h. Control of the operating water level in a cooling tower is important to prevent overflow or splash-out, which can adversely affect effective treatment chemical levels and also result in the release of aerosols. Water level is often controlled by a mechanical float-operated valve, which works well for continuously operated towers. Electrical water-level detection devices are recommended for more precise level control and for towers that are shut down more frequently than once every quarter.

i. Minimising the release of water droplets:

  - High efficiency drift eliminators, which reduce rather than eliminate the loss of water vapour (drift), should be installed in all towers that have fans. The efficacy of drift elimination is dependent on the relationship between fan speeds, density and resistance of the pack, as well as the design and fitting of the eliminator itself. Modern drift eliminators should be able to reduce the drift loss to less than 0.01% of the water flow through the tower.

  - The tower design should allow the easy removal of the drift eliminators which should be in sections that are easy to handle to facilitate inspection, descaling and cleaning. They should be well fitted with no obvious gaps either between the tower fabric or the individual sections. It is important that the airflow is not impeded (e.g. by build-up of leaves or scale).

  - It is important that drift eliminators are regularly inspected for damage as they can become brittle due to chemical attack, ultraviolet radiation from the sun or temperature extremes. Brittleness will lead to breakage of the plastic and this will affect the efficiency of the eliminator.

- Tower fans are commonly automatically controlled by frequency inverters which ensure that the fan speed responds according to the system load. Frequency inverters also regulate the air speed through the drift eliminators, which in turn will limit the amount of drift exiting from the tower.

3.21 Evaporative condensers are sometimes used for air conditioning or industrial cooling applications. An evaporative condenser combines the function of both the cooling tower and the conventional condenser, as water is sprayed over the cooling coils. The volume of water in the evaporative condenser is usually less than in a cooling system.

3.22 Although less common, other systems that do not rely solely on the principle of evaporation are dry/wet coolers or condensers (also known as adiabatic coolers). These systems are able to operate in dry air-cooled mode and wet evaporative cooling mode, but when running in wet mode may present an equivalent risk to a cooling tower or evaporative condenser especially if the cooling water is recycled or not of potable quality. The risk assessment may require similar control measures to conventional towers.

Commissioning

3.23 Following the correct commissioning procedures is essential for the safe onward operation of the cooling tower. Cases of legionellosis have been associated with systems that were not cleaned or properly commissioned before being put into operation.

3.24 Systems should be commissioned by experienced and competent personnel to ensure that the system operates correctly as designed. It is essential that the commissioning process is carried out in a logical and defined manner in full compliance with the supplier’s or installer’s instructions and includes both the evaporative cooling equipment itself as well as any associated pipework, components and water treatment plant. The commissioning procedure should include all aspects of the system including the mechanical and electrical systems which should be coordinated with the disinfection and cleaning processes and the commissioning of the water treatment system to prevent the risk of *Legionella* colonisation and growth. The following factors should be considered when scheduling commissioning (or recommissioning) of a tower:

- Commissioning should not be carried out until the system is required for use, and the system should be filled with water at the last possible time before commissioning takes place to avoid water stagnation and allow microbial growth. If filled just for hydraulic testing, the system should be drained and not refilled until commissioning takes place.
- If a new system is to be taken into use within a week, commissioning can be carried out and the system left charged with treated water, which should include a biocide which is kept circulating through the system.

- The baseline data from the commissioning process (including records of those responsible for carrying it out) should be included within the operation and maintenance manual/logbook so that checks can be made to verify that the installation continues to operate as intended.
- Formal arrangements should be made to for competent supervision of the commissioning process by, for example, a competent independent engineer who is familiar with the type of system and its application and who witnesses the testing is carried out to the required specification and countersigns the relevant documents.

Cooling tower operation

3.25 It is recommended that a WSP is developed and implemented. This should include the governance and accountability arrangements, a formal risk assessment and scheme of control to ensure that there is safe operation, and a maintenance and monitoring programme in place and to ensure the ongoing safety of the system. The WSP should also include supplementary programmes for training, competency checks, communication and internal and external audit (see paragraphs 3.3–3.6). The system should be operated in the way it was designed and in such a way that it avoids system contamination and growth and stagnant water conditions, allows the water treatment control measures to be effective, and minimises the release of aerosols from the system.

3.26 An operation and maintenance manual should be available for the whole system and include manufacturers' instructions for all individual pieces of equipment and details of:

- operation and maintenance procedures that enable plant operators to carry out their duties safely and effectively;
- checks of equipment as fitted and where automated dosing systems are fitted;
- checks to ensure that the treatment is being applied;
- the system as currently in operation;
- schematic diagrams and total water volume of the system;
- specific information on the water treatment programme;
- normal operation control parameters and limits;
- required corrective actions for out-of-specification situations, such as when plant operating conditions or the make-up water quality change;
- cleaning and disinfection procedures;
- monitoring records of the system operation.

3.27 Where chemical additions and bleed-off are controlled automatically they should be checked over their full operating ranges. Where conductivity controls are used, the conductivity cell should be regularly recalibrated. In high-nutrient environments additional controls such as side-stream filtration may be required to reduce the nutrient load on the system.

Considerations for towers used intermittently

3.28 Cooling systems that do not operate continuously such as cooling towers that cycle on and off automatically or those on regular standby duty require particular attention with regard to the biocide programme in order to ensure that effective levels of biocide are maintained at all times.

3.29 The cooling system should therefore be kept in regular use whenever possible. When a system is used intermittently, arrangements should be in place to ensure that treated water circulates through the entire system at least once a week this should be monitored and records kept. The system, including the fans, should run for long enough to distribute the treated water thoroughly.

Short-term standby (e.g. for a week or up to a month)

3.30 If the system is out of use for a week to one month in addition to the above. If a system is to be out of use for a week or longer (e.g. up to a month), biocides should continue to be dosed and circulated throughout the system, as if in normal operation (at least weekly), the water should be treated with biocide immediately prior to reuse.

Longer-term standby (e.g. seasonal use)

3.31 If a system, part of a system or attached equipment is to be out of use for longer than a month, it should be managed so that microbial growth, including *Legionella* in the water, is appropriately controlled. It used to be thought that systems should be drained and decommissioned. However, in large systems it is impossible to ensure all parts of the system do not have residual water (which can lead to biofilm growth), and as it is not possible to fully remove biofilms from a system, current thinking is that systems should be left filled with biocide and the levels checked on a regular basis. Leaving water in the system also helps to avoid other problems associated with systems drying out, including failure of joints and corrosion in metal pipework. The system, including the water treatment regime, should then go through the full recommissioning process before reuse. If it is not possible to ensure regular monitoring and circulation – e.g. if a building falls out of use and it is expected that the cooling system will be required on recommissioning of the building – the system should be drained and sealed, with desiccant left in the system to reduce the effects of corrosion.

Maintenance

3.32 Preventive maintenance is an important measure to assure reliable and safe operation of the cooling system. The operation and maintenance manual/logbook should include a detailed maintenance schedule, listing the various time intervals when the system plant and water quality should be checked, inspected, overhauled or cleaned and disinfected. The completion of every task should be recorded by the plant operatives/contractors.

3.33 Drift eliminators require particular attention with regard to maintenance. To remain effective, they should be regularly inspected to ensure they are well-sealed, clean, properly positioned and not damaged.

3.34 Cleanliness of the tower and associated plant is vital for the safe operation of a cooling system, and effective cleaning should be carried out periodically. All wetted parts such as the internal surfaces of the tower, drift eliminators, water distribution system and fill pack should be accessible for an assessment of cleanliness and cleaned as needed.

3.35 If standby pumps are fitted, any stagnant sections should be flushed with biocide-treated water periodically, typically once every week. If not managed effectively, subsequent disturbance of a dead-leg may result in rapid colonisation of the whole system.

Water treatment

3.36 The operating conditions of the cooling system provide an environment in which microorganisms can proliferate. The water temperatures, pH conditions, concentration of nutrients, presence of dissolved oxygen, carbon dioxide, sunlight (which encourages algal growth) together with large surface areas all favour the growth of microorganisms including protozoa, algae, fungi and bacteria which can support *Legionella* growth. Both surface-adhering (sessile/biofilms) and free-flowing (planktonic) bacteria need to be controlled for a complete and effective treatment programme. In effect the cooling towers are acting as air scrubbers and will accumulate nutrients from the environment especially when operating in industrial applications with a high-nutrient environment (food manufacturing, paper mills, etc.). Particular care must be taken to ensure there is an effective treatment and maintenance regime; in some cases, pre-treatment such as side-stream filtration may be needed.

3.37 An effective water treatment programme should be established based on the physical and operating parameters for the cooling system and taking into account the chemical and biological composition of the make-up water. When a non-potable source is used for cooling, pre-treatment may also be necessary. The components of the water treatment programme should be environmentally acceptable and comply with any local discharge requirements.

3.38 The cooling water treatment programme should be capable of controlling not only *Legionella* and other microbial activity, but also corrosion, scale formation and fouling to maintain the system's cleanliness. All of these need to be monitored regularly to ensure they remain effective. The exact treatment regime required to control a system may vary significantly with different water supplies, cooling system design, operating conditions and periods of use.

Corrosion control

3.39 In many cooling systems, a significant proportion of the construction material is mild steel, which is susceptible to corrosion. Heat transfer equipment may be made of more corrosion-resistant metals such as copper, copper alloys or stainless steel; these metals also need to be adequately protected. Corrosion of mild steel in particular should be inhibited as it may lead to conditions that encourage the growth of legionellae.

3.40 Good corrosion control requires a clear understanding of the cooling water chemistry and metallurgy, the selection of a corrosion inhibitor matched to that chemistry and metallurgy, and adequate control of both the inhibitor and the chemistry within the system. As with all cooling water analysis, a suitably trained and competent person should interpret the results.

3.41 Corrosion and scale inhibitors should be applied continuously and be capable of producing the desired control over corrosion and scaling. For liquid inhibitors a commonly employed method of addition is using a dosing pump controlled by a water meter installed on the cooling system's make-up water supply. *In situ* monitoring of treatment reserves, with feedback control of dosing, can also be employed.

3.42 Inhibitor formulations can be supplied as a single multi-functional product incorporating a number of corrosion and scale inhibitors and dispersant polymers to reduce fouling tendencies. For some large cooling systems, it can be more cost effective, and provide greater flexibility, if the required components are supplied and dosed separately. For further information on fouling, corrosion and scale see HSG274 Part 1 (Health & Safety Executive, 2013b, paragraphs 1.40–1.50).

Scale control

3.43 Scale is the localised precipitation of normally water-soluble inorganic hardness salts. Its formation is influenced by the concentration of calcium salts, pH, surface and bulk water temperatures and the concentration of the total dissolved solids. As an evaporative cooling system operates, the concentration of these various dissolved solids increases and the pH of the water tends to rise, which results in the increased likelihood of scale deposition.

3.44 Scale formation results in loss of heat transfer, reduced flow rates and loss of efficiency, and contributes to deposition. Scale provides niches for microbial adhesion and survival, including legionellae, and reduces the effectiveness of any biocidal treatment.

3.45 One or more of the following techniques are generally used to control scale formation:

- softening the ingoing water;
- adding specific scale inhibitors that extend the solubility of the hardness salts and so prevent precipitation;
- acid-dosing to lower the pH and alkalinity and reduce the scaling potential;
- limiting the system concentration factor to a range within which the hardness salts can remain soluble.

Protection of personnel

3.46 Maintenance, cleaning, testing and operating procedures should all be designed to control the risks to staff and others that may be affected.

3.47 As systems requiring cleaning may have been contaminated, the operator and others closely involved in the work should wear respiratory protective equipment suitable for particle exclusion to European standard EN 143 (European Committee for Standardization, 2000). This can be a powered filter and hood or a power-assisted filter and close-fitting full-face mask. It should be borne in mind that the filter on these systems is liable to get wet, and consequently resistance to air can increase with consequent discomfort to the operator.

3.48 Alternatively, a hood or full-face mask fed with breathing-quality compressed air may be used. The preferred equipment is a full-face close-fitting airline mask with a positive-pressure demand valve under a hood or helmet protecting the rest of the head. The air supply should come from an oil-free compressor drawing air through a filter from a location well upwind of any jetting operation, or through cylinder supplies of compressed air. Further information on respiratory protective equipment can be obtained from *Respiratory Protective Equipment at Work – a Practical Guide (HSG53)* (Health & Safety Executive, 2013d).

Cleaning and disinfection

3.49 Maintaining the cleanliness of the cooling system and the water in it is critical to preventing or controlling microbial growth, reducing the risk of exposure to legionellae and also improving the efficiency and life of the system.

3.50 The WSG/responsible person should determine the appropriate frequency and scope of inspection and monitoring and cleaning operations, and whether a cooling system is clean enough for operation. They may seek advice and help from specialist service providers for water treatment, risk assessment, cleaning and disinfection. However, it remains the responsibility of the WSG/responsible person to ensure that contractors/service providers carry out their roles with adequate supervision to ensure they are safe and effective.

3.51 As *Legionella* are more likely to grow in a fouled cooling system (e.g. where there are biofilms, corrosion products, scale deposits, mud, silt and clay, airborne dust and debris, process contaminants and airborne biological matter such as insects, pollen and plant material), managing both the biological and chemical components of the system are crucial aspects of control. Microbial biofilms can both support and promote growth by providing nutrients and hosts for intracellular growth and protecting the organisms from water treatments. The required frequency and scope of regular cleaning and disinfection operations should be determined by an assessment of the potential for fouling. This assessment should be based on usage, inspection and history of the water treatment, control of microbial activity, scaling and corrosion tendencies and other factors that may result in fouling of the particular system. Fouling tendencies can be controlled by adding specific dispersant chemicals to keep suspended solids mobile and may be helped by incorporating side-stream filtration which filters a proportion of the circulating water and then returns it to the cooling circuit.

3.52 Effective water treatment can significantly reduce fouling in a cooling system, and the risk assessment should consider the history of control of the fouling factors and water treatment programme should be used in conjunction with inspection to determine the frequency and type of cleaning and disinfection operations to be carried out.

3.53 In relatively clean environments with effective control measures it may be acceptable to extend the period between cleaning operations, provided it can be demonstrated that system cleanliness is maintained. The composition of the make-up and cooling water should be routinely monitored to ensure the continued effectiveness of the treatment programme. The frequency and extent will depend on the operating characteristics of the system.

Water treatment

3.54 Most cooling systems are treated using what might be termed conventional chemical techniques. These may be in the form of single-function chemicals or multi-functional mixtures.

3.55 The chemical programme of the system can be augmented by pre-treatment of the make-up water and will include bleed-off control to limit the cycles of concentration. In some instances, acid-dosing may be incorporated as part of the scale control programme and in other instances side-stream filtration may be employed to control the build-up of suspended solids.

3.56 This chemical treatment programme should be carefully selected based on the cooling system design, size (i.e. the water chemistry in smaller volume systems may be more difficult to maintain) and operating conditions, make-up water analysis, materials of the system’s construction and environmental constraints. The different elements of the treatment programme should be chemically compatible. The treatment programme should be capable of coping with variations in the operating conditions, make-up water analysis and microbial loading. Chemical dosage and control should be automated where possible to ensure the correct treatment levels are consistently applied and to minimise exposure of operators to chemical hazards. For each chemical there should be a safety data sheet, a completed chemical hazard risk assessment and control measures applied for their safe handling and use.

