
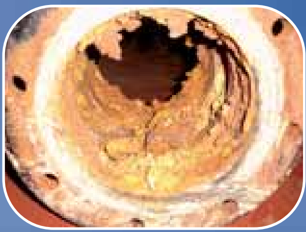



Water safety in buildings

Edited by: David Cunliffe, Jamie Bartram, Emmanuel Briand,
Yves Chartier, Jeni Colbourne, David Drury, John Lee,
Benedikt Schaefer and Susanne Surman-Lee

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Contents

Tables

Figures

Boxes

Foreword

Extensive experience shows that poor design and management of water systems in buildings can cause outbreaks of disease. The types of building, water uses, disease outcomes and individuals affected are diverse. The health risks are preventable and can be readily controlled. However, evidence from outbreak detection suggests that the overall trend is increasing. With increasing global urbanization, the overall exposure of the human population to poorly designed or managed water systems in buildings is increasing rapidly. Consequently, the risk of disease outbreaks is also increasing. Actions to reduce the risk of disease should be considered a public health priority.

One of the challenges is that management of building water supplies is often overlooked. In many countries and regions, management actions for water supplies in buildings may fall outside the responsibility of the drinking-water supplier. This can be influenced by a range of factors, including ownership of assets and rights of access. Water safety plans (WSPs) for managing public water supplies are not typically extended to apply within buildings. In many cases, owners, managers or maintenance personnel are responsible for management of building water supplies, but awareness and application of drinking-water guidelines is often limited.

This text is one of series of supporting documents that provide guidance on implementing the World Health Organization (WHO) *Guidelines for drinking-water quality* (GDWQ) (WHO, 2008). It is intended to support improvement of water safety within buildings.

The third edition of the GDWQ (WHO, 2008) introduced the concept of WSPs within a *Framework for safe drinking-water* (see Figure 1.1 in the introduction, below). The framework focuses attention on effective preventive management and thereby disease prevention. The GDWQ include specific reference to issues associated with large buildings, such as health care facilities, schools and daycare centres, and recommend that these buildings have their own WSPs to ensure the maintenance of safe water supplies. The intention is that such building plans should complement the WSPs of water suppliers.

The issue of water safety in buildings and the need for additional guidance was identified as a priority at the meeting of government-nominated experts who finalized the third edition of the GDWQ. This led to the development of this document. The guidance provided in this document is based on the framework from the GDWQ (WHO, 2008), as well as other supporting texts, particularly those dealing with:

- *Guidelines for safe recreational water environments volume 2: swimming pools and similar environments* (WHO, 2006a)
- health aspects of plumbing (WHO/WPC, 2006)
- heterotrophic plate counts (Bartram et al., 2003)
- *Legionella* and the prevention of legionellosis (Bartram et al., 2007)
- pathogenic mycobacteria (Bartram et al., 2004).

The development of this document was guided by the recommendation of expert meetings hosted first in March 2005 (by the University of East Anglia, Norwich, United Kingdom), then in December 2005 (by the WHO Collaborating Centre for Health Promoting Water Management and Risk Communication, Institute for Hygiene and Public Health, University of Bonn, Germany). These meetings were followed by meetings in February 2007 (by the Instituto Superiore di Sanita, Rome, Italy), in October 2007 (by the Scottish Executive, Edinburgh, Scotland), and finally in July 2008 (by the Federal Ministry of Health in Berlin, Germany). The development of this document was also guided by a series of critical reviews by specialists in the field.

The Department of Public Health and Environment (Programme on Water, Sanitation, Hygiene and Health, WHO) led the production of this document.

This document is written for the full range of "actors" who influence the overall safe management of building water supplies. In particular, it is directed to those who design, construct, manage, operate, maintain and regulate building water systems. It is intended to be a useful resource for the development of training and information material.

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Abbreviations and acronyms

GDWQ	World Health Organization *Guidelines for drinking-water quality*
IHR	International Health Regulations (2005)
PoE	point of entry
PoU	point of use
WHO	World Health Organization
WSP	water safety plan

1 Introduction

This document deals with all buildings where people use or are exposed to water, with a particular focus on buildings that include public use or shared facilities. Many of the principles also apply to sole occupancy dwellings and homes; however, it is not expected that management actions, such as the implementation of water safety plans (WSPs), will be applied in private homes.

Vulnerable population groups may be particularly susceptible to water-related hazards, and certain types of building are therefore of special concern. Important examples include medical and other health-care environments where the growth of a range of opportunistic waterborne pathogens, such as *Pseudomonas aeruginosa*, non-tuberculous *Mycobacteria* and *Legionella*, is a significant health concern and can lead to substantial and avoidable costs.

Outbreaks have been associated with both microbial and chemical contamination. A significant proportion of such waterborne disease is associated with contamination within buildings. This can arise from:

- direct contamination through faults in water systems (e.g. bird and small animal droppings into storage tanks) or leaching from inappropriate materials or corrosion (e.g. copper, lead, nickel, cadmium);
- indirect contamination through cross-connections between drinking-water systems and contaminated water or chemical storages;
- growth of indigenous microbes (e.g. *Pseudomonas aeruginosa*, non-tuberculous *Mycobacteria* and legionellae).

Guidance is provided for managing water supplies in buildings where people may drink water; use water for food preparation, washing, showering, swimming or other recreational activities; or be exposed to aerosols produced by water-using devices, such as cooling towers. These uses occur in a variety of buildings, such as hospitals, schools, child-care and aged-care facilities, medical and dental facilities, hotels, apartment blocks, sport centres, commercial buildings and transport terminals.

Although the focus of this document is managing water supplies within buildings, microbial and chemical hazards may sometimes also be introduced from water delivered to buildings from external sources.

The inadequate management of water in buildings has considerable health effects, as well as significant direct and indirect economic and social impacts. The World Health Organization (WHO) has identified that the benefits of all interventions to reduce risks from unsafe water outweigh costs by substantial margins (Hutton & Haller, 2004). In health-care settings, the costs of nosocomial infections, including those that are waterborne, are substantial and rising—in terms of both direct costs and reputational impacts (Anaissie et al., 2002). Travel and hotel stays are recognized as risk factors for legionellosis (Bartram et al., 2007). In Europe, approximately 20% of detected legionellosis cases are considered to be travel associated (Joseph, 2002; Bartram et al., 2007). Cases of legionellosis in hotels have often received extensive and damaging publicity, with significant economic impacts due to reduced patronage.

The document does not deal with the management or protection of water resources, or the use of recycled water. Further detail on these aspects is provided in the supporting text, *Protecting groundwater for health* (Schmoll et al., 2006), the *Guidelines for safe use of wastewater, excreta and greywater* (WHO, 2006b) and a forthcoming text on surface water.

The guidance provided in this document is based on the *Framework for safe drinking-water*, from the WHO *Guidelines for drinking-water quality* (WHO, 2008). The framework is shown in Figure 1.1.

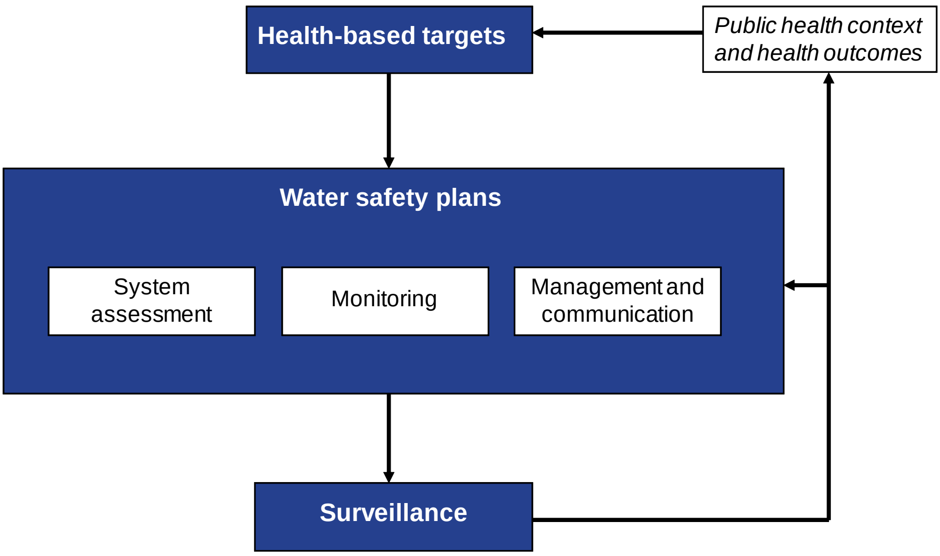


Figure 1.1 Framework for safe drinking-water

This document is divided into four sections:

- **Section 2** is made up of short introductions with principles that describe the core issues of water safety in buildings. It is organized into subsections that address hazards and risks, people and building types.
- **Section 3** deals with the role and responsibilities of stakeholders who influence the safety of water systems within buildings. Stakeholders can be involved in the planning, design, construction and renovation of buildings, as well as development of WSPs, and ongoing maintenance and operation of water systems.