Cooling water biocides

3.57 The biocide regime should be capable of controlling the microbial activity in the cooling water consistently so that microbial growth is controlled. The ease with which this can be achieved will vary from system to system depending on the operating conditions and the availability of nutrients in the water to support microbial growth. The control of the biocide regime should be automated to ensure the correct dosage of biocide is applied at the required frequency.

Oxidising biocides

3.58 This group of biocides can effectively oxidise biological material in the cooling system, including microorganisms, resulting in their destruction if the conditions are maintained to enable them to work effectively. An advantage of oxidising biocides is that they can be monitored by a simple field test to measure the residual biocide in the cooling water and they can be easily neutralised in microbiological samples, whereas the concentration of non-oxidising biocides cannot easily be measured directly and cannot be easily neutralised, and so can interfere with microbiological analysis.

3.59 The oxidising biocides most commonly used in cooling water are those based on compounds of the halogens chlorine and bromine. These may be supplied as a gas, solid tablets, granules or powder, or as solutions. They can be applied continuously or on a slug-dose basis and may be used in conjunction with non-oxidising biocides which are organic-based compounds that are intended to react with specific components of microorganisms to inactivate them.

3.60 On dilution these compounds form free halogens: hypochlorous acid ($HOCl$), hypobromous acid ($HOBr$), hypochlorite ion (OCl^-) and hypobromite ion (OBr^-) in a pH-dependent equilibrium.

3.61 This pH-dependent relationship is important because the hypochlorous and hypobromous acids are more active biocides than the hypochlorite and hypobromite ions. Control of pH may be necessary to optimise biocidal activity; as pH rises the concentration of these active acids declines and the water becomes increasingly alkaline. At higher pH (above pH 8), chlorine compounds tend to become less effective and slower acting, whereas bromine compounds retain much of their activity. For this reason the use of chlorine-based biocide programmes tend to be restricted to larger cooling systems operating at lower cycles of concentration or those employing pH control. Bromine-based biocide programmes are generally considered more appropriate for smaller cooling systems and any system where the cooling water pH is likely to exceed pH 8.

3.62 Oxidising biocides are aggressive chemicals and if overdosed will lead to increased corrosion rates. High concentrations of oxidising biocides can also degrade other cooling water chemicals, such as inhibitors, so it is important that the dosing arrangements are designed to ensure the two chemicals do not mix until they are well diluted (i.e. in the system).

3.63 It is preferable that oxidising biocides are applied continuously or in response to a redox or amperometric control system, pre-set at a level equivalent to the correct halogen reserve required. If, however, halogen biocides are shot-dosed, they should be dosed sufficiently often and in sufficient quantity to maintain effective microbial control at all times.

3.64 Owing to their mode of action, oxidising biocides are not prone to developing microbial resistance, so it is not normally necessary to dose a second biocide alternately, unless the oxidising biocide is dosed infrequently. However, biodispersant chemicals, which are special surfactants, are often applied in conjunction with oxidising biocides to help the penetration and dispersion of biofilms. While it is not normally necessary to dose a secondary biocide where an oxidising biocide is applied continuously, it may be appropriate to control a particular microbial problem such as algal growth in areas of the cooling tower exposed to sunlight.

3.65 Used correctly, both chlorine and bromine biocide programmes are effective at controlling the general microbial count and preventing the proliferation of legionellae even where significant nutrient levels are present. Their efficacy can, however, be affected by certain process contaminants such as ammonia or very high organic loading. Under such circumstances an alternative oxidising biocide such as chlorine dioxide or an appropriate non-oxidising biocide programme may be used.

Dosing

3.66 Halogen-based biocides are typically applied to the tower pond or suction side of the recirculating water pump but should be dosed so that the biocide will circulate throughout the cooling system to establish a measurable reserve using DPD No1, in the range 0.5–1.0 mg/l as Cl_2 or 1.0–2.0 mg/l as Br_2. 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.

3.67 Whatever method is used, it should ensure good mixing and avoid localised high concentration of chemical, which may cause corrosion. In some circumstances, it may be possible to maintain good microbial control at a lower halogen reserve; and in other circumstances, such as more alkaline pH conditions, it may be necessary to increase the halogen reserve to compensate for the reduction in biocidal activity. The effectiveness of the microbial control should be monitored using weekly dip slides and periodic *Legionella* analysis and the target biocide reserves adjusted accordingly.

Chlorine dioxide

3.68 The performance of chlorine dioxide as a biocide is not affected by the water pH; it does not react with ammoniacal compounds and it is often less affected by organic contamination than either chlorine- or bromine-based oxidising biocides. It is extremely effective at penetrating and dispersing biofilms. However, it is more complex to dose and its volatility means that maintaining a measurable residual of chlorine dioxide in the recirculating water downstream of the cooling tower may prove difficult. It tends therefore to be used as a niche biocide for applications where contamination precludes the use of chlorine or bromine. When it is used, it may either be dosed continuously at a low level or intermittently at a higher level with the frequency and dosage level often being determined by the results of microbial monitoring rather than by achieving and maintaining a specific chlorine dioxide residual.

3.69 An advantage of oxidising biocides is that they can be monitored by a simple field test to measure the residual biocide in the cooling water, whereas the concentration of non-oxidising biocides cannot easily be measured directly.

3.70 The effectiveness of the biocide regime should be monitored weekly, conventionally by using appropriate microbial dip slides. Alternative technologies that can quantitatively detect microbial activity (i.e. those that do not rely on culturing bacteria) may be used; however, any new methods should be validated to ensure the results are equivalent, where appropriate, using ISO/TR 13843: “Water quality — Guidance on validation of microbiological methods”). Specific sampling for legionellae should be done on at least a quarterly basis. Adjustments to the dosage and control settings may be needed in response to any high count.

Non-oxidising biocides

3.71 Non-oxidising biocides are organic compounds that are usually more complex than oxidising biocides. They are generally more stable and persistent in the cooling water than oxidising biocides, but their concentration will reduce with time because of system water losses and degradation and consumption of the active material.

3.72 To achieve the right non-oxidising biocide concentration to kill microorganisms, biocide is normally added as a shot-dose. The frequency and volume of applications are dependent on system volume, system half-life, reinfection rate and the required biocide contact time, typically at least four hours. These factors need to be considered to ensure that the biocide concentration necessary to kill the microorganisms 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. The total system volume should be established to ensure that the desired levels of non-oxidising biocides are applied.

3.73 A non-oxidising biocide programme should use two biocides with different kill mechanisms on an alternating basis to minimise the risk of the microbial flora evolving into a population tolerant to a single biocide type. Once the concentration of any biocide has been depleted to below its effective level, the system will be open to infection and allow surviving microorganisms including legionellae to increase. The efficacy of non-oxidising biocides may be influenced by the pH and temperature of the water in the system, and these should be taken into account to ensure that the biocide programme is effective. The list below summarises the important points to consider when selecting a non-oxidising biocide programme:

- retention time and system half-life;
- cooling water analysis (e.g. pH);
- microbial populations;
- system dynamics;
- system contaminants;
- handling precautions;
- effluent constraints;
- considering whether an oxidising biocide programme is more appropriate.

Pre-cleaning, cleaning and post-cleaning disinfection

3.74 The maintenance of an effective biocide regime will provide a hostile environment for microbial life (including legionellae) and minimise biofouling. However, the use of biocides should not be considered in isolation but as part of an overall water treatment programme which includes the manual and chemical cleaning and disinfection of open cooling systems, and in particular the cooling tower.

3.75 Disinfection, cleaning and manual desludging and descaling of cooling towers should be undertaken at least twice a year, but more frequent cleaning may be necessary dependent on local environmental conditions, especially in high nutrient environments, and on the conclusions reached in the risk assessment. Cooling systems that have a short operating period may only need to be cleaned at the beginning and end of each period. However, if on inspection the system shows signs of a significant accumulation of deposits or slime, then disinfection and cleaning should be carried out. The use of chlorine, or other oxidising biocides, to disinfect the tower is an effective approach provided it is part of an overall treatment programme which includes the management of pH, corrosion, and scale and nutrient ingress.

Pre-cleaning disinfection

3.76 To minimise health risks to cleaning staff, the water in the system should be disinfected using an oxidising biocide such as chlorine, bromine or chlorine dioxide before tower cleaning. This is undertaken by the addition of either sodium hypochlorite solution or chloro-isocyanurate compounds available as rapid release tablets to achieve a measured residual of 5 mg/l free chlorine. Sodium hypochlorite solutions typically contain 10–12% available chlorine and rapid release tablets contain 50–55% available chlorine. Such products should be handled following a risk assessment and with care, according to instructions given by the supplier and with appropriate personal protective equipment. A biodispersant should also be used to enhance the effectiveness of the chlorination.

3.77 The chlorinated water containing 5 mg/l free chlorine should be circulated through the entire system for a period of five hours with the fan off, maintaining a minimum of 5 mg/l free chlorine at all times. However, if the system pH value is greater than 8.0, the measured residual will need to be in the range 15 mg/l to 20 mg/l free chlorine in order to achieve the required disinfection level. An alternative procedure to provide more effective use of chlorine is to introduce a heavy bleed-off for several hours to reduce both the pH of the system water and its chlorine demand, before carrying out disinfection. The system should then be dechlorinated and drained.

Cleaning

3.78 Towers should have adequate safe access to all areas to facilitate adequate cleaning. Where practicable, the packs should be removed at least once a year and preferably every six months based on risk assessment. If this is not practicable, it may be necessary to apply supplementary strategies such as side-stream filtration and increased monitoring.

3.79 A risk assessment should consider the potential for disseminating contaminated aerosols during the cleaning process and if deemed necessary appropriate precautions should then be taken. The tower and its pack should be adequately cleaned without creating excessive spray – e.g. high pressure water-jetting should be avoided (see paragraphs 3.46–3.38 on personnel protection). If this is not possible, the operation should be carried out when the building is unoccupied or, in the case of permanently occupied buildings, windows in the vicinity should be closed and air inlets blanked off. The area that is being water-jetted should be isolated by sheeting-off with tarpaulins, for example, to reduce the dissemination of aerosols. Consideration should also be given to other occupied premises in the immediate areas as well as to members of the public who may be in the vicinity during cleaning, especially if there are other adjacent buildings, walkways, etc.

3.80 A risk assessment should be carried out before cleaning to ensure the appropriate protection of staff and people in the vicinity especially when a system is cleaned as a response to adverse results or is associated with a case or cases. Cleaning staff that carry out water-jetting should wear suitable respiratory protective equipment such as a positive-pressure respirator with a full-face piece or a hood and blouse. Staff who use this equipment should be adequately trained and the equipment properly fitted and maintained.

3.81 Where cleaning is ineffective at removing scale or other deposits on the tower and distribution system, chemical descalents can be used to dissolve the scale but care must be taken to avoid those which may damage the fabric of the system. If this is not possible, then routine inspection and testing of water quality should be particularly thorough.

3.82 Finally, the system should be thoroughly rinsed out until the water going to drain is clear.

Post-cleaning disinfection

3.83 Once the system has been cleaned, it should be refilled and chlorinated to maintain a minimum level of 5 mg/l of free chlorine for a period of five hours with the fan off. This needs to be checked hourly to ensure a concentration of 5 mg/l is present for the total period. Using a biodispersant will enhance the effectiveness of this chlorination. If the system volume is greater than 5 m^3, the water in the system should be dechlorinated, drained and flushed, and the system then refilled with fresh water and dosed with the appropriate start-up level of treatment chemicals, including the biocides.

3.84 While the maintenance of a continuous minimum residual of 5 mg/l of free chlorine for a minimum period of five hours is considered best practice, where the downtime to conduct such a lengthy operation is not available, some compromise may be necessary. Under such circumstances it may be acceptable to shorten the pre- and post-chlorination times and to increase the free chlorine level (e.g. 50 mg/l for one hour or 25 mg/l for two hours). This should only be undertaken if the operators are trained in this process because at these levels there is a greater risk of damaging the fabric of the system. The system should then be dechlorinated, drained, flushed, refilled with fresh water and dosed with the appropriate start-up level of treatment chemicals, including the biocides.

3.85 Before water containing high residual free chlorine is discharged to drain, it may need to be dechlorinated to comply with local environmental standards or to prevent damage to sewage works.

3.86 In addition to this regular disinfection, cooling towers should always be cleaned and disinfected before being put back into service:

- immediately before the system is first commissioned;
- after any prolonged shutdown of a month or longer (a risk assessment may indicate the need for cleaning and disinfection after a period of less than one month, especially in summer);
- if the tower or any part of the cooling system has been mechanically altered;
- if the cleanliness of the tower or system is in any doubt;
- if microbiological monitoring indicates that there is a problem.

Monitoring

General monitoring

3.87 Whatever means is used for microbial control, it should be monitored rigorously to ensure control is maintained. Where possible, performance criteria for other non-chemical techniques should be established and monitored.

3.88 The composition of the make-up and cooling water should be routinely monitored to ensure the continued effectiveness of the treatment programme. The frequency and extent will depend on the operating characteristics of the system, the minimum recommended frequency being one once a week to ensure that dosage and bleed rates are correct (see Table 3).

Table 3 Typical on-site monitoring checks recommended for good operating practice

Parameter[7]	Timing	
	Make-up water	Co
Calcium or total hardness as mg/l $CaCO_3$ Total alkalinity as mg/l $CaCO_3$	Monthly Quarterly	Monthly Monthly
Conductivity µS/cm (total dissolved solids)	Monthly	Weekly
pH	Quarterly	Weekly
Inhibitor(s) level (mg/l)	Not applicable	Monthly
Oxidising biocide (mg/l)	Not applicable	Weekly
Microbiological activity	Quarterly	Weekly
Legionella	–	Quarterly
Total iron as mg/l Fe	Quarterly	Monthly
Chloride as mg/l Cl	Monthly	Monthly
Concentration factor (calculated value)	–	Monthly
Calcium balance (calculated value)		Monthly
Sulphate as mg/l SO_4 Suspended solids (mg/l)	Quarterly Quarterly	Quarterly Quarterly
Temperature (°C)	–	Quarterly
Soluble iron as mg/l Fe	Quarterly	Quarterly

3.89 Many routine monitoring tasks can be performed in-house provided the individuals are trained and competent. Any laboratory tests such as culturing for *Legionella* should be performed by laboratories accredited to ISO/IEC 17025 (International Organization for Standardization, 2005) and accredited for the parameters required.

3.90 The identification of changes in the water chemistry such as pH, dissolved and suspended solids, hardness, chloride and alkalinity should allow any necessary corrective actions to be taken to the treatment programme or system operating conditions. In addition, levels of treatment chemicals should be measured such as scale and corrosion inhibitors and oxidising biocides. Circulating levels of non-oxidising biocides may be difficult to measure but the quantity added to the systems should be checked and recorded weekly. Monitoring corrosion rates may also be appropriate.

3.91 Where monitored parameters are out of specification, immediate remedial actions should be instigated to restore control and an investigation begun to determine the root cause. During this period increased monitoring should be implemented until the system is shown to be under long-term control.

Microbiological monitoring

3.92 The monitoring programme should also include the routine sampling and testing for the presence of bacteria, both general (aerobic) bacterial species and legionellae. Since the detection of *Legionella* requires specialist laboratory techniques, routine monitoring for aerobic bacteria is used as an indication of whether microbiological control is being achieved.

[7] These parameters are typically required to check that the correct level of each treatment chemical is applied and that adequate control is maintained over scaling, corrosion and microbial activity. They are not universally applicable and tests may be omitted or added to, as appropriate, for the specific cooling system, make-up and system water character, and the water treatment techniques employed.

Monitoring microbial activity

3.93 The most common method of measuring microbial activity within a cooling system is using dip slides. These are commercially available plastic slides which are coated with sterile nutrient agar – a medium on which many microorganisms will grow, but not legionellae. Personnel using dip slides should be trained in their use and interpretation. Bacteria in the cooling water will grow on the agar and form visible colonies. Comparison with a chart will indicate the number of bacteria in the water, expressed as colony forming units per millilitre (cfu/ml). Care should be taken to ensure that a confluent growth is not interpreted as being no growth.

3.94 Cooling system water should be tested weekly using dip slides (or similar). The timing of dip slides and other microbial sampling is important, especially in relation to the timing of biocide dosing. The sampling point should be remote from the biocide dosing point (not, for example, downstream of the dosing point) and for biocides that are applied in a shot-dose, sampling should be taken when the residual biocide is at its lowest and ideally performed at the same time each week (the worse-case scenario approach). Dip slides should be used to sample the system water downstream of the heat source. The water sample is usually taken from the return line to the tower. If a sample point is used, it is important to flush it to ensure a representative sample before the slide is dipped. The dip slide should be placed into its sterile container and into an incubator set at 30°C for a minimum of 48 hours. The incubation period and the temperature should be the same each time the test is performed. Checks should periodically be carried out with a calibrated thermometer to ensure the incubator is working correctly and maintaining the target temperature.

3.95 While the number of microorganisms is itself important, it is also necessary to monitor any changes from week to week, particularly if there are any increases in the numbers of microorganisms detected. This should always result in a review of the system and the control strategies. A graphical representation of these data will often help to monitor any trends.

Legionella

3.96 In addition to the routine sampling for aerobic bacteria, the routine monitoring scheme should also include periodic sampling for the presence of legionellae. This should be undertaken at least quarterly (see Table 3) unless sampling is necessary for other reasons, such as:

- to assist in identifying possible sources of the bacteria during outbreaks of Legionnaires' disease;
- when commissioning a system and establishing and validating a new or modified treatment programme – for which sampling should initially be carried out weekly and the frequency reviewed when it can be shown that the system is under control;
- if a *Legionella*-positive sample is found, more frequent samples may be required as part of the review of the system risk assessment to help establish the source of the contamination and to confirm the system is back under control;

- the risk assessment indicates more frequent sampling is required (e.g. because of close proximity to susceptible populations, poor-quality feed water or a high-nutrient environment).

3.97 The method of sampling and analysis should be in accordance with ISO 11731 (International Organization for Standardization, 2017) and the biocide neutralised where possible. When non-oxidising biocides are used and neutralisation is not possible, for the results to be meaningful it is important that the laboratory staff are informed of whether neutralisation has been possible or active biocide is likely to remain in the sample and that the samples are transported and processed without delay. As non-oxidising biocides are generally applied in shot dosages, where possible, the water sample should be taken immediately before an application of biocide to minimise the impact of the biocide on the test result (worst-case scenario). Samples should be transported to the laboratory and processed as soon as possible.

3.98 Samples should be taken as close to the heat source as possible and timed so that the biocide is likely to be at its lowest (ideally to ensure the treatment system is working effectively at all times, sampling should represent the worst-case scenario). They should be tested by a laboratory accredited by the national accreditation body for all the parameters required and for *Legionella,* and participate and perform well in an external quality assessment scheme for the isolation of *Legionella* from water. The laboratory should also apply a minimum theoretical quantification limit of less than, or equal to, 100 colony forming units (cfu) legionellae per litre of sample.

3.99 *Legionella* are commonly found in almost all natural water sources, so sampling of water systems and services may yield positive results. Failure to detect legionellae, however, does not mean that legionellae are not present in the system and should not lead to the relaxation of control measures and monitoring. Neither should monitoring for the presence of legionellae in a cooling system be used as a substitute in any way for vigilance, especially with regard to monitoring of control strategies and the measures identified in the risk assessment. The interpretation of any results should be carried out by experienced microbiologists. See Table 4 for action levels that need to be taken following microbial monitoring for cooling towers. The inspection frequencies for cooling water installations are detailed in Checklist 1 at the end of this section.

Table 4 Action levels following microbial monitoring for cooling towers

Aerobic count (cfu/ml) at 30°C (minimum 48 hours' incubation)	*Legionella* (cfu/l)	Interpretation/action required
10,000 or less	Not detected	Acceptable
	1000 or less	Refer to the Responsible Person / WSG and ensure all real time monitoring parameters such as pH, biocide levels etc. are within target limits[8]
More than 10,000 and up to 100,000	More than 1000 and up to 10,000	**Review risk assessment, programme operation and monitoring results**: The count should be confirmed by immediate resampling. If a similar count is found again, a review of the control measures and risk assessment should be carried out to identify any remedial actions.
More than 100,000	more than 10,000	**Implement corrective action**: Turn the tower off until it is known that the controls are in place and the system safe. The system should immediately be re-sampled. It should then be shot-dosed with an appropriate biocide as a precaution. The risk assessment and control measures should be reviewed to identify remedial actions

[8] Assuming samples are taken at the time and sample point which represents the worst-case scenario. However in towers where legionellae have not previously been detected a positive sample may indicate a contamination event, take repeat samples and maintain vigilance.

Hot and cold water systems[9]

3.100 Hot and cold water systems are those that supply water for domestic purposes (drinking, cooking, food preparation, personal hygiene and washing), and these vary depending on the size and complexity of the building. This section provides information on the different types, designs and uses of systems available to supply hot and cold water services. There are a variety of these available systems:

- smaller hot and cold water systems (e.g. directly fed mains cold water to outlets with localised point-of-use (POU) water heaters);
- pressurised systems that can be directly mains-fed or incorporate storage and booster pumps supplying cold water and unvented water heaters with or without secondary recirculation;
- gravity-fed cold water systems incorporating storage tanks (cisterns) and larger water heaters (calorifiers) for the provision of hot water. Hot water systems typically operate without secondary hot water recirculation in smaller premises and with recirculation in larger premises. Cold water distribution systems do not normally recirculate cold water and require outlets to be operated to prevent stagnation in adjacent parts of the system.

Smaller hot and cold water systems

No storage

3.101 Small systems without storage capacity systems are typically found in smaller buildings such as domestic dwellings, small hotels, holiday lets, bed and breakfast accommodation, and small office and commercial buildings where cold water outlets are fed directly from the water supply. Hot water is supplied generally from combination boilers or instantaneous water heaters which are directly fed from the cold water supply by heating the water as it passes through the heater. These units supply continuous hot water at a rate that is usually limited by their power rating. The temperature of heated water can be affected by the flow rate through the heater; if the flow is too fast then the water may not be heated sufficiently to reach the target temperature.

Small volume storage

3.102 Low storage volume POU water heaters are those that store no more than 15 litres of hot water. These systems generally heat water to a set point that is often variable via a simple dial on the unit. These systems deliver a small volume of stored hot water before they need to be left to recover and bring the temperatures back to the set point.

[9] This guidance is based on the UK Health & Safety Executive's HSG274 Part 2 (Health & Safety

Executive, 2014).

Combination water heating systems

3.103 Combination water heaters store a volume of cold water (ranging from 10 to 200 litres) above the hot water storage unit (ranging from 15 to 150 litres). In these units there is a cold water header tank which feeds the hot water storage vessel as the hot water is drawn from the system on demand. The cold water header tank is topped up directly from the cold water supply, usually via a float-operated valve. The combination water heater may be fitted with an expansion pipe so that any expanding hot water returns into the cold water header tank. This may compromise the control of microbial growth within the tank and is not recommended particularly in areas where the cold water intake is close to or exceeds 25°C. The thermostat should be set as close to 60°C as is practicable without exceeding it, and hot water at the outlets should be at a minimum of 50°C; correct setting of the thermostat and regular water usage is necessary to keep the temperature increase in the cold water to a minimum. Where this is not possible (e.g. during times of low use such as overnight or out-of-season periods), fitting a timer which switches off the immersion heater may prove effective. The timer should be set to switch the immersion heater on again in time to ensure the water is heated sufficiently to achieve microbial control and the system flushed through with hot water before use.

3.104 Electrical immersion heaters usually heat combination heaters but some units incorporate internal coils for primary boiler heating circuits.

3.105 In some combination units, the header tank is split into two sections: one feeding the water heater below and the other supplying cold water to the closed heating system. The risk assessment should consider the potential for cross-contamination and lack of temperature control in these systems, particularly during periods of low or no use.

Gravity system without circulation

3.106 Gravity-fed systems may be either with or without recirculation. Typically, the cold water feed is via the rising main, which feeds an intermediate cold water storage tank located in the building roof space from where it is distributed to the outlets by means of gravity. The cold water storage tank provides backflow protection to the mains supply and a stable pressure and reserve in the system if the mains pressure fails or demand exceeds the capacity of the mains supply in the system. Cold water from this storage tank is fed to the water heater where it is heated either directly or indirectly. The hot water system can be recirculating or non-recirculating.

3.107 Non-circulating hot water systems are those which are generally installed in domestic dwellings and small buildings as described above. Cold water from the tank is fed to the calorifier (hot water cylinder) where it is heated and drawn via pipes with spurs to sinks, washbasins, baths, showers, etc. The hot water only flows when it is being used, so in periods of low or no use the water will cool and stagnate, posing a risk of legionellae growth.

3.108 Hot water systems present the greatest risk in the cooler parts of the system that allow the proliferation of *Legionella*, for example:

- at the base of storage water heaters where the incoming cold water merges with the existing hot water;
- water held in pipes between a recirculating hot water supply and an outlet (e.g. tap or shower), particularly when not in use as hot water and biocides (if used) will not be drawn through to the outlet;
- water in uninsulated pipework.

Cold water

3.109 Cold water systems may be contaminated with *Legionella* which enter cold water storage systems from the mains supply; the risk is increased in areas with warm cold water supplies (>20°C). This should be assessed in the risk assessment with temperatures measured when and where the supply water is likely to be warmest. *Legionella* will grow in cold water systems and the distribution pipework when there are increased temperatures (e.g. above 20°C) due to heat gain, appropriate nutrients and stagnation. Where incoming temperatures are above 25°C, the rate of growth rapidly increases; therefore, consideration should be given to point-of-entry treatment.

3.110 Some of the features of gravity hot water systems may also increase the risk of exposure to *Legionella*, including open header/feeder tanks and relatively large storage volumes which can be eliminated by moving to mains pressure systems. Other problems, such as the maintenance of water temperatures throughout the distribution system and changes in demand, can be simplified by changing to POU water heaters with minimal or no storage.

Gravity system with recirculation

3.111 Gravity systems with recirculation (e.g. see Figure 3) are typically installed in larger buildings such as large hotels and commercial premises. Cold water enters the building from a rising main and is stored in a cold water storage tank or tanks as above. The tank provides backflow protection to the mains supply and a stable pressure in the system; it also provides a reserve if the mains pressure fails or demand exceeds the capacity of the mains supply. Cold water from this storage tank is fed to the calorifier.

3.112 The hot water is continuously circulated from the calorifier around the distribution circuit and back to the calorifier by means of one or more pumps which are usually installed on the return to the calorifier, but can be on the flow. This is to ensure that hot water is always available at any of the taps, ideally within a few seconds, irrespective of their distance from the calorifier; this also reduces the risk of localised temperature fluctuations. The circulation pump should be sized to ensure the return temperature to the calorifier is not less than 50°C. For water systems in new buildings, design engineers should consider the recommendations (60°C for water in taps in 30 seconds and 55°C hot water returning to the calorifier) within CEN/TR 16355 (European Committee for Standardization, 2012b).

3.113 The expansion of water as it is heated within the system is accommodated by a slight rise in the levels of the tank and through a vent pipe. This should not discharge into the cold water tank and compromise the cold water storage temperatures, increasing the risk of legionellae growth. The vent should discharge into a separate tundish/drain which is at a safe and visible point and acts as a warning pipe. On rare occasions discharge may be necessary to prevent a heat exchanger from drying out in the event of a mains failure. In this instance the risk assessment should identify whether alternative control measures are necessary.

3.114 Cold water is usually fed by gravity directly from the cold water storage tank to the points of use without recirculation, though some newer systems are now being installed which also recirculate cold water to avoid stagnation. The risk assessment should consider the potential for heat gain and the need for additional control measures.

Pressurised system

3.115 In cold water systems, the term “pressurised system” refers to systems in which the water is distributed by means of a pressure pump and without cold water storage.

3.116 The rising main is connected directly to the water heater. A double non-return valve on the cold feed to the water heater provides backflow protection. There may also be a pressure-reducing valve or, in large buildings, a pump and pressure vessel. Since the water in the system will expand with temperature, an expansion vessel and a safety temperature and pressure relief valve are required. Hot water distribution from pressurised systems can be used in both recirculation systems (which are normally fitted in large buildings) and non-recirculation systems (which are normally found in dwellings and some small buildings). In recirculating systems there is a continuous circulation of hot water from the water heater around the distribution circuit and back to the heater. The purpose of this is to ensure that hot water is quickly available at any of the taps, independent of their distance from the storage water heater.

Hot water heaters: calorifiers and hot water cylinders

3.117 There are varieties of hot water heaters available. The specification will depend on the size and intended usage of the system.

3.118 Hot water heaters are water storage vessels heated:

- directly by gas or oil flame;
- by electricity, normally by means of an electric immersion heater within the vessel;
- by primary heating circuits of low pressure hot water or steam which is passed through a heat exchanger inside the vessel; or
- by an external heat exchanger (sometimes returning to a holding buffer vessel).

3.119 Direct heating vessels are heated from below usually by gas or oil and are considered of low *Legionella* risk as they avoid the reduced temperature areas found in indirect heating calorifiers; they also have lower storage volumes and even temperature. In contrast, in indirect heating calorifiers the cold water typically enters at the base of the calorifier, creating an area below the coil where the initial blended water temperature may support microbial growth.

Shunt pumps

3.120 Stratification, which may occur in large calorifiers, should be avoided. Fitting a timer-controlled shunt pump to circulate the water from the top of the calorifier to the base during the period of least demand for at least an hour (when the temperature inside the vessel is at its highest (at least 60°C) – typically in the early hours of the morning) should be considered to pasteurise the base water on a daily basis.