- **Section 4** describes the steps in developing and implementing WSPs, and provides examples on how those key principles can be applied to buildings. This section is organized into subsections explaining how to assemble teams; understand the water system; identify hazards and assess risks; put in place control measures, operational monitoring and management procedures; and establish verification and supporting programmes.
- **Section 5** deals with the environment that supports the delivery of safe water within buildings but does not affect water quality directly. This section is organized into subsections addressing independent technical inspection and surveillance, disease surveillance and detection of outbreaks, regulatory and policy frameworks, and capacity building and training.

2 What are the issues?

This section describes the issues that confront engineers and planners when planning and implementing water safety plans (WSPs). It discusses water-system design, hazards and risk assessment, the end-users and building type.

2.1 Background

The World Health Organization (WHO) *Guidelines for drinking-water quality* (GDWQ) (WHO, 2008) describe a quality of water that is safe for a lifetime of consumption. The focus of the guidelines is the *Framework for safe drinking-water*, incorporating WSPs. This framework is applicable to all drinking-water systems, ranging from those serving the largest of cities to the smallest non-piped and household supplies. The framework is also applicable to delivery of drinking-water within buildings.

2.1.1 Purpose of WSPs

WSPs are the most effective means of consistently ensuring the safety of drinking-water supplies through a comprehensive risk-management approach that encompasses all steps, from source through treatment and distribution to consumers. The WSP approach is based on identifying all significant risks to public health, ensuring that effective controls and barriers are applied to minimize these risks to acceptable levels, and monitoring the operation of the controls and barriers to ensure that safety is maintained.

Application of WSPs and good management by those responsible for drinking-water production and distribution can assure drinking-water safety. However, management of building water systems can be complicated by a number of factors, including ownership of assets and rights of access that change on building property boundaries. Drinking-water systems in buildings are generally designed, installed and controlled independently from public water supplies. This contributes to buildings representing specific environments with specific hazards and hazardous events. Other complicating factors include:

- designated uses of buildings (e.g. hospitals, medical centres, residential care);
- use of supplementary water supplies, such as roof rainwater, greywater and water from private supplies (e.g. wells, bores and springs);
- supplementary point-of-entry treatment for water supplied from public systems;
- connection of drinking-water systems with water-using devices, such as cooling towers, evaporative condensers, boilers, swimming pools, washing machines, dishwashers, dental chairs, medical devices and industrial equipment;
- the vulnerabilities of people using buildings (e.g. in hospitals and aged-care facilities);
- the potential for multiple owners and shared assets, particularly in larger buildings.

In addition, buildings can have complex plumbing systems with at least two distinct systems for drinking-water and wastewater (sewage and greywater). In some buildings, a third system might be installed to distribute recycled water (treated sewage or greywater) for uses such as toilet flushing. The drinking-water system is typically divided into two sections providing hot and cold water, and large buildings may incorporate a separate section conveying water for firefighting.

2.1.2 Factors that affect WSP operation

One of the consequences of the separation of ownership and oversight has been a tendency for water safety in buildings to be overlooked, or at best receive limited attention. While public water supplies are generally maintained by water utilities or agencies with particular expertise, this is often not the case with water supplies within buildings. A general perception can be that water systems in buildings connected to public supplies are safe, ignoring the potential for contamination (both chemical and microbial) and growth of waterborne opportunistic pathogens within the building water systems. This also applies to devices (e.g. cooling towers, boilers, washing machines, swimming pools, hot tub pools) and equipment. Water systems are often managed by general maintenance staff with little training or expertise in managing water quality. Regulatory authorities often establish working relationships and provide oversight of public water supplies, but this is more challenging with building managers. There may be a limited number of public water suppliers in urban areas, but many thousands of independently owned buildings.

As a result, there are many examples where faults within buildings have led to outbreaks of drinking-water-derived disease (Kuroki et al., 1996; CDC, 1997a; Blackburn et al., 2004; Robert Koch Institute, 2004; Yoder et al., 2004, 2008ab; Djiuban et al., 2006; Liang et al., 2006; Vianelli et al., 2006). These have included diverse outcomes such as outbreaks of gastrointestinal disease associated with contamination of drinking-water by *Cryptosporidium* and *Cyclospora*, legionellosis (Legionnaires' disease) associated with hot and cold water systems and cooling towers, and methaemoglobinemia from boiler fluid contamination of drinking-water. Aesthetic issues, such as taste and odours, can be caused by water stagnation and through back-siphonage from flexible hoses connected to devices such as washing machines and ice machines. Turbidity and colour can be caused by corrosion or resuspension of biofilms and sediments from storage tanks and hot-water tanks.

A common theme associated with outbreaks has been poor management of building water systems. Outbreaks can be prevented through design and application of WSPs. WSPs should deal with all sources of water, including community and private supplies (e.g. roof rainwater or groundwater) and should consider the characteristics and quality of the available sources. This includes determining whether community supplies have established WSPs. Building WSPs should be complementary to any existing plans developed by operators of community supplies. In these circumstances, drinking-water suppliers should provide assistance and information to building owners and managers responsible for developing WSPs.

Public health and regulatory authorities should provide guidance on development and implementation of WSPs. These authorities should also undertake surveillance to ensure that WSPs are operating effectively (see section 4).

2.2 System design

The basic requirements for establishing effective WSPs are good design and a sound knowledge of the physical characteristics of water systems. Water systems in buildings are often designed with limited attention to minimizing risks to public health. Retrofitting existing systems to improve management and safety is expensive. Every effort should be made in designing and constructing new systems to support the implementation of WSPs. This should include minimizing sources of hazards (e.g. stagnant water, long branch pipes and dead legs), as well as enabling access for monitoring and maintenance.

Knowledge of the characteristics of existing systems is often lacking, and in many cases there are no accurate, well-maintained maps of water systems. This is particularly true for large buildings and can be complicated in buildings that have been renovated or repaired. Pipework belonging to various networks (drinking-water, wastewater, recycled water, etc.) are often poorly labelled, which increases the likelihood of cross-connections and associated health risks. In addition, when problems arise, responses can be delayed by first having to map the system.

2.3 Hazard identification and risk assessment

Effective management of drinking-water systems in buildings requires a comprehensive understanding of the system, including the range of potential hazards, hazardous events and risks that may arise during delivery and use of water by occupants and visitors to buildings. It also requires an understanding of the quality and management of the water delivered to buildings. This can vary from high-quality, well-managed urban water supplies to poor-quality, intermittent community supplies or independent building-specific supplies.

2.3.1 Hazards

The GDWQ (WHO, 2008) describe a range of hazards that can threaten drinking-water supplies. All these hazards could enter buildings if present in external water supplies or could be introduced within buildings. Hazards include the following:

- **Enteric pathogens** (bacteria, viruses and protozoa) from faecal contamination can enter the system through faults in water supplies provided to buildings or within internal plumbing systems.
- **Environmental organisms** such as *Legionella* and *Pseudomonas* can grow in distribution systems and water-using devices, such as cooling towers and hot-tub pools. Growth is promoted by conditions such as low flow, stagnant water and warm water temperatures. In hospitals, a broader range of environmental bacteria and fungi such as *Acinetobacter* spp., *Aeromonas* spp., *Burkholderia cepacia* and *Aspergillus* have been identified as causes of nosocomial infection (Annaisie et al., 2002; Sehulster et al., 2004).
- **Chemicals** from external environmental, industrial and agricultural sources can enter the water-supply system. In addition, chemical hazards can be introduced from treatment processes, leached from unsuitable materials, or released from corrosion of pipework and fittings (e.g. copper, lead, cadmium and nickel) used in plumbing systems. Corrosion can be exacerbated by stagnation.