3.121 Ideally, the shunt-pump return should be as low down on the calorifier as possible. For existing calorifiers without suitable connections, the cold water feed may be used. Shunt-pump operation should not be done or any alteration carried out before cleaning and descaling the calorifier, as operating the pump may disturb sludge or sediment. As an alternative to shunt pumps, some calorifiers are fitted with coils extending to the base to promote convective mixing during heating.

3.122 Particulate matter and sludge can accumulate at the base of the calorifier, so the design should incorporate an easily accessible and safe means to drain the vessel.

Calorifiers attached to solar heating systems

3.123 It is important that solar heating of hot water is designed so that it does not compromise the temperature control of the hot water system particularly during times when there is little heat gain from the solar panels. When there is little heat gain from the panels, there may be a larger volume of water at a reduced temperature than in a conventional system and the temperatures may be insufficient to maintain *Legionella* control. Consideration should be given to programming the boiler to heat the entire contents of the solar hot water cylinder once daily to 60°C, preferably during a period when there is little demand for hot water. A shunt pump may also be used to move hot water from the top of the calorifier to the base as described above. Where temperature control cannot be achieved, other measures such as using appropriate biocides should be considered.

3.124 Where hot water heaters are attached to solar heating systems, the risk assessment should assess the management and controls throughout the year as for conventionally heated calorifiers, taking account of when there is the potential for little solar generation during winter months. As with a conventional calorifiers, there will be temperature stratification providing favourable conditions for microbial growth, including legionellae, at the base of the vessel.

Design and construction

3.125 Plant or water systems should be designed and constructed to be safe and without risks to health for all users and all types of use and comply with current European Standards (European Committee for Standardization, 2006a, 2006b, 2012a). Waterborne hazards may be of a physical, chemical or microbial nature including the risks associated with colonisation and growth of legionellae within water systems, their components and the equipment attached to or filled from them. The type of system installed depends on the size and configuration of the building and the needs of the occupants; but the water systems should be designed, managed and maintained to minimise the risks associated with waterborne hazards. Hot and cold water storage systems in commercial buildings and public buildings, including hotels and leisure complexes, are often oversized relative to the actual usage, because of uncertainties in occupation at the design stage. This can lead to poor water movement and turnover and consequently an increased risk of *Legionella* growth. If the design needs to allow for future growth in hot or cold water demand, then this should be organised by designing the system to be expanded in a modular fashion. This enables additional plant to be added at a later stage if required.

3.126 Hot and cold water systems should comply with the national regulations and be designed to aid safe operation by preventing or controlling conditions which permit the growth of *Legionella* and to allow easy cleaning and disinfection. In particular, the following should be considered:

- The source water quality should meet the requirements of the EU Drinking Water Directive (Council Directive 98/83/EC) and any additional national requirements.
- Materials, components and associated equipment for management and maintenance purposes (e.g. tanks, calorifiers, TMVs, blending valves and circulation pumps) used in building water systems must be compatible with the physical and chemical characteristics of water supplied to the building to reduce corrosion or prevent excessive scale formation of system pipework and components.
- Materials which encourage microbial growth such as natural rubber, hemp, linseed oil-based jointing compounds and fibre washers should not be used in domestic water systems. Materials and fittings for use in water systems should have been shown not to support microbial growth.
- Similarly, any synthetic materials used should not adversely affect water quality by supporting microbial growth.
- Cold water storage tanks should be fitted with covers which comply with the national water regulations and ideally be secure; insect screens should be fitted to any pipework open to the atmosphere (e.g. the overflow pipe and vent). They should be insulated and sited to avoid heat gain from the surrounding environment.
- Multiple linked cold water storage tanks should be avoided because of operational difficulties due to possible unequal flow rates and stagnation. Where they are present there should be cross-flow across the tanks to avoid areas of stagnation.
- Accumulator/expansion vessels on pressure-boosted hot and cold water services should be fitted with diaphragms which are accessible for

draining and cleaning, but not be located in warm environments where they will be subject to heat gain.

- Point-of-use hot water generators, with minimal or no storage for remote low-use outlets, should be considered.
- TMVs, if fitted, should be sited as close as possible to the point of use and preferably within the outlet. Ideally, a single TMV should not serve multiple tap outlets but, if they are used, the distance to the outlet should be kept as short as possible, ideally less than 2 m. Where a single TMV serves multiple outlets/showerheads, it is important to ensure that these are flushed frequently.

Good design features

3.127 A well-designed system should incorporate the following points:

- An adequate supply of wholesome hot and cold water should be available, particularly at periods of peak demand, while avoiding excessive storage. In buildings where stored water is not essential, consideration should be given to direct mains systems with local POU water heaters.
- All parts of the system including storage tanks, water heaters, pipework and components and associated equipment containing water should be:
    - designed to avoid water stagnation by ensuring flow through all parts of the system; and
    - be made of materials which do not support microbial growth.
- Low-use outlets should be installed upstream of frequently used outlets to maintain frequent flow (e.g. an emergency shower installed before a frequently used toilet). Consideration should be given to self-flushing fittings which are validated to show they are effective and do not introduce any additional risks. However, where these are fitted, they must be maintained to minimise microbial colonisation.
- Avoidance of temperatures that support microbial growth, including legionellae, in any water storage vessels, distributed water pipework and any associated equipment.
- Single check valves are commonly used to prevent backflow of hot water to the cold feed. These valves should be rated for hot water use, as one side will be in contact with potentially hot water. Where applicable, an anti-gravity loop should be installed in the supply pipework as a failsafe mechanism should the single check valve fail.
- Design measures to improve energy efficiency targets and reduce water usage should be assessed at the design stage to ensure the control of *Legionella* is not compromised. Isolation valves should be included in all locations to facilitate maintenance and the implementation of control measures.

- The pipework and any components should be easy to inspect so that the thermal insulation and temperature monitoring can be checked.
- All alternative water supplies (e.g. greywater and rainwater collection) must be risk-assessed and managed to minimise the risk of microbial contamination and colonisation.

3.128 In buildings where there are those with an increased susceptibility to infection or with processes requiring specific water characteristics, operational controls and materials of an enhanced quality may be required.

Hot water systems

3.129 The general principles of good water system design aim to avoid temperatures within the system that encourage the growth of legionellae. Consideration should be given to the following:

- Maintaining a supply temperature of at least 60°C from the heat source (calorifier) and/or storage vessel
- The hot water circulating loop should be designed to give a return temperature to the calorifier from each loop of at least 50°C and ideally 55°C.
- Appropriate means for measuring temperature (e.g. thermometer/immersion pockets fitted on the flow and return to the calorifier and in the base of the calorifier).
- All pipe branches to individual outlets should be insulated and sufficiently short to enable the hot water at each outlet (or entry into a TMV) to reach 50°C (preferably 55°C) within one minute of turning on the tap[10].
- The storage capacity and recovery rate of the calorifier should be selected to meet the normal daily fluctuations in hot water use without any significant drop in target supply temperature. The open vent pipe from the calorifier should be sufficiently raised above the water level and suitably sited in the water circuit to prevent hot water from being discharged in normal circumstances. The open vent should ideally discharge to atmosphere via a tundish providing a safe and visible warning of a fault condition.
- Where more than one calorifier is used, they should be connected in parallel and deliver water at a temperature of at least 60°C.
- To overcome localised failures in the distribution system, circulating pump design and the correct commissioning of balancing valves are key issues to ensure flow throughout all parts of the hot water system, particularly the hot water return legs. Balancing the hot water system flow and return

[10] A scalding risk assessment should be carried out and where the assessment identifies user groups with a high risk of scalding such as the very young and those with reduced capacity to react to high temperatures; consideration should be given to fitting thermostatic mixing valves, preferably within the outlet. A maintenance regime will be necessary to ensure safe temperatures.

circuits is critical to avoid long lengths of stagnant pipework that is likely to be at a lower temperature.

- The calorifier drain valve should be located in an accessible position at the lowest point and as close as possible to the vessel so that accumulated particulate matter can be safely drained.
- All types of water heaters, including storage calorifiers, should be designed and installed so that they are safe to use and maintain, and able to be inspected internally, where possible. The storage capacity and recovery rate of the water heater should be selected to meet the normal daily fluctuations in hot water use without any drop in the supply temperature.
- Where fitted, the vent pipe from the storage water heater, which allows for the increase in volume of the water, should be of sufficient size and not discharge into a cold water tank but be directed to drain. Where more than one storage water heater is used, they should be connected in parallel.
- If temperature is used as a means of control, each storage water heater should deliver water at a temperature of at least 60°C.
- All storage water heaters should have a drain valve located in an accessible position at the lowest point of the vessel so that accumulated sludge can be drained easily and the vessel emptied in a reasonable time.
- A separate drain should be provided for the hot water system vent (particularly if the feed to the storage water heater incorporates a non-return valve). It should be possible to balance the flow of water throughout the hot water circuit by adjusting regulating valves to ensure that the target temperature and adequate water pressure is achieved throughout the system under all levels of water consumption.

Note

The flow of water expected within the pipes must be within the design specification of the regulating valve to ensure that sufficiently sensitive control of the flow can be obtained – i.e. the flow that the design engineers intend to achieve within the pipework must be above the minimum which the valve is designed to work with.

If temperature is used as the means of controlling legionellae, the hot water circulating loop should ideally be designed to give a return temperature to the storage water heater of 55°C but certainly not less than 50°C. The pipe branches to the individual hot taps should also be of sufficient size to enable the water in each of the hot taps to reach 55°C, but certainly not less than 50°C, within one minute of turning on the tap. There should be adequate international signage warning of the risk of scalding. Where there are several return loops in a hot water system, on each floor of a building or several risers, it is important to be able to measure the temperature of each return and not just the combined return to the heater. In addition to those required for control, thermometer/immersion pockets should be fitted on the flow and return to the storage water heater and in the base of the storage water heater.

Shunt pumps

3.130 In larger storage water heaters, the fitting of time-controlled shunt pumps should be considered to overcome temperature stratification of stored water. These should not operate continuously but during periods of low draw-off for a short period (typically 1–2 hours) and fitted so that they take hot water from the top of the vessel to the base.

3.131 Hot water distribution pipes should be sufficiently insulated so as not to affect cold water pipes, and where running alongside each other, cold pipes should be below the hot pipes and the air gap between them sufficient to allow for insulation around both, in order to prevent heat radiation and conduction between them.

Expansion vessels

3.132 Expansion vessels in systems operating at steady temperature and pressure may have long periods without exchanging any significant amount of water; they therefore can be at risk of aiding microbial growth. To minimise the risk of microbial growth, expansion vessels should be:

- installed in cool areas on cold flowing pipes;
- mounted as close to the incoming water supply as possible;
- mounted vertically on pipework to minimise any trapping of debris;
- installed with an isolation and drain valve to aid flushing and sampling;
- designed so as to minimise the volume retained within them;
- designed to stimulate flow within the vessel.

Thermostatic mixing valves (TMVs)

3.133 The use and fitting of TMVs on wash-hand basins should be informed by a comparative assessment of scalding risk versus the risk of infection from *Legionella*. Where a risk assessment identifies the scalding risk as insignificant, TMVs are not required. Downstream of TMVs it is not usually possible to retain control by means of heat, and it is also difficult to achieve control with biocides added to the hot and cold water. Some designs have the TMV in the outlet itself, which limits the potential for colonisation downstream. There are also TMVs that include an override mechanism enabling the downstream portions to be flushed with hot water. Where this is not possible, colonisation will have to be limited through regular cleaning, descaling and disinfection of the TMV and its associated downstream attachments, such as the showerhead and any associated hoses.

Cold water systems

3.134 Potable water which is continuously suppled from a public utility should ensure good water quality at point of entry. Where the supply is intermittent and/or from a private supply (e.g. from a spring or well, or bunkered in via tankers), point-of-entry treatment should be considered which may include filtration, ultraviolet treatment and/or biocide treatment. The temperature of the incoming water should be monitored during the warmest part of the year to enable an assessment of inherent risk and whether there is a need for additional water treatment on the incoming cold supply. Where temperatures are close to or exceed 25°C, then consideration should be given to POE treatment.

Cold water storage tanks

3.135 Where possible, cold water storage tanks should be sited in a cool place and protected from extremes of temperature by thermal insulation. Piping should be insulated and kept away from hot ducting, hot piping and other sources of heat to prevent excessive temperature rises in the cold water supply; typically an increase of no more than 2°C over the incoming water temperature should be allowed. The pipework should be easy to inspect so that the thermal insulation can be checked to see that it is in position and has remained undisturbed.

3.136 Access hatches should be provided on cold water tanks for inlet valve maintenance, inspection and cleaning (more than one hatch may be needed on large tanks).

3.137 The volume of cold water stored should be minimised and where supply is consistent should not normally be greater than one day’s water use. Multiple cold water storage tanks require care in the connecting piping to ensure that the water flows through each of the tanks, so avoiding stagnation in any one tank.

3.138 Screening should be provided to prevent the ingress of insects, birds and small animals.

Management of hot and cold water systems using the temperature control regime

Leak-testing

3.139 New pipework has traditionally been filled with water to detect leaks. In large buildings such as hotels and hospitals this is often done many months before the building is occupied. Newly constructed systems may also contain nutrients for microbial growth from the surfaces of new components, fluxes or other compounds used in jointing, or from dirt entering during construction and other activities. This can lead to the system becoming heavily colonised with microorganisms including legionellae before the building is occupied, resulting in a risk to the new occupants. Initially leak-testing can be done by pressurising the system with air. This avoids the risk of leaving the system filled with water for prolonged periods before occupation and is the preferred option, especially in healthcare premises.

3.140 If leak-testing is done by filling with water, precautions need to be taken to limit colonisation by dosing the system with a biocide, for example, while it remains unused and by ensuring some water flow in the system. Whatever precautions are taken following leak-testing, within two weeks of the occupation of the building, the water systems should be disinfected and flushed with fresh water in order to remove microbial growth and the build-up of nutrients.

Commissioning and recommissioning

3.141 Commissioning of a water system means the bringing of a new system into operation and applies to all component parts of a building water system including attached equipment. The aim of such commissioning is to check the system is performing to design specifications, that there are no leaks and that the flow of the hot water system is balanced. From a microbiological perspective, the period between filling the system and bringing it into normal use is potentially the most hazardous and if not carried out to limit the potential for colonisation the building is likely to be problematic for the rest of the system's life and be more costly to manage both economically and environmentally. A risk assessment should be performed before commissioning to identify and take into account the potential for stagnation as this may lead to microbial growth where buildings are not to be fully occupied immediately or where systems are commissioned as occupation occurs (e.g. infrequently or intermittently used buildings). Where it is planned that the entire building should not be fully occupied initially, consideration should be given to compartmentalisation so that each module can be filled and commissioned as required.

3.142 Any new water system will require, as a minimum, flushing before being brought into use to remove flux and cutting fluids, etc. Larger more complex systems are likely to also require disinfection. The building risk assessment carried out prior to the commissioning process should take into account the size and complexity of the water system. A new correctly designed and installed water system should provide wholesome water at every outlet; where there are any problems, the design or installation defect should be identified and rectified.

3.143 Before commissioning, the nature and quality of the incoming water supply must be determined. If it is a continuous public water supply, the water supplier will be able to provide details of the testing carried out in the local water supply zone in which the building is situated. If there is any doubt about the condition of the underground supply pipe connecting the building to the public supply main, the water supplier should be contacted so that it can carry out an appropriate investigation and advise whether it or the premises owner will need to take any action. If the building has an intermittent or a private water supply, (from a well, borehole, spring, etc.), the appropriate authority should be contacted to carry out a private water supply risk assessment to ensure the supply is of a potable quality and complies with the EU Drinking Water Directive (Council Directive 98/83/EC), if this has not been done already. The building owner is responsible for complying with the regulatory requirements as notified by the water supplier or the local authority, as appropriate, irrespective of whether it is a public or private water supply, or a combination of both.

Small buildings

3.144 Small developments where water systems are simple (individual commercial or light industrial units, small offices, rented domestic houses, etc.) should be thoroughly flushed before use, but this should be done as close to occupation as possible to minimise the possibility of microbial growth.

Large systems

3.145 Before use, all water systems should be cleaned, flushed and disinfected. This involves adding an effective disinfectant, such as chlorine or chlorine dioxide, drawing it throughout the system and leaving it for a specified time (the contact time) to take effect. It is important to monitor the levels of residual chlorine at selected outlets to ensure the minimum required concentration is maintained throughout the contact period. Where chlorine is used as the biocide, the pH of the water should be checked as the efficacy of chlorine can be adversely affected at pH values over 7.6.

3.146 If water turnover is anticipated to be low initially, it may be advisable not to commission certain parts of the system, such as cold water storage tanks, until the building is ready for occupation. This will ensure flushing during low-use periods will draw directly on the mains supply rather than intermediate storage. The manufacturer of any component to be bypassed should be consulted for any requirements, such as whether it needs to be filled or can remain empty until it is brought into use.

3.147 Following the commissioning of a new hot water system, the water temperature should be measured continuously over a typical day both at the bottom and at the outlet of the storage water heater. If the storage vessel is of sufficient capacity to deal with the demand, then the outlet temperature should not fall below 50°C for more than 20 minutes in a day. If the storage water heater is undersized, then the outlet temperature will fall during use and remedial action may be required, particularly if temperature is used as a control method. If the system changes from the original specification, this procedure will need to be repeated.

3.148 Standby storage water heaters should be emptied of water and there should be specified procedures in place to be followed before they are bought back into use. If a storage water heater or any substantial part of a hot water system is on standby or has been taken out of service for longer than one week, then the water in the storage water heater should be isolated from the system and brought up to at least 60°C for one hour before the isolation valves are opened to connect the heater to the system. If there are standby recirculating pumps on the hot water circuits, then they should be used at least once per week. If the system is to be treated with biocides as a means of controlling *Legionella*, the biocide concentration in the system should be monitored and reach normal operational levels throughout the system before being used.

Operation

<u>Cold water</u>

3.149 Cold water from the water utility is usually delivered to consumer buildings with a trace of active chlorine disinfectant and in a potable state to the customer, but users should not rely on this to treat the hot water system. Where water comes from rivers, lakes, boreholes or other sources, it needs to be pre-treated so that it is of equivalent quality to the mains supply. Where the water is of high turbidity or has particulates, this may require filtration prior to treatment.

3.150 Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption makes no specific recommendation about the temperature of the water supplied to premises. In practice the water temperature in winter is likely to be below 20°C in most parts of Europe. However, during summer, the incoming water temperature at some sites can become warm. If the incoming water is above 25°C, the water supplier should be advised to see whether the cause of the high temperature can be found and removed. If this is not possible, the risk assessment should reflect this increased risk and appropriate action taken if necessary.

Water softening

3.151 In hard water areas the water supply to the hot water system should be softened to reduce scale formation. Water softeners can occasionally become colonised with microorganisms including legionellae. For this reason it is advisable to have a sample point installed just downstream of the softener to enable water samples to be collected at least once a year and to be tested for the aerobic colony count and legionellae. The aerobic colony count should be compared with that of the incoming mains supply water. If there is evidence of colonisation as indicated by a rise in count relative to the incoming supply or the presence of legionellae, then the softener and its resin bed will need to be disinfected according to manufacturers' guidelines. If there is no colonisation, there is no need to disinfect the softener as this may shorten the life of the resin bed.

Hot water

3.152 Hot water may be heated with or without storage in a number of ways.

(1) Storage water heaters:

3.153 In storage water heaters the water can be heated by hot water or steam from a boiler which is passed through a coiled heat exchanger sited inside the hot water storage vessel (indirect heating). The storage water heater can also be heated by means of an electric immersion heater within the vessel. Finally, some storage water heaters can be heated directly by gas or oil flame; these water heaters have been shown to have the lowest incidence of colonisation by *Legionella*.

3.154 In a storage water heater, cold water enters at the base of the vessel with hot water being drawn off from the top for distribution. A control thermostat to regulate the supply of heat to the storage water heater should be fitted near the top of the vessel and adjusted so that the outlet water temperature is constant. The water temperature at the base of the storage water heater (i.e. under the heating coil) will usually be much cooler than the water temperature at the top and potentially create a zone of water temperature conducive to the growth of legionellae. One method of preventing growth is to ensure that the whole water content of the storage water heater, including that at the base, is heated to a temperature of at least 60°C for at least one hour each day. A shunt pump to move hot water from the top of the storage water heater to the base is one way of achieving this. Ideally the storage water heater will have specific connections for the shunt-pump return, as low down on the storage water heater as possible. The period of operation of this shunt pump needs to coincide with the operation of the heat source and a period of low demand (e.g. during the early hours of the morning). In all cases the operation of the pump should be controlled by a time clock.

3.155 Where more than one storage water heater is installed to supply one hot water system, they may be connected in parallel or in series. If they are connected in series, they should be designed and operated so that all of the water in all of the storage vessels is heated to at least 60°C for at least one hour each day and that there is sufficient storage capacity to ensure that the feed temperature to the system never drops below 60°C.

(2) Non storage water heaters:

3.156 Hot water may also be heated by “instantaneous” water heaters such as Angeleri-type heaters in which steam is used to directly heat the circulating water in a coil. Such systems and storage water heaters are increasingly being superseded by plate heat exchangers in which steam or hot water from a boiler passes on one side of thin metal plates and the water to be heated passes on the other. Plate heat exchangers are very efficient and may be used in conjunction with a hot water storage vessel, sometimes called a buffer vessel. The system should be operated to ensure that the circulating hot water remains at 60°C throughout the day and the whole volume of water within the storage vessel reaches at least 60°C for at least one hour each day.

Point-of-use instantaneous heaters

3.157 In some instances water may be heated at the point of use by an instantaneous heater. Such systems are generally considered to be of low risk of growing legionellae provided the cold feed is cold enough to prevent growth. Where there is the capacity to store water within these, they may constitute a risk where usage is low or intermittent.

Energy saving

3.158 There are various forms of energy-saving developments which are being introduced for both hot water and recreational systems. Where these are in accommodation sites and public buildings, *Legionella* control must be inherent in the design. This may mean that supplementary heating is necessary to boost temperatures especially in the cooler months in temperate areas. While energy saving is desirable, it should not be at the expense of water safety – all energy-saving measures should be risk-assessed for their impact on *Legionella* control. Where hot water systems are turned off for periods of time (e.g. in low season), they should be recommissioned before the building is reoccupied. For shorter intervals (e.g. for a few days) the water should be heated to 60°C and circulated and flushed through all outlets.

Solar heating

3.159 Solar energy is increasingly being utilised to heat domestic hot water. The principles of *Legionella* control must still be applied to these systems. The water may be heated directly by passage through the solar collector or via a heat exchanger. Systems should still be designed so that water is delivered to the hot water system at 60°C. This may require supplementary heating particularly during the cooler months. There are various designs of solar heating available, particularly in the more temperate parts of Europe, and systems may need testing for legionellae to confirm that control is being achieved.

Maintenance

Scale control

3.160 Some form of scale control is desirable in hard water areas. This is because there is a risk of calcium being deposited at the base of the storage water heater at temperatures greater than 60°C. Control is normally achieved by softening the cold water feed (see paragraph 3.151). An inspection port or hatch should be fitted in the side of the storage water heater so that the cleanliness of the base can be checked regularly and cleaned when needed.

Avoiding stagnation

3.161 Dead-legs and blind ends create areas which allow biofilms to develop and this increases the risk of legionellae growth within both the biofilms and their associated protozoan hosts. Whenever outlets are not used frequently (at least once a week), they should be flushed until the water temperature and biocide levels reach equilibrium with the supply water. If the outlet is no longer required for use, they should be removed and the pipe cut back as far as possible to the supply pipework/circulating loop.

3.162 Where standby units are provided, there should be procedures in place to enable incorporation of these units into routine use. Standby pumps should be changed over and used each week to avoid water stagnation. If storage water heaters or mobile air conditioning units are put on standby because they are not needed, they should be isolated and emptied of water and there should be specified procedures in place to be followed before they are brought back into use.

3.163 Maintaining the cleanliness of water softeners, filters, aerators, flow restrictors, TMVs, etc. is also important and best achieved by following manufacturers' recommendations. Coarse filters and strainers should be checked and cleaned regularly to prevent the build-up of organic contaminants.

Regular flushing of showers and taps

3.164 Before the following procedures are carried out, consideration should be given to the removal of infrequently used showers and taps. If they are removed then the redundant supply pipework should be cut back, as far as possible, to a common supply (e.g. to the recirculating pipework or the pipework supplying a more frequently used upstream fitting).

3.165 The risk from *Legionella* growing in peripheral parts of the domestic water system such as dead-legs off the recirculating hot water system may be minimised by regular use of these outlets. When outlets are not in regular use, weekly flushing of these devices for several minutes (see paragraph 3.161) can significantly reduce the number of *Legionella* discharged from the outlet.

3.166 Where it is difficult to carry out weekly flushing, the stagnant and potentially contaminated water from within the showerhead and hose/tap and associated dead-leg needs to be purged to drain before the appliance is used. It is important that this procedure is carried out with the minimum production of aerosols (e.g. additional piping may be used to purge contaminated water to drain).

Treatment and control programmes

3.167 It is essential that system cleanliness is achieved and maintained because the efficacy of the control method (both temperature and biocide activity) may be reduced substantially in systems that are fouled with organic matter such as slimes or inorganic matter such as scale and corrosion products.

3.168 It is recommended that hot water should be stored at 60°C and distributed such that a temperature of at least 50°C and preferably 55°C is achieved within one minute at the hot water outlets. Care is needed to avoid much higher temperatures because of the risk of scalding. At 50°C the risk of scalding is small for most people, but the risk increases rapidly with higher temperatures and for longer exposure times. The difference between the highest and lowest temperatures recorded at the taps after one minute should not be greater than 10°C. A wider difference may indicate inadequate flow, a poorly balanced system and a lack of insulation or backflow of cold water into the hot system.

Monitoring the temperature regime

3.169 Mixer taps and thermostatic mixing valves usually contain non-return valves within their hot and cold feeds in order to prevent backflow of hot water into the cold water or vice versa. Failure of the non-return valves can be detected by monitoring the temperatures of the cold water and the hot water supplies. If such a fault is found it can be overcome by installing non-return valves in the cold and hot water feeds.

3.170 In addition to the routine monitoring and inspection when using temperature as a control regime, the checks in Table 5 should also be carried out and appropriate remedial action taken if necessary.

Biocide treatments

3.171 Where biocides are used to treat water systems they, like the temperature regime, will require meticulous control if they are to be equally effective. It is recommended that the control system be checked at least weekly to ensure that it is operating correctly and continuing to control *Legionella*. A daily visual check on the levels of biocide used can serve as an early warning to problems with the dosing system. Biocides commonly used to control legionellae in hot and cold water systems include chlorine, chlorine dioxide and copper/silver ionisation.

Monitoring oxidising biocides (chlorine, chlorine dioxide)

3.172 For most hot and cold water systems, routine inspection and maintenance will usually be sufficient to ensure control if the following areas are checked at regular intervals and appropriate remedial action taken when necessary, with details of all actions being recorded. These include:

- the quantity of chemicals in the reservoir;
- the rate of addition of the agent to the water supply;
- the concentration of the agent measured monthly at the sentinel taps;
- the concentration of the agent measured annually at a representative number of outlets.

3.173 If the levels are less than expected, then appropriate investigations should be carried out to determine the remedial work needed, and the frequency of monitoring should be increased until control is re-established to the predetermined levels.

3.174 Where there have been either changes to the control regime and system or component failures or adverse monitoring results, the frequency of monitoring should be increased (weekly) until control is re-established and verified to be effective. The interval between samples may then be increased – e.g. initially to monthly and then quarterly until there is confidence that system controls are effective in the long term.

Table 5 Monitoring the temperature control regime

Frequency	Check	Standard to meet		
		Cold water	Hot water	
Monthly	Sentinel taps (see Glossary)	The water temperature should be 25°C or less (ideally ≤20°C) after running the water for up to two minutes	The water temperature should be at least 50°C within one minute of running the water.	This check makes sure that that the supply and return temperatures on each loop are unchanged (i.e. the loop is functioning as required). If the cold water temperature cannot be maintained below 25°C in all areas, then alternative control strategies are necessary to minimise the risk of exposure to legionellae
	If fitted, input to TMV on a sentinel basis		The hot water supply to the TMV temperature should be at least 50°C (preferably 55°C) within one minute of running the water.	One way of measuring this is to use a surface temperature probe on the inlet pipes to the TMV
	Water leaving and returning to the water heater		Outgoing water should be at least 60°C, return at least 50°C	If fitted, the thermometer pocket at the top of the hot water storage heater and on the return leg are useful points for accurate temperature measurement. If installed, these measurements could be carried out and logged by a building management system. In complex systems the temperatures of individual returns from each loop and not just the combined returns should be monitored. This is because the overall return may mask an individual low temperature on a return loop
Six monthly	Incoming cold water inlet (at least once in the winter and once in summer)	The water should preferably be below 20°C at all times		The most convenient place to measure is usually at the ball-valve outlet to the cold water storage tank
	If fitted, cold input to TMV			
Six monthly	Representative number of taps on a rotational basis	The water temperature should be 25°C or less (ideally ≤20°C) after running the water for two minutes	The water temperature should be at least 50°C (preferably 55°C) within one minute of running the water. The difference between the highest and lowest temperature recorded at the taps after one minute should not be greater than 10°C	This check makes sure that the whole system is working properly

Monitoring ionisation

3.175 For most systems, routine inspection and maintenance will usually be sufficient to ensure control if the following parameters are also monitored at regular intervals and appropriate remedial action taken when necessary, with details of all actions being recorded. These include:

- the rate of release of copper and silver ions into the water supply;
- the silver ion concentrations at a small number of sentinel outlets should be checked at least quarterly;
- the measurement of silver ion concentrations at representative taps selected on a rotational basis once each year;
- the condition and cleanliness of the electrodes when fitted should be checked at least monthly unless an anti-scaling type of electrode cell is employed;
- the measurement of the pH of the water supply, along with the other analyses.

3.176 Unless automatic controls are employed, fluctuations in concentrations of treatment may occur and therefore it is advisable to regularly check the concentrations of both silver and copper ions.