2.3.2 Hazardous events

Buildings represent specific independent environments that can include a wide range of conditions and situations (hazardous events), leading to the occurrence of hazards. The likelihood of hazardous events is influenced by the size and complexity of buildings and can be exacerbated by poor design, construction, operation and maintenance. These hazardous events include:

- poor flow and stagnation due to
  - poor design, including long branch pipes and dead ends
  - intermittent use or extended periods with no use (e.g. floors or wings of hotels with seasonal occupancy; schools during holidays);
- poor temperature control, including
  - inadequate heating capacity and poor design of hot-water systems, including long branch mains
  - elevated temperatures in cold-water systems due to proximity of hot-water systems and poor insulation;
- unsuitable materials used in plumbing
  - products that leach hazardous chemicals or support microbial growth
  - materials incompatible with the physical and chemical characteristics of water supplied to the building (leading to increased corrosion or scaling);
- open water-storage tanks allowing access of external contamination;
- cross-connections with independent water systems (e.g. roof rainwater), fire systems or recycled water systems, and inadequate backflow prevention from connected water-using devices (e.g. cooling towers, heat exchangers, boilers, washing machines, dishwashers) and liquid storages;
- poor management of water-using devices (e.g. cooling towers, drinking-water fountains, hot-tub pools and baths, swimming pools);
- poor management, maintenance and repair, exacerbated by inadequately mapped systems (e.g. schematic diagrams not updated following modifications) and poorly labelled pipework (e.g. distinguishing drinking-water, wastewater and recycled-water systems);
- unauthorized repairs and modifications (e.g. installation of point-of-use [PoU] devices such as carbon filters).

2.3.3 Risk assessment

Once potential hazards and hazardous events have been identified, the levels of risk need to be assessed so that priorities for risk management can be established. Risk assessments need to consider the likelihood and severity of hazards and hazardous events in the context of exposure (type, extent and frequency) and the vulnerability of those exposed.

Although many hazards may threaten water quality, not all will represent a high risk. The aim should be to distinguish between high and low risks so that attention can be focused on mitigating risks that are more likely to cause harm.

2.4 People who use buildings

Buildings represent specific environments and can provide specific services (e.g. hospitals, clinics, dental surgeries, aged-care facilities and schools). To determine the health risk associated with hazards from building water systems, it is necessary to consider:

- the vulnerability of people who work in, live in or visit the building
- the number of occupants and visitors
- the frequency and length of visits
- the types of water use and exposure.

2.4.1 Users of buildings

The types of people who use buildings will depend on the purpose of the buildings and services that are provided. Different groups can include:

- residents (e.g. of apartment blocks);
- long-term and short-term residents of hotels;
- hospital inpatients, outpatients and visitors;
- elderly residents in retirement complexes or aged-care facilities;
- dentists, doctors and nurses;
- patients at health-care centres and dental or medical clinics;
- visitors to museums, theatres, sports stadiums, shopping centres and garden centres;
- users of services (e.g. restaurants, food outlets and cafes);
- users of facilities (e.g. fitness centres, swimming pools, sporting clubs and leisure centres, ice rinks);
- workers in residential buildings;
- workers with particular exposures (e.g. lifeguards and swimming instructors);
- maintenance employees and contractors, particularly those with responsibilities relating to water systems and water-using devices;
- university and school students;
- very young children attending child-care facilities;
- prisoners.

2.4.2 Vulnerabilities

Those at greatest risk of waterborne disease are infants and young children, people who are immunocompromised, and the elderly. For most buildings, the health and vulnerability of users, visitors, residents and workers in buildings will be representative of the general population. However, some buildings will be used or visited by greater numbers of people who are more vulnerable to waterborne disease. These include very young children at child-care facilities and in hospitals; the elderly in retirement complexes or aged-care facilities; patients attending doctors' surgeries; outpatients at hospitals and other health-care facilities; inpatients, particularly those who are immunocompromised (e.g. cancer patients); transplant patients; and those with acquired immunodeficiency syndrome. Patients with respiratory disorders may be more susceptible to waterborne organisms transmitted by inhalation (e.g. *Legionella* and mycobacteria).

Renal dialysis patients are vulnerable to microorganisms, endotoxins, toxins and chemical contaminants. This vulnerability was demonstrated in 1996 by the death of 50 patients after exposure to water contaminated by high levels of microcystin (Jochimsen et al., 1998; Pouria et al., 1998) and 10 patients from aluminium encephalopathy (Berend et al., 2001). In the latter case, a community desalinated water supply was used for dialysis without further treatment for a number of years. The deaths occurred when corroding ductile-iron pipes were coated with a cement mortar containing aluminium. Dialysis patients are also sensitive to chemical disinfectants used to disinfect drinking-water supplies (Ward, 1996; Davidovits et al., 2003; Hoenich, 2009).

Due to advances in medical care, the proportion of people in communities with greater susceptibility to disease is increasing, particularly in developed countries. Communities are ageing, and survival of cancer patients and transplant recipients is improving.

2.4.3 Exposure

Exposure will be influenced by the length of occupancy, the frequency and length of visits, the nature of the building and the type of user.

Length of exposure will range from permanent residents of apartment buildings to long-term employees and workers; regular attendees at universities, schools, fitness centres and swimming pools; long- and short-term hospital patients; occasional attendees at medical and dental surgeries; and occasional visitors to restaurants, hotels and museums.

The type and nature of exposure will vary. While consumption of drinking-water involves potentially the highest volume exposure, other transmission pathways need to be considered. Exposure could include direct ingestion of drinking-water or indirect consumption through food and beverages prepared at restaurants, food outlets, cafes, hotels and bed-and-breakfast facilities. Ingestion and contact with water could occur through normal bathing activities, as well as through the use of swimming pools, hydrotherapy pools and hot-tub pools. Aerosols from showers, hot- and cold-water outlets, hot-tub pools or cooling towers can be inhaled, as can disinfection by-products released into the air at indoor swimming centres. Aerosols can also be generated by decorative fountains, irrigation systems used in garden centres or misting devices used in food markets.

Exposure could be associated with equipment used in hospitals, such as humidifiers and nebulizers, or in dental surgeries.

Exposure could also occur though inappropriate uses of piped water supplies. For example, drinking-water supplies are generally not suitable without additional treatment to wash wounds and burns or to wash and rinse medical equipment. Water used for renal dialysis needs to be highly treated to ensure that it is microbially and chemically safe.

2.5 Building types

Buildings can include specific environments that influence the level of risk associated with drinking-water systems. This can also be influenced by vulnerabilities of those who use and visit different types of buildings.

2.5.1 Large buildings

All buildings can represent sources of hazards and hazardous events. Large buildings can present particular challenges related to size and complexity. Drinking-water distribution systems in large buildings tend to be very long and complex, with many branch pipes. They can include large variations in flow, including very low flows at the end of long branches and dead legs. Plumbing systems are often poorly documented, particularly as buildings age and are modified or extended. Control over distribution systems in large buildings is also more difficult to maintain. Temporary or even extended periods of non-use of sections of buildings and associated plumbing systems are often poorly documented or managed.

Storage tanks can be used to maintain water pressure within the building (under-roof) or to provide buffering storage. The integrity of storage tanks needs to be maintained. In hot climates, the temperature of water—particularly in under-roof storage tanks—can increase and support the growth of environmental opportunistic pathogens.

Addition of PoU devices can occur without the knowledge of building management and maintenance staff. The potential for inadvertent cross-connections between drinking- and non-drinking- water systems increases in relation to the size and complexity of buildings. Large buildings are more likely to incorporate independent fire systems, which are prone to stagnation and the development of biofilms. Although they are generally supplied with mains water, these systems need to be kept independent through the installation of backflow-prevention devices. Ideally, fire systems should have a separate connection to the external mains water system.

The use of recycled water in large buildings is increasing; for example, greywater for toilet flushing (e.g. in environmentally friendly buildings). Recycled-water pipework and any accessible outlets should be marked to indicate that the water is not suitable for drinking. Where recycled-water systems are installed, there is a potential to lower flows and increase detention times in the drinking-water system due to reduced usage.

Large buildings are more likely to use evaporative condensers and cooling towers as part of air-conditioning systems and boilers to provide heating. Evaporative condensers and cooling towers can be sources of harmful microorganisms such as *Legionella*, while hazardous chemicals can be used to treat or condition boilers (e.g. nitrates and metaborate).