General monitoring

3.177 All water services should be routinely checked for temperature, water demand and inspected for cleanliness and use. Ideally, the key control parameters should be monitored by a building management system, if one is present. This will allow early detection of problems in maintaining the control regime.

3.178 The frequency of inspection and maintenance will depend on the system and the risks it presents. All the inspections and measurements should be recorded and should include:

- the name of the person undertaking the survey, their signature or other identifying code, and the date on which it was made. Computer records are acceptable;
- a simple description and plan of the system, and its location within and around the building. This should identify piping routes, storage and header tanks, hot water storage heaters and relevant items of plant, especially water softeners, filters, strainers, pumps and all water outlets;
- records of any untoward incidents (e.g. a pump failure or monitoring results that are out of range) and any remedial actions taken.

Annual check

3.179 This should include:

- Visually inspecting the cold water storage tank in order to check the condition of the inside of the tank and the water within it. The lid should be in good condition and fit closely. The insect screen on the water overflow pipe should be intact and in good condition. The thermal insulation on the cold water storage tank and associated pipework should be in good condition so that it protects it from extremes of temperature. The water surface should be clean and shiny and the water should not contain any debris or contamination. The cold water storage tank and ball-valves should be cleaned, disinfected and faults rectified, if considered necessary. If debris or traces of insects and/or vermin are found, then the inspection should be carried out more frequently.

- Making a record of the total cold water consumption over a typical day to establish that there is reasonable flow through the tank and that water stagnation is not occurring. Whenever the outlet/building-use pattern changes, this measurement should be repeated.
- Checking that all outlets are regularly used; any water outlets that are no longer used should be removed.
- Draining the hot water storage heater and checking for debris in the base of the vessel. The hot water storage heater should then be cleaned if considered necessary.
- Checking the plans for the fire and the hot and cold water circuits to make sure they are correct and up to date – this should be done by physical examination of the systems, if possible. Plans should be updated if necessary.
- Ensuring that the operation and maintenance schedules of the hot and cold water systems are readily available and up to date with named and dated actions throughout the previous year. Any insulation should be checked to ensure that it remains intact.
- Checking the presence of, and documentation for, all water connections to outside services including kitchens, fire hydrants and chemical wash-units and ensuring there has been maintenance as required and there is appropriate backflow prevention.
- Checking there is documentary evidence that all fire and sprinkler systems undergo regular maintenance and are tested by a qualified person annually. This should include checks on the integrity of one-way or backflow regulators in any connection to the cold water system.
- Reviewing the lines of responsibility, training and competence of staff.

Microbiological monitoring

3.180 The water used to supply hot and cold water systems should be of potable quality. There is not normally any requirement to test for the aerobic colony count although this may be useful as part of the checks before and after cleaning and disinfection of tanks or other parts of a system when a pre-treatment microbial count can be compared to the count following cleaning and disinfection. It is important, however, to ensure that samples are not taken for at least 48 hours after disinfection to allow the system and injured-but-not-killed organisms to recover. This recovery time interval reduces the likelihood of false negative results.

Monitoring for Legionella

3.181 It is recommended that this should be carried out:

- in hot water systems treated with biocides where storage and distribution temperatures are reduced from those recommended in the section on the use of temperature to control *Legionella* (see paragraphs 3.139–3.159). This should be carried out on a monthly basis initially for 12 months and if satisfactory results are obtained, quarterly thereafter;
- in systems where control levels of the treatment regime (e.g. temperature and biocide levels) are not being consistently achieved. In addition to carrying out a thorough review of the system and treatment regime, frequent samples (e.g. weekly) should be taken until the system is shown to be under control;
- when an outbreak is suspected or has been identified;
- as part of the risk assessment process:
    - when there is doubt about the efficacy of the control regime, or
    - where there are novel systems or there have been modifications to the system, or
    - where a system has been offline and not used for some time (e.g. during refurbishment or when in seasonal use), or
    - to verify that the recommissioning procedure has been effective.

3.182 Samples should be taken as follows:

- Cold water system – from the cold water storage tank, the furthest outlet from the tank and the warmest part of the system.
- Hot water system – from the hot water storage heater outlet or the nearest tap to the hot water storage heater outlet plus the return supply to the hot water storage heater or nearest tap to that return supply. Samples should also be taken from any cool parts of the system identified by temperature monitoring and the base of the hot water storage heater where drain valves have been fitted. The furthest outlet from the hot water storage heater should also be sampled.

3.183 The complexity of the system will need to be taken into account in determining the appropriate number of samples to take. For example, if there is more than one loop main present in the building, taps on each loop (see Figure 3) will need to be sampled. In order to be representative of the system as a whole, samples should be of circulated treated water and not be taken from temporarily stored water, for example at TMV-controlled taps and showers. These may require sampling but this should be determined by risk assessment.

3.184 Analysis of water samples for *Legionella* should be carried by a laboratory accredited to ISO 17025, which includes within its scope of accreditation the detection of *Legionella* (including *Legionella pneumophila*) from water, swabs and also ideally from sludges and biofilms, and which takes part in an external quality assessment scheme for the isolation of *Legionella* from water. The interpretation of any results should be carried out by experienced microbiologists who are familiar with the water systems.

3.185 Table 6 gives guidance on the actions to be taken in the event of finding *Legionella* in the water system.

Table 6 Action levels following *Legionella* sampling in hot and cold water systems

***Legionella* (cfu/litre)**	**Action required**
Not detected	Acceptable
<100 to 1000	Refer to the Responsible Person / WSG and ensure real-time monitoring (biocide levels, temperatures, etc.) are within target limits throughout the system.
>1000 to <10,000	Either: (i) If a small proportion of samples (10–20%) are positive, the system should be re-sampled. If a similar count is found again, then a review of the control measures and risk assessment should be carried out to identify any remedial actions; (ii) If the majority of samples are positive, the system may be colonised, albeit at a low level, with *Legionella*. Disinfection of the system should be considered but an immediate review of control measures and a risk assessment should be carried out to identify any other remedial action required.
≥10,000	The system should be re-sampled and an immediate review of the control measures and risk assessment carried out to identify any remedial actions, including whether a disinfection of the whole system or affected area is necessary.

Cleaning and disinfection

3.186 Hot water services, and exceptionally cold water services, should be cleaned and disinfected in the following situations:

- if routine inspection shows it to be necessary;
- if the system has been out of use for more than one month (e.g. a hotel during the low season);
- if the system or part of it has been substantially altered or entered for maintenance purposes in a manner which may lead to contamination;
- following adverse microbiological results;
- during or following an outbreak or suspected outbreak of Legionnaires' disease.

3.187 Disinfection can be carried out by the use of chemical or thermal disinfection as described in this part. It is preferable to use chemical disinfection. It is essential that the system is clean prior to disinfection and that all parts of the system are treated, not just those that are readily accessible.

3.188 The inspection frequencies for hot and cold water systems are detailed in Checklist 2 at the end of this section.

Spa pools and hot tubs

3.189 A spa pool (also known as a spa bath, hot tub, whirlpool spa and commonly known as a Jacuzzi – which is a trade name and should not be used generically) is a bath or a small pool for persons to sit in (not swim) where warm water is constantly recirculated, often through high velocity jets or with the injection of air to agitate the water. Spa pools may come in a range of shapes and sizes and larger spa pools may incorporate different areas and equipment such as bubble beds (steel lounger-shaped frames with bubble jets). There are several risk factors which increase the likelihood of waterborne infections caused by spa pools, and they are the third most common cause of outbreaks of Legionnaires' disease.

3.190 Risk factors include:

- The water is not changed after each user; instead it is filtered and chemically treated.
- The water temperature is normally greater than 30°C and falls within the temperature range which allows legionellae and other potential waterborne pathogens to grow, including legionellae, *Pseudomonas aeruginosa* and environmental mycobacteria.
- The generally high ratio of bather to water volume leads to a high-nutrient content of the pool water especially as many users do not shower before using the pool.
- The deliberate agitation creates a spray or aerosol above the surface of the water which can be readily inhaled both by pool users and those in the vicinity.

3.191 Infectious agents can be easily introduced to a spa pool via bathers, from dirt entering the pool, especially when situated outside, or from the water source itself. Spa pools can therefore be a risk even when not being used by bathers (e.g. when being run for display purposes). Careful attention to design, maintenance and cleaning of equipment such as filters, and regular water treatment to prevent/control the risk from *Legionella* is required.

3.192 **Hot tubs** (discrete units filled with water) are increasingly being installed in holiday accommodation, campsites, etc. where they may be for the use of a single family, for example, or for multiple users. It is more difficult to effectively manage water quality in hot tubs due to the design, mode of disinfection and high user-to-bather volume. When used in these situations it is essential that they are actively managed, especially during periods of low or no occupation.

Regular checks should be made of the disinfectant and pH levels to ensure effective disinfection and pH levels.

3.193 **Whirlpool baths** (baths fitted with high velocity water jets and/or air injection but without water recirculation) do not present the same risk of causing outbreaks as spa pools because the water is discharged after each use and only a limited number of people are exposed. Like spa pools, biofilms can build up within the system pipework associated with the air and water booster jets, so regular cleaning and disinfection is recommended.

3.194 **Swim spas** are small swimming pools with jets which produce a counter-current to swim against in a relatively small volume of water.

3.195 Bather loads and water temperature will not be as high as in spa pools but there have been cases of Legionnaires' disease when the jets have been removed, leaving a void where sludge and stagnant water can build up encouraging the growth of waterborne pathogens including legionellae.

3.196 **Natural spas,** especially those using thermal/mineral water and associated equipment, can provide an ideal habitat for the growth of protozoa and legionellae. They may be used for the therapeutic values of the natural water and so have minimal if any water treatment. As the potential for waterborne infections is relatively high, the risks may be minimised by ensuring bathers shower before using the pool, maintaining frequent changes of water, regular physical cleaning above and below the water line and screening users to exclude those at a high risk of infection. Some natural pools may be treated by filtration, UV treatment and superheating the water to 70°C on a daily basis when the pool is not being used. Communication with users is important to ensure they understand the infection risks from using such pools. (For more information see the WHO's (2006) *Guidelines for Safe Recreational Water Environments: Volume 2 – Swimming Pools and Similar Environments*.)

Pool design

3.197 The design of the pool and associated equipment is critical in maintaining a safe pool and environment. It needs to be ensured that there is sufficient space for effective inspection, maintenance, and cleaning and disinfection of the pool and pipework, water treatment plant, balance tank, etc. and that any equipment (loungers, headrests, etc.) is fully accessible for all surfaces to be effectively cleaned. The design should also ensure that all areas can be drained and that electrical safety, the risk of entrapment, the surfaces chosen to minimise slips, trips and falls, safe chemical handling and storage, air quality management, etc. are also considered.

3.198 Ideally showers should be sited to encourage bathers to shower before using the spa pool, and pool usage periods should be managed by siting the jet action buttons away from the poolside to encourage users to leave the pool. This is so that the pool has rest periods to allow for the recovery of effective biocide residuals.

3.199 Water supplying the pools should be of potable quality and ideally filled from copper-plumbed piping and not fed from a hosepipe. Hosepipes and plastic piping can provide nutrients which leach and support microbial growth. Where stagnant water remains within plastic piping in a warm environment, there is the potential for microbial growth including *Pseudomonas aeruginosa* and legionellae. Spa pools and hot tubs on board ships pose extra challenges due to the movement of the ship and water used for filling especially where salt water is used.

Spa pool management

3.200 As with other systems in large and complex facilities such as large hotel complexes with leisure facilities, there should be a WSP approach to managing all water including pools and associated systems/equipment (see paragraphs 3.3–3.6). The WSG should also include specialists in pool water treatment. There should be clear governance and lines of accountability.

3.201 It is important that those in charge of the pool water systems have sufficient training, experience and competence to manage the pools safely. The objectives of pool water management are to ensure the safety of all users and those in the immediate environment and include:

- the removal of suspended matter to improve pool clarity and appearance;
- the removal of nutrient sources which can support microbial growth;
- the breakdown of nitrogenous pollutants which reduce air quality and produce unpleasant odours;
- the removal, or destruction, of microorganisms including potential waterborne pathogens;
- maintaining an active biocide residual to rapidly destroy introduced pathogenic bacteria;
- the maintenance of the pH of the water at an optimum level for effective water treatment and user comfort;
- the maintenance of a comfortable temperature for bathers.

3.202 In smaller pools and hot tubs at least half the water in the spa pool should be replaced each day. In larger pools the risk assessment will determine the frequency of water change taking into account bather load, bather ratio to water volume, etc.

3.203 The pools should be fitted with a sand filter of the type fitted to swimming pools. This should be backwashed at the end of each day when the pool will not be used for several hours to allow the filter media to resettle so that it remains effective. The turnover time (the time taken for the whole volume of the system to cycle through the filter and back to the pool) should be six minutes.

3.204 Paper or polyester filters should not be used for commercial purposes or in spas used in holiday accommodation. The pool should be treated automatically and continually with an oxidising biocide, preferably chlorine, ideally injected prior to the filter. Hand-dosing must not be used except in an emergency. Where chlorinating disinfectants are used, a free chlorine residual of 3–5 mg/l should be maintained in the spa water. The pH should be 7.0–7.6. The pumps and disinfection system should be left operating 24 hours per day. The residual disinfectant concentration and pH should be measured before use and every two hours during use. Pool waters should be tested microbiologically once a month for colony count, coliforms, *Escherichia coli* and *P. aeruginosa*. The colony count at 37°C should be less than 100 cfu/ml and preferably less than 10 cfu/ml; there should be <10 cfu *P. aeruginosa* per 100 ml and there should be no coliforms or *E. coli* in 100 ml. Spa pools should also be sampled quarterly for *Legionella*.

3.205 Pools on display in retail outlets should be treated in the same manner as if they were being used. Details on the maintenance of spa pools are given in the booklet *The Control of Legionella and other Infectious Agents in Spa-Pool Systems* (Health & Safety Executive, 2017) and in Surman-Lee et al. (2007). See Table 7 for the action levels required following Legionella sampling in spa pools.

Table 7 Action levels following *Legionella* sampling in spa pools

***Legionella* (cfu/litre)**	**Action required**
Not detected	Under control –maintain vigilance
>100 but <1000	Refer to the Responsible Person / WSG Resample and ensure real time parameters including pH, biocide levels, clarity etc. are kept under review. Advise to drain clean and disinfect. Review controls and risk assessment and carry out any remedial measures identified. Refill and retest next day and 1–4 weeks later.
≥1000	Close pool immediately and exclude the public from the area. Shock-dose the pool with 50 mg/l chlorine for one hour, circulating the water sufficiently to ensure all parts of the pipework are disinfected. Drain clean and redisinfect. Review control and risk assessment and carry out any remedial measures identified. Refill and retest next day and 1–4 weeks later. Keep closed until all remedial work has been completed, legionellae are not detected and the risk assessment is satisfactory.

3.206 The inspection frequencies for spa pools are detailed in Checklist 3 at the end of this part.

Other risk systems

3.207 There are a number of other systems (which produce aerosols) which may pose a risk of exposure to *Legionella* (see the UK Health & Safety Executive guidance HSG274 Part 3 (Health & Safety Executive, 2013c)).

Humidifiers and air washers

3.208 Atomising humidifiers, ultrasonic misters/humidifiers, irrigation systems and spray-type air washers may use water from reservoirs or tanks where the water temperature exceeds 20°C. Misters/humidifiers are increasingly being used in food display cabinets in supermarkets and some hotels and have been associated with outbreaks. Unless they are installed correctly, regularly cleaned and maintained, they can become heavily contaminated, especially in industrial environments. The risk can be prevented by using humidifiers which do not create a spray (i.e. steam humidifiers).

3.209 The actions that need to be taken with regard to these and other risk systems are detailed in Checklist 4. In general, these systems should be maintained in a clean state, will often require regular disinfection and should be monitored on a regular basis where appropriate. There is also a duty to carry out a risk assessment and to maintain records of all maintenance that is carried out together with monitoring results. Great care needs to be taken during installation and commissioning to ensure that cross-connections do not occur between different water systems (e.g. fire mains and the cold water system) and there is adequate backflow protection.

Recommended inspection frequencies for risk systems

Checklist 1: Cooling water installations

System/ service	Task	Frequency
Cooling towers and evaporative condensers	Monitor water quality, water use and biocide/chemical use to assess and ensure effectiveness of water treatment regime, including key chemical and microbiological parameters, and observations of internal condition of pond, pack and water.	See Table 3
	Monitor central control function, conductivity sensor calibration, blow-down function, uniformity of water distribution, condition of sprays/troughs, eliminators, pack, pond, immersion heater, fans and sound attenuators. Check all valves, such as bypass valves, are adjusted as intended.	Monthly to three monthly, according to risk (see Table 3)
	Clean and disinfect cooling towers/evaporative condensers, make-up tanks and associated systems, including all wetted surfaces, descaling as necessary. Packs should be removed and cleaned where practicable	Six monthly

Checklist 2: Hot and cold water services

Service	Task	Frequency
Hot water services	Arrange for samples to be taken from hot water heaters, in order to note condition of drain water.	Annually
	Check temperatures of flow and return of calorifiers and returns on each loop.	Monthly
	Check water temperature after one minute of running the outlet to see if it has reached 50°C in the sentinel taps.	Monthly
	Visual check on internal surfaces of water heaters for scale and sludge. Check representative taps for temperature as above on a rotational basis.	Annually
Cold water services	Check tank water temperature remote from ball-valve and mains temperature at ball-valve. Note maximum temperatures recorded by fixed max/min thermometers where fitted.	Six monthly
	Check that temperature is below 20°C after running the water for up to two minutes in the sentinel taps.	Monthly
	Visually inspect cold water storage tanks, check temperature and carry out remedial work where necessary. Check representative taps for temperature as above on a rotational basis.	Annually
Showerheads and hoses	Dismantle, clean and descale showerheads and hoses.	Quarterly or more frequently if necessary
Thermostatic mixing valves	Check operation of TMV and dismantle, descale and disinfect if necessary.	Six monthly or more frequently if necessary
Little used outlets	Flush through and purge to drain.	Weekly
Fire and sprinkler systems	Check they are maintained on an annual basis including checks on the integrity of backflow prevention devices.	Annually

Checklist 3: Spa pools

Task	Frequency
Check water clarity.	Daily at opening and every 2 hours thereafter
Check automatic dosing systems are operating (including ozone or UV lamp if fitted).	Daily at opening
Check that the amount of dosing chemicals in the reservoirs are adequate.	Daily at opening
Determine pH value and residual disinfectant concentration.	Daily at opening and every 2 hours thereafter
Determine TDS	Daily
Clean water-line	Daily at end of the day/user-period with a fresh damp cloth using sodium bicarbonate (sodium hydrogen carbonate)
Clean overflow channels, grilles and skimmers.	Daily at end of the day/user-period
Clean spa pool surround.	Daily at end of the day/user-period
Backwash sand filter (for diatomaceous earth filters, comply with the manufacturer's instructions).	Daily at the end of the day or session when nobody will be using the pool for several hours (ensure water is completely changed at least every 2 days)
Inspect strainers, clean and remove all debris if needed.	Daily
Record the throughput of bathers.	Daily
Record any untoward incidents.	Daily as they occur
Check any automatic systems are operating correctly.	Daily
Inspect accessible pipework and jets for presence of biofilm; clean as necessary.	Weekly
Drain spa pool, clean whole system including strainers, then refill.	Daily to weekly based on risk assessment
Drain and clean balance tank.	At least twice per year based on risk assessment and weekly visual checks
Disinfect flexible hoses.	Weekly
Microbiological tests.	Monthly for ACC, coliforms, *E. coli, P. aeruginosa* and quarterly for *Legionella*
Full chemical test.	Monthly or as determined by risk assessment
Clean input air filter when fitted.	Monthly
Check residual current circuit breaker/earth leakage trip is operating correctly.	Weekly
Check all automatic systems are operating correctly (safety cut-outs, automatic timers, etc.).	Daily
Disinfectant/pH controller – clean electrode and check calibration	See manufacturers' instructions, but at least quarterly
Check effectiveness of filtration.	Monthly or according to manufacturers' instructions
Where possible clean and disinfect airlines.	Quarterly
Check all written procedures are correct.	Annually

Checklist 4: Other risk systems

System/service	Task	Frequency
Spray humidifiers, air washers and wet scrubbers	Clean and disinfect spray humidifiers/air washers and make-up tanks including all wetted surfaces, descaling as necessary.	Six monthly
	Confirm the operation of non-chemical water treatment (if present).	Weekly
Water softeners	Clean and disinfect resin and brine tank – check with manufacturer what chemicals can be used to disinfect resin bed.	As recommended by manufacturer
Emergency showers and eye-wash sprays	Flush through and purge to drain.	Six monthly or more frequently if recommended by manufacturers
Sprinkler and hose reel systems	When witnessing tests of sprinkler blow-down and hose reels, ensure that there is minimum risk of exposure to aerosols.	As directed
Lathe and machine tool coolant systems	Clean and disinfect storage and distribution system.	Six monthly
	Clean and disinfect entire system.	Weekly
Horticultural misting systems	Clean and disinfect distribution pipework, spray heads and make-up tanks including all wetted surfaces, descaling as necessary.	Annually and more frequently where the public have access
Dental station cooling systems	Flush. Drain down and clean.	At the beginning of each working day At the end of each working day
Car/bus/train washers	Check filtration and treatment system, clean and disinfect system.	See manufacturers' instructions
Fountains and water features (particularly indoors)	Clean and disinfect ponds, spray heads and make-up tanks including all wetted surfaces, descaling as necessary.	Interval depending on condition
Industrial water systems	Check the occurrence of *Legionella*. If legionellae detected, improve chemical disinfection or protect personnel and visitors.	Frequency: at least once yearly
Wastewater treatment systems	Check occurrence of *Legionella*. If legionellae detected, diminish water aerosolisation and protect the personnel and visitors.	At least once yearly

Part 4: Treatment methods for different water systems

4.1 Treatment of water in building water systems should not be an alternative to using good quality source water and ensuring that systems are in place to minimise any deterioration within the system to the point of use. The WHO's WSP approach to building water management advocates the use of a multiple barriers to prevent waterborne illness and does not just rely on end-point monitoring; negative microbiology results do not necessarily mean the water is safe. There are many factors in both sampling and analysis which can interfere with the accuracy of the microbiological test result; this is especially true when carrying out microbiological testing in disinfected systems. The WSP approach (see paragraphs 3.3–3.6) is a holistic water management approach that puts greater emphasis on identifying all the potential hazards and risks and putting in place validated risk-reduction measures to mitigate those risks and a comprehensive monitoring programme to ensure the control regime remains effective.

4.2 It is important when choosing a biocide that advice is sought to ensure there is no conflict with national regulations for the use and disposal of disinfected waters and there are no adverse effects due to water chemistry or to the materials used within the systems to be treated. Components, equipment, dosing plant, etc. introduced into drinking water systems must also comply with national plumbing codes and the requirements of water suppliers.

4.3 The potential for the production of disinfection by-products should also be considered, and alternative strategies may have to be used where these exceed safe guideline or legislative limits. However, it is worth noting that where there is the potential for waterborne infections, the WHO (2011) states: "Disinfection should not be compromised in attempting to control disinfection by-products".

4.4 No treatment strategy will be effective in systems which are not designed, maintained and operated to ensure there is good flow around the system. For any treatment to be effective it has to be able to reach, and be maintained at, the effective target levels in all parts of the system. Areas of stagnation will not achieve target-effective levels of either heat or biocides so it is important that the design optimises the flow and creates no areas where there is no or reduced flow around the system.

4.5 No water treatment system will be effective in a poorly engineered system. The efficacy of treatment regimens depends on the mode of action of the biocide chosen, water chemistry, temperature, contact time, cleanliness, pH, presence of biofilms, scale and corrosion. There is no one panacea and each scheme of control must be validated to ensure it is effective in the individual system. Ongoing monitoring is then essential to verify ongoing control.

4.6 Depending on the dosage and length of contact time, biocide treatment may result in degradation of system components and pipework; the materials used within building water systems therefore should be chosen with the potential consequences of disinfection treatments in mind.

Cooling systems

Biocides

4.7 Biocides are used for the long-term control of microbiological activity in cooling systems and can be oxidising or non-oxidising or a combination of both. The frequency and dosage will depend on the microbiological activity of the system and the surrounding environmental conditions. Cooling systems in high-nutrient environments will usually have a higher treatment demand.

4.8 Biocides are not effective unless applied and controlled as part of a comprehensive water treatment programme. Many factors will influence the selection of chemicals required for the treatment programme. The success of the treatment programme depends on several factors including:

- compatibility with the fabric of the system;
- compatibility with all chemical treatments/components used;
- adherence at all times to the recommended dosage throughout the entire system together with appropriate monitoring and control procedures.

4.9 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 be circulated 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.

4.10 Specific surfactants (biodispersants) function by wetting biofilms and aiding penetration of the biocides into the films. In microbiologically contaminated 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. Then installation of side-stream filtration can significantly reduce suspended dirt in systems that are prone to process contamination or severe dust contamination from the incoming air.

4.11 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, storing 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. However, the control regime must be validated in each system to show it is effective.

Oxidising biocides

4.12 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^-). Hypochlorous acid has greater oxidising potential and is a more active disinfectant than hypochlorite ions. The relative ratios of hypochlorous acid to hypochlorite ions in water are determined by pH. At low pH (6–7), hypochlorous acid dominates, while at high pH (>8.5) the hypochlorite ion dominates. The activity (in terms of time taken to have an effect) of chlorine is therefore significantly reduced at alkaline pH and additions of this biocide need to be adjusted to take account of this. Thus, the pH of the incoming water may be a factor when deciding upon the use of chlorine as a disinfectant. In all cases the applied dosage should be sufficient to maintain a free reserve in the range of 1.0–2.0 mg/l chlorine/chlorine dioxide and 2.0–3.0 mg/l bromine in the return water. Reserves consistently above 3 mg/l free chlorine/bromine should be avoided (except in exceptional circumstances) as this may increase the potential for system corrosion. 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 four 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.

4.13 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 reinfection and repopulation by microorganisms.

4.14 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.

4.15 Oxidising biocides have several advantages in 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.

4.16 Their major disadvantage is that they can be corrosive and their activity, particularly for chlorine, is pH-dependent.

Non-oxidising biocides

4.17 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.

4.18 To achieve the right non-oxidising biocide concentration to kill microorganisms, 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 microorganisms 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.

4.19 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 reinfection. 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.

4.20 In contrast to oxidising biocides, non-oxidising biocides cannot be readily neutralised in sample bottles. It is important when taking samples that these are taken at the point where the biocide is likely to be at the lowest level (immediately before dosing). The samples should be transported to the laboratory without delay and processed immediately on receipt to minimise the likelihood of false negative results.

Hot water systems

4.21 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. Biocides may have a detrimental effect on the lifecycle of both metallic and non-metallic components and the pipework of the system dosed. Good design, choice of materials, management and operation will reduce the requirement for biocide treatment. Although effective water treatment can be used successfully to control outbreaks, it does not necessarily eliminate legionellae from the system but controls them at a level that prevents further cases.

Thermal shock

4.22 Thermal shock treatment at 70ºC to 80ºC for relatively short periods has been used both for emergency disinfection and as part of long-term control programmes. However, recolonisation can frequently occur rapidly, even within a couple of weeks. This method carries an increased risk of scalding and must be carefully managed to avoid the risk. It is no longer recommended as part of a long-term control programme.

4.23 Thermal disinfection is carried out by raising the temperature of the whole of the contents of the hot water storage heater from 70ºC to 80ºC then circulating this water throughout the system for up to three days. To be effective, the capacity and temperature of the hot water storage heater should be sufficient 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, taking appropriate precautions to minimise the risk of scalding; this should also be measured. For effective thermal disinfection, the water system needs to be well insulated.

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

4.25 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.

4.26 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 TMVs unless the valves can be overridden, 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. Where pipework and components lack sufficient insulation, heat transfer can occur and compromise cold water temperatures in adjacent parts of the system.

Constant maintenance of the temperature between 55°C and 60°C

4.27 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 legionellae. Circulating water at 60°C – such that the temperature at each outlet or feed to a TMV reaches at least 50ºC, and preferably 55ºC, within one minute of opening the outlet – is the method most commonly used to control legionellae in hot water distribution systems. Provided there is sufficient heating capacity, it is relatively easy to implement and is easy to monitor continuously. It is important that the temperatures of the returns on each loop of the system are monitored as well as the tap and flow temperatures. It has the possible disadvantage of increasing energy consumption and there is an increased risk of scalding. Where TMVs are installed to reduce scalding risk, based on a comparative risk assessment of scalding risk versus the risk of legionellosis, they must be subjected to a programme of planned monitoring and maintenance.

Chlorination

4.28 Chlorine has also been used for the treatment of hot water systems though in hot water it may be difficult to achieve consistent effective levels due to gassing-off. Once diluted in water, the chlorine-based products dissociate to form hypochlorous acid and hypochlorite ions. The bactericidal action of the hypochlorite is pH-sensitive and decreases rapidly at values above pH 7; the pH of the water will therefore have to be monitored and may need adjustment. In systems which are colonised, the chlorine residual will be quickly used up; it is therefore essential that monitoring of distal points in all parts of the system is carried out to ensure there is an effective concentration of free chlorine available. The WHO's (2011) health-based guideline maximum value is 5.0 mg/l for total chlorine in drinking water. However, at high levels chlorine is likely to cause corrosion with prolonged use. Levels used for treatment of domestic drinking water are usually maintained at between 0.2 and 1 ppm (mg/l) at the point of delivery when used continuously in domestic systems.

4.29 Disadvantages of chlorine are its corrosive properties and its ability to react with organic matter such as biofilms within water systems to produce trihalomethanes and other halogenated disinfection by-products.

Shock hyperchlorination

4.30 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. For discharge to drain it may be necessary to neutralise the chlorine before discharge to avoid damage to, for example, wastewater treatment plants. The system should be flushed and 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

4.31 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 1 and 2 mg/l.