Particular types of large buildings include the following:

- **Educational facilities.** Schools, colleges, technical colleges, further education facilities and universities provide drinking-water for typical uses, as well as specialized uses in teaching and research laboratories and technical training facilities. Technical equipment using water and storages could present sources of hazards. Laboratories are also likely to include eye-wash stations and safety showers, which—like fire systems—are prone to stagnation and growth of biofilms unless flushed regularly.

Water use in educational facilities and associated buildings (residential, sport clubrooms, etc.) can be intermittent, with extended periods of stagnation possible, particularly during holidays.

- **Hotels.** Hotels can include recreational facilities such as swimming pools and hot-tub pools, and, in some cases, rooms can be provided with single-use hot-tub baths, which can be a source of environmental pathogens. Occupancy of hotels and other accommodation facilities can vary markedly depending on seasons; buildings, parts of buildings or floors may be closed during "off seasons". Associated water-using devices such as cooling towers and evaporative condensers may also be shut down for extended periods.
- **Conference centres.** Where accommodation is provided, these centres can include similar features to hotels.
- **Apartment blocks** (low rise and high rise)**.** Maintenance and management can be complicated by individual ownership or leasing of apartments. Risks in shared hot- and cold-water systems can be increased where individual apartments are used infrequently or remain empty for extended periods, and through connection of PoU treatment (e.g. carbon filters) and water-using devices such as washing machines and dishwashers, and by other modifications undertaken by tenants and apartment owners.
- **Office blocks.** Like apartment blocks, maintenance and management can be complicated by multiple ownership or tenancies.
- **Public buildings** (e.g. museums, art galleries, theatres and cinema complexes). A common concern with these buildings is maintaining hygiene and ensuring that drinking-water outlets are kept clean.
- **Shopping centres** can include decorative fountains, garden shops and fresh fruit and vegetable markets that use misting machines to keep produce fresh. These spray and mist devices produce aerosols that can disseminate organisms such as *Legionella* and *Mycobacterium* spp. if present. Centres can also include speciality shops such as hairdressing salons.
- **Factories, manufacturing industries and production centres.** These buildings can include storages of liquid chemicals and distribution systems that circulate water used for cooling or liquid coolants. Industrial buildings can include devices for worker safety, such as eye-wash stations and safety showers.
- **Transport terminals**. Transferring water at terminals to aeroplanes, ships, trains or buses needs to be managed to ensure that water safety is maintained. Specific guidance for aeroplanes and ships is provided in the WHO *Guide to hygiene and sanitation in aviation* (WHO, 2009) and the *WHO Guide to ship sanitation* (WHO, 2010). The hygiene and safety principles described in these guides should also be applied for trains and buses.

2.5.2 Hospitals

Hospitals can be very large buildings or complexes with extensive water systems. Due to the vulnerability of some patients, hospitals are more likely to provide additional treatment at the point of entry of external piped supplies. Common forms of treatment include filtration, disinfection, softeners and deionizers. Treatment is also likely where hospitals use private water supplies (e.g. wells, bores). These processes can represent sources of treatment chemicals (e.g. membrane de-scalants, coagulants, disinfectants and disinfection by-products). Wards and rooms are not always occupied continuously. This can provide intermittent flows or stagnation in water systems.

Drinking-water should be suitable for human consumption and for all usual domestic purposes, including personal hygiene for most patients. However, it may not be suitable for all patients or uses in a hospital, and further processing or treatment or other safeguards may be required. Patients in intensive or critical care facilities, including cancer wards, transplant wards and renal wards, can be immunocompromised and at increased risk from waterborne disease through ingestion, contact or inhalation. In wards where patients are in protected environments with filtered air and modified diets, equal attention needs to be paid to drinking-water, beverages and ice. There are many examples of legionellosis being recorded in hospitals (Bartram et al., 2007). Inhalation of aerosols from showers, hot- and cold-water outlets, nebulizers and humidifiers has been identified as a route of transmission, while aspiration from ice has been associated with infection of immunocompromised patients or those with significant respiratory impairments (WHO, 2007).

Drinking-water can contain a range of microorganisms that represent little concern through water consumption by most patients. However, some organisms (e.g. *Pseudomonas aeruginosa, Acinetobacter, Aspergillus*) can cause severe infections in those who are immunosuppressed or immunocompromised. They can also cause infections if present in water used to wash or irrigate wounds and burns; to wash medical devices, such as endoscopes and catheters; or in devices such as nebulizers and humidifiers. Water used for such purposes needs to be of a higher quality than described in the GDWQ (WHO, 2008) and may require additional processing, such as microfiltration, disinfection or sterilization, depending on use.

Renal dialysis requires large volumes of water that exceed the chemical and microbial quality requirements for drinking-water. Water used for dialysis requires special processing to minimize the presence of microbial and chemical hazards, including residual disinfectants.

Hot-water distribution systems may be maintained at lower temperatures (warm water) or have thermostatic mixing valves installed before outlets to reduce the risk of scalding (typically 41–45 °C). Warm-water systems or pipework downstream of mixing valves can provide environments for growth of environmental pathogens.

Hospitals may operate hydrotherapy pools as part of treatment regimes and include ice machines and drinking-water fountains.

2.5.3 Other medical and health facilities

Medical and health facilities include medical clinics, health centres, doctors’ surgeries and dental surgeries. As in hospitals, risks can be elevated in these facilities due to the types of exposures involved and the potential vulnerabilities of some patients

Water of appropriate quality should be used in medical and dental equipment and procedures (e.g. washing and irrigation of wounds and burns). For example, dental chairs often include water systems that deliver water to high-speed equipment, de-scalers and rinsing sprays. These sprays can be inhaled and aspirated by patients. Dental water lines can become colonized with bacteria, fungi and protozoa. Most of these organisms are of limited significance, but pathogenic species, including *Legionella*, *Pseudomonas aeruginosa* and *Mycobacterium* spp., have been detected (Sehulster et al., 2004).

2.5.4 Aged-care facilities and retirement homes

Aged-care facilities and retirement homes house elderly people who can be more susceptible to waterborne disease. In some cases, residents will have underlying illnesses that increase this susceptibility.

Like hospitals, water systems can be extensive and supply water to wards and rooms that are not always occupied. Hot-water distribution systems may be maintained at lower temperatures or have thermostatic mixing valves installed to reduce the risk of scalding.

2.5.5 Child-care facilities

Child-care facilities can cater for very young children who can be more susceptible to disease. Children's hygiene is not always well developed, and attention needs to be paid to keeping water outlets and toilets clean (Adams et al., 2009). Young children are also more susceptible to contaminants such as lead (WHO, 2008). Corrosion and leaching of metals such as lead can be exacerbated by intermittent water use, with stagnation over weekends and during holidays.

Hot-water distribution systems may be maintained at lower temperatures or have thermostatic mixing valves installed to reduce the risk of scalding.

2.5.6 Small hotels, bed-and-breakfasts, farmstays and campsites

Hotels, motels and bed-and-breakfasts provide water for drinking and bathing for guests and may use drinking-water supplies in water-using devices, such as swimming pools and hot-tub pools. In some cases, rooms can be provided with single-use hot-tub baths.

Some facilities may have private water supplies that can be potential sources of microbial and chemical hazards.

Campsites can include permanent buildings providing shared facilities (e.g. for cooking, bathing). In some cases, separate non-drinking-water supplies may be provided for bathing. These need to be appropriately marked using words as well as symbols, noting that the water is not suitable for drinking.

Like hotels, these accommodation facilities can be subject to seasonal use.

2.5.7 Sporting facilities and health centres

Sporting facilities and health centres can include sports grounds, stadiums, leisure centres, swimming pools, ice rinks, health clubs and fitness centres. These facilities can include swimming pools or hot-tub pools.

Swimming pools have been associated with outbreaks of illnesses such as cryptosporidiosis, and hot-tub pools with legionellosis and hypersensitivity pneumonitis (from mycobacteria). Indoor pools can generate elevated levels of chloramines and other disinfection by-products, which can lead to eye, nasal and respiratory irritation. Disinfection byproducts at indoor pool centres could be associated with asthma in children (Weisel et al., 2009).

At large sporting clubs, immersion pools and communal pools are used to assist recovery of competitors.

2.5.8 Garden centres and conservatories

Garden centres, greenhouses and conservatories typically use irrigation systems to water plants. In large centres, these irrigation systems can include storage tanks and sumps. Often, irrigation pipes include materials that are not suitable for contact with drinking-water.

Irrigation systems typically use spray and mist devices to produce aerosols, which can disseminate organisms such as environmental pathogens, if they are present. Water features and hot-tub pools on display in garden features may also generate aerosols. In warm environments (especially those exposed to sunlight), water in the irrigation pipes and hoses of these systems can heat up and cause microbial growth.

2.5.9 Detention centres, prisons and military barracks

These buildings can house large numbers of people in relatively confined spaces. Bathing and sanitary facilities are typically shared by groups of people, and breakdown in hygiene can be a source of microbial hazards. Due to the numbers of occupants in close proximity, the secondary spread of disease is likely.

2.5.10 Other buildings

Other buildings include restaurants, fast-food outlets, cafes, veterinary surgeries, ambulance and fire stations, beauty salons and hairdressers. Each type of building can include specific uses of water requiring appropriate management.

3 Roles and responsibilities

This section describes the roles of stakeholders and other responsible personnel to ensure that the water supply is safe. Many people are involved in water safety, from the initial water planners to ongoing operation and maintenance providers, and their range of duties is illustrated in this section.

3.1 Background

A large number of stakeholders can influence the safety of water systems within buildings. These stakeholders can be involved in the planning, design, construction and renovation of buildings, as well as development of water safety plans (WSPs), and the ongoing maintenance and operation of water systems. The specific titles of stakeholders and divisions of responsibilities will vary between different countries and jurisdictions, but the broad range of tasks will remain fairly consistent. Figures 3.1–3.3 (at the end of this section) provide examples of roles and responsibilities in one jurisdiction.

Stakeholders can include:

- building commissioners who are involved before construction of new buildings or renovation of existing buildings, such as developers, planning officers, architects, design engineers, builders, plumbers, manufacturers and suppliers;
- building operators, including building managers and owners, tenants and employers;
- employees, residents and users of buildings;
- service providers and specialist consultants who provide technical assistance, such as plumbers, maintenance contractors, water-treatment specialists, risk assessors and auditors;
- professional bodies who develop guidance and training;
- infection-control personnel in dental and medical facilities, and infection-control teams in hospitals and health-care facilities;
- regulators responsible for oversight of building and plumbing codes, public health requirements and occupational health and safety;
- public health and environmental health officials;
- standard-setting bodies and certification agencies;
- training providers;
- providers of laboratory services.

3.2 Building commissioners

A range of stakeholders can be involved in the design, construction and modification of buildings, including the installation of water systems. All stakeholders should be aware of relevant regulations, codes and standards and should implement requirements that apply to the building being commissioned. Many countries have codes and design standards that apply to water systems and devices, including cold- and hot-water systems, cooling towers, ice machines, swimming pools and hot tubs. In some cases, requirements are incorporated within building and plumbing codes, while in others codes and standards have been issued for specific components such as cooling towers. For further discussion, see section 4. Most countries have building and plumbing codes that include accreditation and approval requirements. However, these codes may not provide sufficient detail for the design of complex systems (e.g. direction on calculation of hot-water return-pipe capacities). Specific requirements for preventing the growth of microorganisms (notably avoiding long periods of stagnation of tepid water) may also not be included in these codes. Separate legislation and standards may apply to specific components of water systems (e.g. water-cooling devices, swimming pools, hot-tub pools). Where codes and standards do not provide sufficient detail, expert advice will need to be sought.

It is essential that those involved in design, construction and modification of buildings document their actions and ensure that final plans and specifications are provided to building owners and managers.

3.2.1 Developers

Developers are ultimately responsible for oversight of the entire process of construction and installation. This includes ensuring that appropriate design requirements and standards are applied.

Where buildings are intended for specific purposes (e.g. health facilities), particular requirements associated with the use should be determined through consultation with the user and from relevant legislation such as building codes and plumbing codes. Developers engage the architects, design engineers, builders, plumbers and others who design and construct buildings. Selected professionals and contractors should be familiar with the requirements associated with the intended use.

3.2.2 Planning officers

Planning officers can play a role relating to appropriate design of buildings and design and installation of water systems. Planners need to be aware of requirements relating to water systems. It is good practice for planning or development applications to be referred to health agencies for assessment of potential public health risks before approval is issued.

3.2.3 Architects

Architects are responsible for the overall design of buildings and need to have an understanding of the operation of, and requirements associated with, water supplies and devices that use water such as cooling towers. Good design can prevent or reduce many of the risks that can arise in water systems within buildings. Architects work in partnership with design engineers and other professionals who are responsible for construction details.

Designs need to take into account requirements associated with specific uses, such as:

- residential health care
- hospitals
- dental surgeries
- medical surgeries
- renal dialysis clinics
- schools
- food retailers
- hotels and guest accommodation (including specialist accommodation such as ski stations).

In the case of renovation or modification of existing and occupied facilities, architects should consult with users of the building. The extent of consultation will be influenced by the complexity of the project; however, it should include all those involved in management and maintenance of water systems. In the case of hospitals and health-care facilities, it should involve consultation with infection-control specialists.

3.2.4 Engineers

Design engineers are responsible for translating the architectural plans into building designs, taking into account structural integrity and ensuring compliance with building and plumbing standards. Project and construction engineers are responsible for completion of buildings, including installation of water systems. When buildings are being renovated, or existing structures are being modified, engineers provide a key role in establishing risk-management plans to minimize risks to people currently using the building. These risk-management plans should include instructions on how to deal with potential problems and disruptions to services, and they should ensure that technical standards and regulations are met. Risk-management plans should include education of maintenance and construction workers. Project engineers are typically responsible for final certification of satisfactory completion of building construction.

3.2.5 Plumbers

Protection of water quality and proper operation of water systems rely on plumbers. Plumbers should be appropriately qualified and have the competence and knowledge to design, install and maintain plumbing systems. Plumbers play a key role in managing risks by ensuring compliance with applicable standards and codes. In addition, plumbers and other plumbing professionals can play an important role in water conservation.

Well-designed plumbing systems are necessary to ensure that the installations are efficient, safe and appropriate for the different circumstances they serve. The design of a good plumbing service must be based on an understanding of the technical requirements and relevant regulatory restrictions. Where industry-based risk-management strategies and procedures have been established, they should be applied.

Plumbers have to ensure that water systems are intact and that intrusion of microbial and chemical contaminants is minimized. Unintended or unprotected cross-connections should be prevented, and backflow-prevention devices should be installed where necessary. Only approved materials and devices should be used or installed.

Plumbing systems have to comply with building plans. All work has to be documented, and installations and modifications need to be included within building plans.

3.2.6 Manufacturers and suppliers

Anyone involved in the manufacture and supply of water systems components, and specialized equipment and devices (e.g. cooling towers, washing machines, water-using medical devices) should ensure that they are designed and constructed so that they are safe when used for their designated purpose. Components and devices should be designed, constructed and installed in compliance with existing codes and design standards. Systems need to be constructed from materials that are appropriate for the function of the water system and device. In addition, systems should be designed to enable ease of operation, cleaning, inspection and maintenance. Training should be provided to people who operate devices, where appropriate.

3.3 Building operators

Building operation and management can be undertaken by a range of different stakeholders, with specific responsibilities influenced by ownership and tenancy agreements. Legislative requirements may also assign responsibilities to specific parties. Requirements will generally include responsibilities relating to protecting the health and safety of residents and users of buildings. Employers have a specific duty to protect the health and safety of employees.

Building operation can be the responsibility of a building owner, leasing agency, building manager, tenants, employers or combinations of these parties. In some cases, building owners maintain control over infrastructure including water systems, but in other cases this task might be undertaken by a leasing or building management agency. Alternatively, occupiers and tenants may install and manage water devices. Regulations and codes of practice often identify responsibilities for a number of parties. For example, the Victorian Government (in Australia) has published *Legionnaires' disease: managing the health risk associated with cooling tower and warm water systems* (the Health *Legionella* Regulations) (Vic DHS, 2001), which identifies responsibilities for:

- owners of land to register certain types of water devices and to take all reasonable steps to ensure that a risk-management plan is prepared, reviewed and audited on an annual basis;
- owners or tenants of buildings to prevent conditions that may represent a risk to public health;
- owners, managers or controllers of water devices to undertake appropriate levels of maintenance;
- employers to maintain a safe workplace.