4.32 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

4.33 Chlorine dioxide is a potential alternative to chlorine disinfection although unlike chlorine it does not provide a residual effect. Chlorine dioxide has been successfully used to control *Legionella* in some hot water systems. It has the advantage over chlorine in that it is effective over a wider pH range than chlorine and is not as volatile at high temperatures as chlorine. The main concerns with chlorine dioxide are with the residual concentrations of chlorine dioxide and the by-products chlorite and chlorate. According to the WHO, typically 60–70% of the applied dose is converted to chlorite in the treated water, particularly in high pH water. This can be addressed by controlling the dose of chlorine dioxide at the treatment plant.

4.34 The WHO (2011) guideline limit is 0.7 ppm for both chlorite and chlorate although national limits may be less. The WHO (2011) states that these guideline values for chlorite and chlorate are designated as provisional because use of chlorine dioxide as a disinfectant may result in the chlorite and chlorate guideline values being exceeded, **and difficulties in meeting the guideline value must never be a reason for compromising adequate disinfection**.

Monochloramine

4.35 Monochloramine is more persistent than chlorine and has been shown to have greater efficacy against biofilms than chlorine does. According to the United States Environmental Protection Agency (USEPA) (1994), its use results in fewer complaints of taste and odour. 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. Appropriate dosing systems are now available for buildings. Typical concentrations of chloramine in drinking water are between 0.5 and 2 mg/l with a WHO maximum guideline value of 3 ppm.

Like chlorine, the use of monochloramine can cause corrosion of the pipes and materials used in water systems.

Ionisation

4.36 Ionisation is the term given to the electrolytic generation of copper and silver ions for use as a water treatment. Copper and silver ions are generated by passing a low electrical current between copper and silver electrodes. When used correctly, copper and silver ionisation has been shown to be effective at controlling legionella while other studies have shown that *Legionella* can be protected when in biofilms (USEPA, 2016). They act on the cell wall of the microorganism that alters the cells permeability which, together with protein denaturisation, leads to cell lysis and death.

4.37 The concentration of ions in the water depends on the power applied to the electrodes and the water flow rate. In the UK the Water Supply (Water Quality) Regulations 2000 set a standard for copper of 2 mg/l, which must not be exceeded. However, there is currently no standard for silver ion concentrations used for domestic purposes; neither the EU nor the WHO have established limits for silver. The WHO (2011) states: “there is no adequate data with which to derive a health-based guideline value for silver in drinking water” and that “special situations exist where silver may be used to maintain the bacteriological quality of drinking water and higher levels of up to 0.1 mg/litre could be tolerated in such cases without risk to health”. Equipment manufacturers generally recommend copper (0.2–0.8 mg/l) and silver (0.02–0.08 mg/l) ion concentrations to control *Legionella* effectively.

4.38 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 accumulation of scale on the electrodes in some systems, 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 accumulation of scale and concentration of dissolved solids therefore need to be carefully controlled so that suitable ion levels are consistently maintained throughout the system. This may require additional water treatments.

4.39 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. Advantages include a long residual time and effectiveness against a range of potential waterborne bacterial pathogens including pseudomonads*, Stenotrophomonas and Acinetobacter* spp*.* Disadvantages include maintaining effective concentrations of ions in hard water systems as scale builds up on the electrodes, difficulties of on-site monitoring, high costs of monitoring silver ion concentrations and staining of bathroom fittings. Some studies have shown *Legionella* may develop resistance to copper and silver ions and like other disinfectants can increase corrosion. The presence of chlorides and phosphates can also reduce effectiveness (USEPA, 2016).

4.40 Routine maintenance and monitoring recommendations from the Health & Safety Executive (2014) include:

- weekly – check rate and release of copper and silver ions in the water supply and install equipment capable of proportional dosing relative to flow;
- monthly – check copper and silver ion concentrations at sentinel outlets;
- annually – check the measurement of copper and silver ion concentrations at representative taps selected on a rotational basis once each year;
- check the condition and cleanliness of the electrodes and the pH of the water supply.

Hydrogen peroxide and silver

4.41 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. As with any water treatment programme, it should be validated to ensure it is effective in controlling target microorganisms including legionellae. When silver-stabilised hydrogen peroxide is used as an emergency disinfection, the system should be flushed and refilled. Silver hydrogen peroxide should not be used in water systems supplying dialysis units.

Ultraviolet (UV) radiation

4.42 Irradiation with UV light is an alternative method for the disinfection of drinking water. UV light (254 nm) inactivates bacteria by producing thymine dimers in their DNA that inhibit replication. The application of UV 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 UV 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 legionellae remain in the biofilms, dead ends, blind ends and other stagnant areas of the system.

Terminal filtration

4.43 There are commercially available bacterial filters that can be fitted to taps and showerheads containing filters that can be fitted in place of the conventional showerhead. These will prevent all legionellae and other bacteria from being released by the outlets to which they are fitted. They need to be replaced at the interval recommended by the manufacturer. They have been used particularly in healthcare premises where they have been very effective in preventing infection.

4.44 Filters must be validated to confirm they will retain legionellae and where fitted they should be checked to ensure there is sufficient activity space to minimise the contamination from outlet users (e.g. ensuring there is sufficient airspace above a filled basin/bath) and to prevent splashback contamination from drains. Once fitted they should not be removed for sampling and the same one refitted because of the risk of contamination.

4.45 The POU filters should be capable of delivering water in accordance with national and international standards for sterilizing grade filters and for standards which ensure the materials used will not leach nutrients into the water – e.g. BS 6920 on non-metallic materials and products for use in contact with water intended for human consumption (British Standards Institution, 2016) and Regulation (EC) No 1935/2004 relating to materials and articles intended to come into contact with food.

Cold water systems

4.46 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. Where chlorine dioxide is used, the concentration in water that is to be drunk should not exceed 0.5 mg/l and this is often not enough to achieve control in colonised systems. Therefore it may be necessary to use it at a higher concentration (e.g. 1–2 mg/l) and to provide alternative sources of potable water until the legionellae are shown to be under control. This may take a considerable period of time.

Spa pools

4.47 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 3–5 mg/l of chlorine. Public spa pools should be equipped with a sand filter of the type used for swimming pools and this should be backwashed each day. Alternatively, pre-coat filters including diatomaceous earth filters may be used and backwashed according to the manufacturer's instructions. At least half of 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 should be measured several times a day. Spa pools on display should be treated in the same way as those used by bathers.

List of abbreviations

CEN: Committee for European Standardization (Comité Européen de Normalisation)

cfu: colony forming units

ECDC: European Centre for Disease Prevention and Control

ELDSNet: European Legionnaires' Disease Surveillance Network

ESCMID: European Society of Clinical Microbiology and Infectious Diseases

ESGLI: ESCMID Study Group for Legionella Infections

EWGLI: European Working Group for Legionella Infections

EWGLINET: European Surveillance Scheme for Travel Associated Legionnaires' Disease

GU: genome units

ISO: International Organization for Standardization

PCR: polymerase chain reaction

POE: point of entry

POU: point of use

ppm: parts per million

q-PCR: quantitative polymerase chain reaction

TDS: total dissolved solids

TMV: thermostatic mixing valve

TVC: total viable counts

USEPA: United States Environmental Protection Agency

WHO: World Health Organization

WSG: Water Safety Group

WSP: Water Safety Plan

Glossary

Adiabatic	Adiabatic cooling uses the latent heat of evaporation of water sprayed onto the incoming air stream to cool the air supplied to an otherwise dry chiller.
Aerosol	A suspension in a gaseous medium of solid particles, liquid particles or solid and liquid particles having negligible falling velocity. In the context of this document, a suspension of particles (droplet nuclei) derived from fine droplets from which the water has evaporated leaving small airborne particles, typically <5 µm, containing legionellae which can be inhaled deep into the lungs.
Algae	Small, usually aquatic, plants which require light to grow, often found on exposed areas of **cooling towers,** tanks and walls of spa pools exposed to sunlight.
Air conditioning	A form of air treatment whereby temperature, humidity and air cleanliness are all controlled within limits determined by the requirements of the air conditioned enclosure.
Antibodies	Substances in the blood which destroy or neutralise various toxins or **components of bacteria** known generally as antigens. The antibodies are formed as a result of the introduction into the body of the antigen to which they are antagonistic as in all infectious diseases.
Bacteria	(Singular bacterium) a microscopic, unicellular (or more rarely multicellular) organism.
Biocide	A substance which **kills microorganisms.**
Biofilm	A community of **bacteria** and other **microorganisms**, embedded in a protective layer with entrained debris, attached to a surface such as pipework within a water system.
Blow-down/bleed-off	Water discharged from the system to control the concentration of salts or other impurities in the circulating water; usually expressed as a percentage of recirculating water flow.
Calorifier	An apparatus used for the transfer of heat to water in a vessel by indirect means, the source of heat being contained within a pipe or coil immersed in the water.

Chlorine	An oxidising chemical element (halogen) used in **disinfection.**
Cold water system (CWS)	Installation of plant, pipes and fitting in which cold water is stored, distributed and subsequently discharged.
Cooling tower	An apparatus through which warm water is discharged against an air stream, where the latent heat of evaporation is used to cool the water. The cooler water is usually pumped to a heat exchanger to be reheated and recycled through the tower.
Concentration factor	Compares the level of dissolved solids in the cooling water with that dissolved in the **make-up water** (also known as cycle of concentration). Usually determined by comparison of either the chloride or magnesium hardness concentration.
Corrosion inhibitors	Chemicals which protect metals by: (i) passivating the metal by the promotion of a thin metal oxide film (anodic inhibitors); or (ii) physically forming a thin barrier film by controlled deposition (cathodic inhibitors).
Dead end/blind end	A length of pipe closed at one end through which no water passes.
Dead-leg	Pipes leading to a fitting through which water only passes when there is draw-off from the fitting.
Dip slide(s)	A means of testing the microbial content of liquids. It consists of a plastic carrier bearing a sterile culture medium that can be dipped in the liquid to be sampled. It is then incubated to allow microbial growth. The microbial colonies resulting are estimated by reference to chart.
Disinfection	A process which destroys or irreversibly inactivates **microorganisms** and reduces their number to a non-hazardous level.
Distribution circuit	Pipework which distributes water from hot or cold water plant to one or more fittings/appliances.
Domestic water services	Hot and cold water intended for personal hygiene, culinary, drinking water or other domestic purposes.
Drift	Circulating water lost from the tower as liquid droplets entrained in the exhaust air stream: usually expressed as a percentage of circulating water flow but for more precise work it is parts of water per

	million by weight of air for a given liquid-to-gas ratio.
Drift eliminator	More correctly referred to as drift reducers or minimisers – equipment containing a complex system of baffles designed to remove water droplets from **cooling tower** air passing through it.
Evaporative condenser	A heat exchanger in which refrigerant held in coils is condensed by a combination of air movement and water sprays over its surface.
Evaporative cooling	A process by which a small portion of a circulating body of water is caused to evaporate, thereby taking the required latent heat of vaporisation from the remainder of the water and cooling it.
Fill/packing	That portion of a **cooling tower** which constitutes its primary heat transfer surface; sometimes called “packing” or “pack”.
Fouling	Organic growth or other deposits on heat transfer surfaces or within pipework causing loss in efficiency.
Half-life	Ratio of system volume to purge rate.
Hot water system (HWS)	Installation of plant, pipes and fittings in which water is heated, distributed and subsequently discharged (not including the cold water feed tank or cistern).
Legionnaires’ disease	A form of pneumonia caused by ***Legionella.***
Legionella	A genus of aerobic bacteria that belongs to the family Legionellaceae which has over 50 species. These are ubiquitous in the environment and found in a wide spectrum of natural and artificial collections of predominantly warm water.
Legionellae	Plural of legionella, a single bacterium of the genus *Legionella*.
Legionella pneumophila	The species of *Legionella* that most commonly causes Legionnaires’ disease.
Legionellosis	Any illness caused by exposure to ***Legionella.***
Make-up water	Fresh water which is added to a water system e.g. a cooling water system to compensate for wastage (e.g. via system leaks), evaporative loss and bleed.
Microorganism	An organism of microscopic size including **bacteria** fungi, protozoa and viruses.

Non-oxidising biocide	A non-oxidising biocide is one that functions by mechanisms other than oxidation, including interference with cell metabolism and structure (e.g. isothiazolone and glutaraldehyde).
Nutrient	A food source for **microorganisms.**
Oxidising biocide	Agent capable of oxidising organic matter (e.g. cell material, enzymes or proteins that are associated with microbiological populations resulting in death of the microorganisms). The most commonly used oxidising biocides are based on chlorine or bromine (halogens) which liberate hypochlorous or hypobromous acids on hydrolysis in water. The exception is chlorine dioxide, a gas which does not hydrolyse but which functions in the same way. Other oxidising biocides are ozone and hydrogen peroxide.
Pasteurisation	Heat treatment to destroy pathogens usually at high temperature for a given period of time.
Pontiac fever	An upper respiratory illness caused by ***Legionella***, but less severe than **Legionnaires' disease.**
ppm	Parts per million, a measure of dissolved substances given as the number of parts there are in a million parts of solvent. It is numerically equivalent to milligrams per litre (mg/l) with respect to water.
Pond retention time	Time a chemical is retained in the system.
Risk assessment	Identifying and assessing the risk of **legionellosis** from work activities and water sources on premises and determining any necessary precautionary measures.
q-PCR	A DNA amplification method (polymerase chain or PCR) that can be detected in real time (also named real-time PCR). The method also allows the quantification of the DNA molecules (q-PCR) present in the sample.
Scale inhibitors	Chemicals used to control scale. They function by holding up the precipitation process and/or distorting the crystal shape, thus preventing the build-up of a hard adherent scale.
Sero-group	A sub-group of the main species.

Sentinel taps	For hot water services – outlets selected for routine monitoring purposes usually the first and last taps on a recirculating system. For cold water systems (or non-recirculating hot water systems), the nearest and furthest taps from the storage tank or point at which the supply enters the building. The choice of sentinel taps may also include other taps which are considered to represent a particular risk.
Sessile sludge	A general term for soft mud-like deposits found on heat transfer surfaces or other important sections of a cooling system such as the base of the pond.
Shunt pump	A circulation pump fitted to hot water service/plant to overcome the temperature stratification of the stored water used during periods where there is little expected draw-off of water from the system usually in the early hours of the morning to circulate the hot water from the top of the calorifier/buffer vessel to the cooler base.
Slime	A mucus-like exudate which covers a surface usually produced by some **microorganisms.**
Stagnation	The condition where water ceases to flow within a system and is therefore liable to microbiological growth.
Strainers	A coarse filter usually positioned upstream of a sensitive component such as a pump control valve or heat exchanger to protect it from debris.
Thermal disinfection	Heat treatment to disinfect a system.
Thermostatic mixing valve	Valve with one or more outlets, which mixes hot and cold water and automatically controls the mixed water to a user-selected or pre-set temperature.
Total viable counts (TVC)	The total number of living **microorganisms** (per volume or area) in a given sample remembering that it only includes those organisms detectable by the particular method used.

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