In other jurisdictions, assignment of responsibilities may be different, but the tasks remain generally consistent. The tasks and individual responsibilities should be described in a WSP. Whoever takes the lead role in building management needs to be responsible for the design and implementation of the WSP, including ensuring completion and documentation of tasks assigned to competent employees or to specialist contractors.

Competence should be supported by training. Owners, managers or employers should ensure that those who are assigned to undertake specific tasks have appropriate levels of training. Additional training should be provided where required. In some countries, certification programmes have been established to provide evidence of training. Where such programmes have been established, owners, managers or employers should ensure that work is undertaken by employees or contractors with relevant certificates.

Building managers and employers need to communicate with residents, users of buildings and employees in relation to:

- potential risks associated with water systems;
- management plans developed for these systems;
- notification and information relating to any incidents that give rise to potential or perceived risks to public health; they should also report such incidents to the appropriate regulatory agencies.

3.4 Employees, residents and users of buildings

Employees, residents and users of buildings are often the first to detect change or faults in water systems. These could be detected due to changes in temperature, appearance, odour or taste of water; reduced flow; or leaks. Reporting of changes and faults should be encouraged, and mechanisms should be established to support reporting. Feedback should be provided on the outcome of investigations and any remedial action.

Employees and residents have responsibilities to operate and use water systems as intended and not to introduce modifications. For example, point-of-use devices should not be installed without permission from building managers. Devices and controls such as thermostats should not be altered without permission. This should be reinforced with education and communication from building managers.

3.5 Service providers and specialist consultants

Building operators may use service providers and consultants as sources of specialist skills that are not available within their own organization. Service providers and contractors can be used to undertake a wide range of services associated with water systems, including:

- installation of water-treatment devices and plumbing fittings
- routine and emergency maintenance
- risk assessments and development of WSPs
- audits.

Building operators should only engage providers who can demonstrate competence and compliance with relevant formal requirements (e.g. certification).

Service providers need to be able to demonstrate competence in undertaking tasks for which they contract. In some cases, certification programmes have been established.

In other cases, levels of service or training may be specified by industry associations. Service providers need to be able to provide evidence of compliance with established programmes and, where available, certification.

Service providers should provide evidence in the form of formal reports or certificates of completion to demonstrate that tasks have been completed in accord with requirements.

3.5.1 Risk assessors

Risk assessors need to have the expertise, knowledge and resources to undertake the task competently. Risk assessors should have expertise in:

- public health aspects of water quality;
- local legislative requirements, standards and codes of practice;
- development of WSPs;
- water systems in buildings, including water-using devices and equipment;
- identification of hazards and potential sources of these hazards;
- determination of risk;
- identification and assessment of appropriate control measures;
- operational monitoring procedures to ensure that the control measures remain effective;
- verification procedures.

In large buildings with complex water systems (e.g. hospitals), more than one risk assessor may be required to deal with the piped systems and the broad range of connected equipment and devices. Risk assessors need to comply with formal requirements, including certification and approval conditions established by regulatory agencies. If unacceptable risks are identified, they should be reported immediately to whoever commissioned the assessment. If a serious and potentially immediate risk to public health is identified, notification of the regulatory authority will be required.

3.5.2 Independent auditors

Some jurisdictions use and certify independent auditors to determine the effectiveness of WSPs and compliance with occupational health and safety requirements. Levels of knowledge and expertise, as well as the need to comply with formal requirements, are similar to those described for risk assessors. Auditors should also have expertise in assessing documentation and reporting mechanisms. Auditors may be required to submit reports of their findings to the regulatory agency.

3.6 Professional bodies

Professional bodies (e.g. for dentists, medical practitioners, hospital engineers, nurses) can perform a number of functions, including:

- developing and advocacating for policies and codes of practice relating to water systems;
- establishing practical guidelines to support implementation of WSPs;
- training for members and their employees;
- identifying practical issues associated with implementation;
- providing mechanisms for gathering information relating to incidence of infection that may be related to water systems;
- reporting notifiable diseases and unusual or elevated incidence of disease to public health agencies;
- providing mechanisms for gathering information on successful management approaches.

3.7 Infection control

3.7.1 Infection-control coordinators

In small health facilities, clinics or surgeries, infection-control coordinators should be appointed to manage established control programmes. The coordinator could be the head of the facility or an employee trained for the task. The head of the facility is responsible for establishing the programme, ensuring that it is implemented, and ensuring that the coordinator has (or receives) appropriate training.

3.7.2 Infection-control teams

Hospitals and other health-care centres use infection-control committees and teams to prevent nosocomial infections, including those arising from water systems. The committees should include representatives from all relevant sections, including management, nursing, physicians, hospital engineers, microbiology, maintenance, cleaning and sterilization services, housekeeping and supply. These teams should contribute to ensuring that water systems are well managed, as follows:

- Management is responsible for establishing and supporting the infection-control team, and should ensure that staff have sufficient understanding of water systems and water-using devices within the building. Management should ensure that a WSP has been developed and implemented by appropriate staff.
- Nursing staff should be aware of the correct operation of relevant water-using devices and equipment and how this equipment should be cleaned and disinfected.
- Maintenance and hospital engineers are responsible for implementing WSPs, including operational monitoring; for example, monitoring temperatures in cold- and hot-water systems, monitoring disinfection residuals in water systems, and monitoring water-using devices such as hydrotherapy pools. They are also responsible for maintaining water systems and devices to ensure that they function as required at all times.

- Physicians are responsible for ensuring safe use of water systems, water-using devices and equipment. Physicians should consider the potential contribution of water systems to nosocomial infections.
- Microbiologists are responsible for monitoring cleaning, disinfection and sterilization, where appropriate, of water-using devices and equipment. They should be aware of appropriate procedures for collecting environmental samples.

Infection-control teams should contribute to internal reviews of WSPs. This should include periodic review of potentially waterborne nosocomial infections as an assessment of effectiveness of the plan. One approach could be to establish a subgroup with primary responsibility for water management. This subgroup should work with, and report to, the full team.

3.8 Regulators

A number of activities and requirements are subject to regulation. These include compliance with building and plumbing codes; occupational health and safety requirements; and codes applying to operation of devices, such as water-cooled air-conditioning plants, swimming pools and hot-tub pools. Implementation of these regulations may be administered by different agencies, including those with responsibilities for public health, environmental health and occupational health and safety. It is important that there is a shared understanding of agency responsibilities and the functions of different regulations to maintain consistency of purpose.

In some countries, the “regulator” may not be an institutional body but a public officer from an agency or authority (e.g. government agency, local health authority). The regulator will have the responsibility for dealing with specific technical issues covered by regulations. The regulator may operate through multilateral committees and expert consultants.

3.8.1 Public health agencies

Public health agencies are responsible for ensuring that public health standards are maintained. They may act in a number of areas, including surveillance and auditing of water systems; they may also help to set standards and codes, detect and investigate disease, and monitor disease trends. Public health agencies are responsible for ensuring compliance with regulations designed to protect public health, and that the actions required by regulations or by codes of practice are followed. This can include regulations and codes applying to specific devices, such as water-cooled air-conditioning plants, swimming pools and hot-tub pools. Required actions can include development of WSPs.

In the event of known or suspected disease outbreaks, public health officials are responsible for inspecting buildings, auditing WSPs and collecting water samples.

Public health officers are also responsible for issuing directions relating to remedial action, and issuing public notifications where required.

Disease surveillance

The role of public health agencies normally includes detecting and investigating disease, and monitoring disease trends (for more information, see section 5.2) Public health authorities need to establish criteria that would initiate an investigation and procedures on how such investigations will be performed. This should include procedures for identifying and confirming potential sources of disease. In the case of investigations involving illnesses associated with buildings, public health agencies should work with owners, managers and users of buildings. Advice and warnings may need to be issued to occupants and employees of buildings, as well as the general public. This should be done in a timely manner to reduce or contain public health impacts, and to provide appropriate information about the level of risk, responses and triggers for seeking medical attention.

Monitoring of disease trends can provide evidence of the need to improve management of water systems. Once a new strategy has been implemented, information on disease trends can provide evidence of the strategy's impact.

Public health agencies should establish networks with professional bodies to help detect disease, and to disseminate public health information.

3.8.2 Surveillance of water supplies

Independent surveillance of water supplies is an important element of quality assurance. Surveillance of water systems in buildings will include features similar to those applied to drinking-water supplies, but may also incorporate additional elements to deal with specific uses of the water, with water-using devices such as cooling towers, and with occupational health and safety needs. The resulting surveillance programmes may include a range of activities and agencies. For example, there could be specific surveillance programmes for cooling towers, swimming pools and other devices. Specific surveillance programmes could also involve agencies responsible for public health and for occupational health and safety.

The role of different agencies and the requirements for specific surveillance programmes should be identified and coordinated to avoid unnecessary duplication, and to ensure that appropriate levels of surveillance are applied to all parts of water systems in buildings. In some cases, surveillance could be performed by third parties such as contractors or registered auditors under programmes directed by regulators. Such programmes should include mechanisms to monitor the effectiveness of the third-party audits.

Surveillance and auditing should include processes for approving WSPs, as well as processes for verifying that WSPs are being implemented appropriately and protect public health effectively.

3.8.3 Occupational health and safety agencies

Occupational health and safety regulations can be administered by specific departments or agencies within government. In some jurisdictions, these regulations are the primary legislative mechanism applied to water-using devices (e.g. cooling towers, evaporative condensers), while in others they support or supplement public health legislation.

Administration of occupational health and safety requirements should be coordinated with other functions and regulations designed to protect public health from water systems. Administration may include either random or routine inspections of workplaces, and occupational health and safety inspectors should be aware of other requirements developed to control risks associated with water systems.

3.9 Standard-setting and certification bodies

Devices and materials used in water systems need to meet quality requirements and comply with applicable standards and codes of practice. Some countries have established standard-setting bodies and certification systems to provide assurance that, when used in accord with design specifications, devices and materials will perform as required and be safe. Standards can apply to the design, installation, maintenance and operation of devices such as cooling towers and evaporative condensers, swimming pools, hot-tub pools, hot-water systems and plumbing devices. Standards can also apply to materials used in plumbing systems, including pipework. Material standards can deal with physical attributes, and ensure that products do not give rise to unacceptable contamination of water or support microbial growth. Standards should include criteria for achieving and measuring compliance.

Certification is used to confirm that devices and materials used in water systems meet standards or alternative criteria. Certification can be undertaken by government agencies or private organizations. Certification agencies may assess data and information provided by manufacturers, undertake specific testing, or conduct inspections and audits. Certification may be issued subject to application of defined conditions. These conditions could identify specific applications and uses of certified products (e.g. where devices can and cannot be used).

Standards are typically developed in cooperation with manufacturers, technical experts, regulatory agencies, certifying agencies and consumers. Public health agencies should participate in developing or approving parts of standards that are intended to protect public health.

Standards can:

- represent technical provisions and norms to be adopted on a voluntary basis as good practice;
- be adopted as requirements by government or local government authorities;
- be adopted by reference in regulations.

Standard setting and certification also applies to sample collection and laboratory analysis. Samples need to be collected, stored and transported using established procedures and appropriate equipment (e.g. correctly prepared sample bottles). Similarly, laboratories need to be competent to perform the tests that they undertake. This includes using suitable methods, appropriate testing equipment, and qualified and capable personnel. Some countries have established standards supported by certification and accreditation systems for laboratory services.

3.10 Training providers

Design, installation and management of water systems can involve a range of personnel, all of whom must be competent to undertake assigned or required tasks. Training providers can provide courses to support competence. In some cases, course work can be combined with supervised “on-the-job” training. Training should be consistent with existing regulations, standards, codes of practice and requirements of regulatory authorities.

Training can be provided by water companies, professional associations (e.g. builders, plumbers, engineers, environmental health institutes, dental and medical associations) and specialist technical colleges and institutes. In some countries, training programmes are subject to certification and accreditation programmes. Training providers should ensure that they comply with the requirements of such programmes.

Training providers should regularly review the content of their courses. They should also consult with regulators and those seeking training to ensure that their needs are being met.

The aim of training programmes is to produce personnel with sufficient expertise and training to undertake specific tasks. However, measuring the level of competence can sometimes be challenging. Measuring competence is easier when tailor-made courses and certification programmes are available—and many countries have accreditation systems for professional and technical personnel. In some cases, requirements for accredited operators can be included in regulations.

Measuring competence is difficult when competence is based on degree of experience. A flexible approach to measuring may be needed, while ensuring that tasks are only performed by people who have sufficient expertise and knowledge. Codes and legislation that include reference to “competent persons” need to identify criteria for establishing competence, including qualifications, training requirements and relevant experience.

Figures 3.1–3.3 show an example of the roles and responsibilities of people involved in water safety.

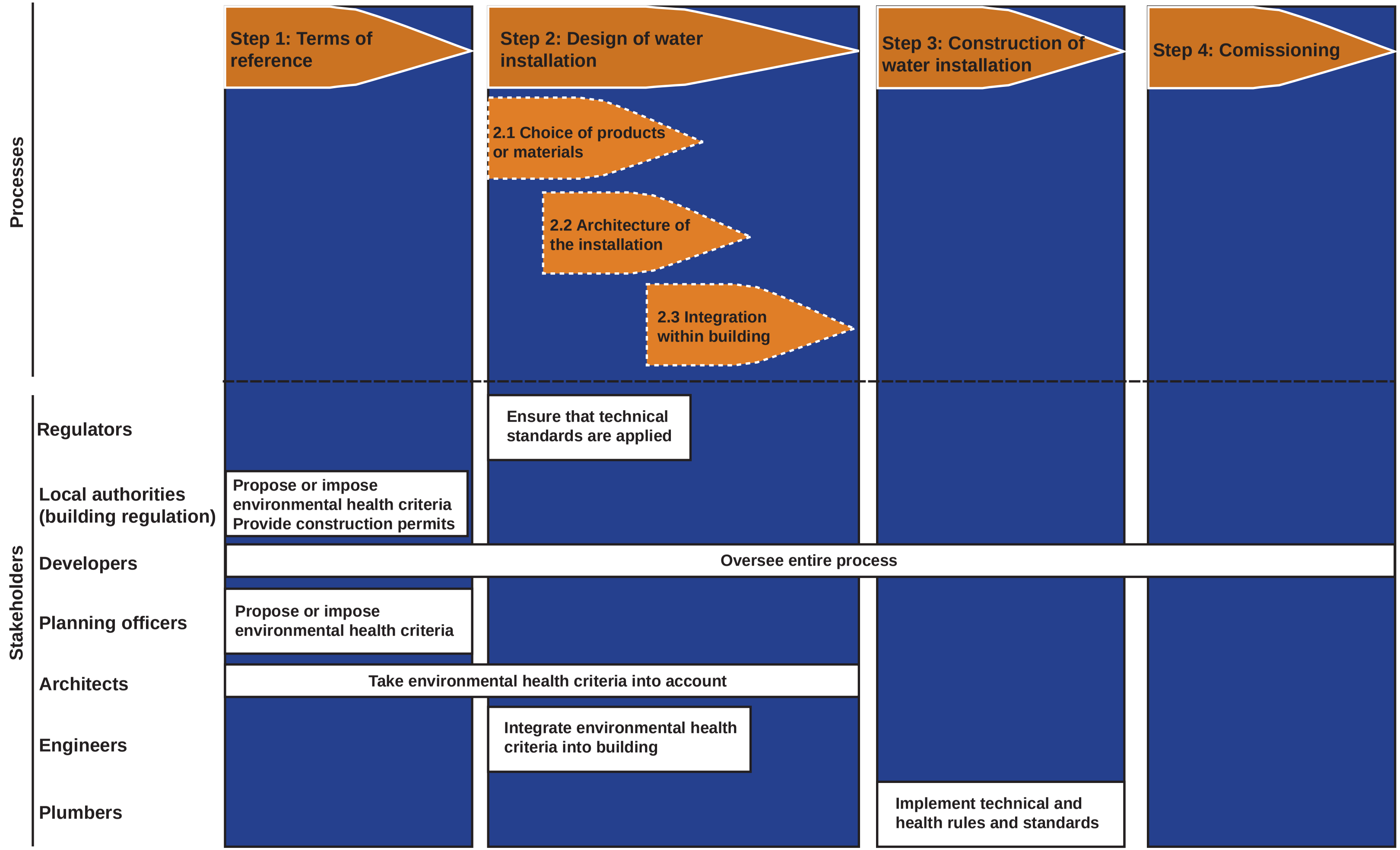


Figure 3.1 Roles and responsibilities for major projects or significant modifications

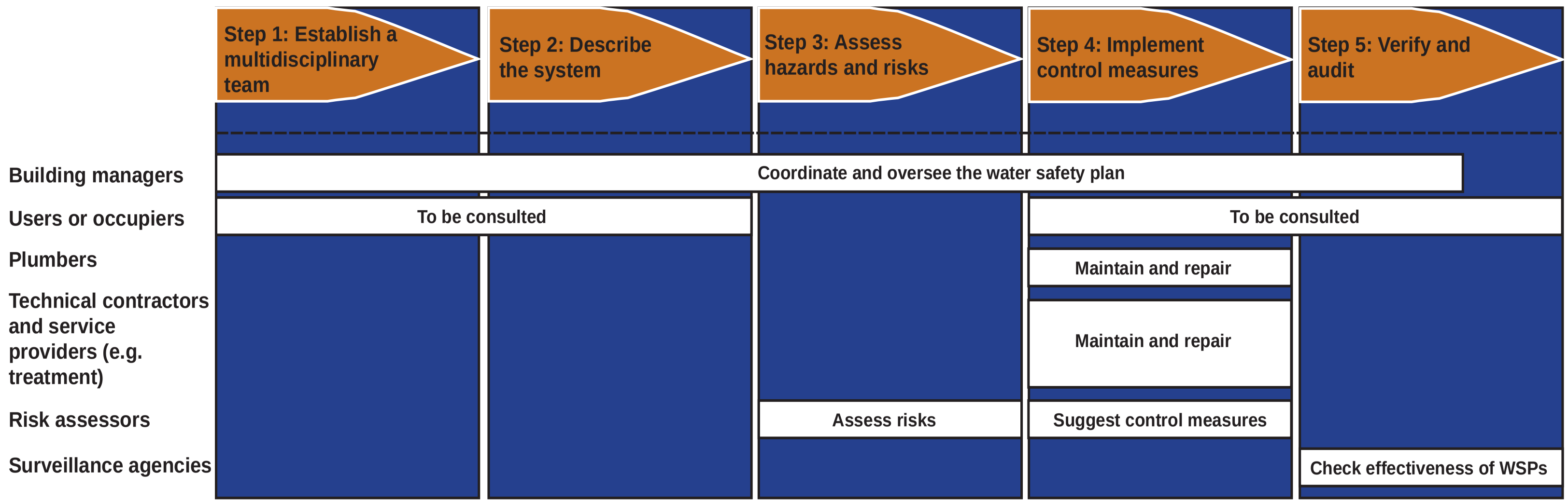


Figure 3.2 **Roles and responsibilities for existing installations**

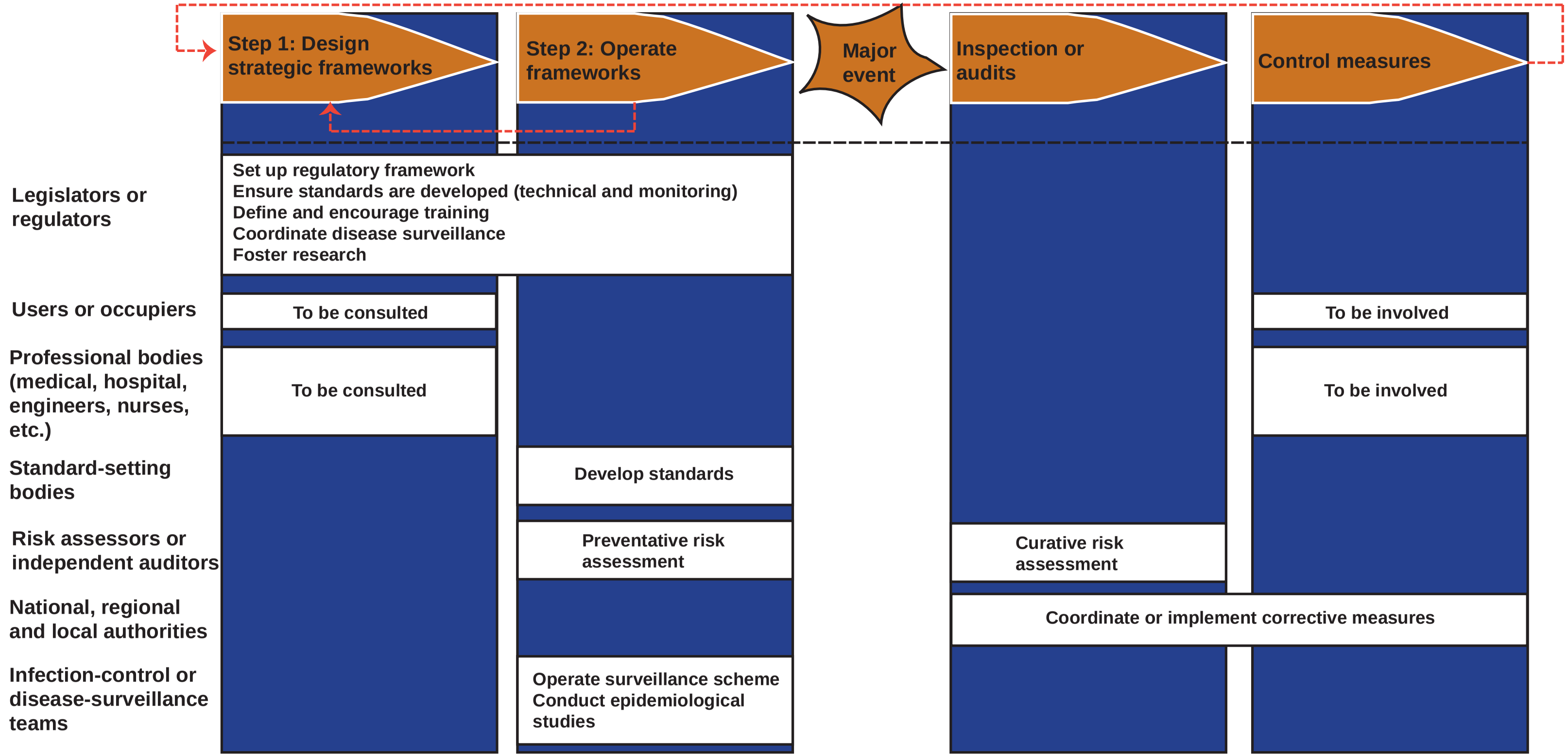


Figure 3.3 Roles and responsibilities for surveillance and supporting requirements

4 Water safety plans

This section describes, in more detail, water safety plans (WSPs), including the steps required to set one up, and how the key principles can be applied to buildings. Information is also provided on how to organize a WSP team, and what actions to take if a water supply becomes contaminated.

This section also explains risk assessments, control measures, operational monitoring and management procedures. Information that should be considered when designing and constructing new installation systems is also provided.

4.1 Background

The continuous delivery of safe water requires effective management and operation throughout the water-supply chain, from catchments to consumer taps and points of use. The *Guidelines for drinking-water quality* (GDWQ) (WHO, 2008) indicate that this is most effectively achieved through the *Framework for safe drinking-water*, which encompasses the following elements:

- establishing health-based targets as “benchmarks” for defining safety of drinking-water;
- assuring safety by developing and implementing a WSP to systematically assess and manage risks;
- establishing a system of independent surveillance to verify that WSPs work effectively and are capable of consistently delivering water that meets the health-based targets.

WSPs provide a preventive risk-management approach that builds on other risk-management and quality-assurance principles. They systemize long-established principles and good practices in drinking-water supply, covering both water quality and quantity management issues. These principles also apply to management and use of water-using devices and equipment. WSPs for buildings should address drinking-water networks and consider connected devices and equipment.

The development and implementation of WSPs can be the responsibility of various stakeholders: while WSPs for water treatment and distribution of public water supplies are typically the responsibility of the supplier, WSPs for buildings are the responsibility of building owners or managers, with support from various other stakeholders, as discussed in section 3. The level of detail and complexity of WSPs will depend on the size and nature of the building, including the level of risks posed by the installation, and on the population exposed to the water system inside the building. Nevertheless, the implementation of well-designed WSPs is recognized as the most effective tool to ensure provision of safe water supplies.

Development of WSPs should not be considered as overwhelming or too complicated. The aim is straightforward: to ensure consistent supply of safe water to consumers. To a large extent, WSPs document established good practice, and the most important step is getting started.

Figure 4.1 provides an overview of the steps involved in developing a WSP.

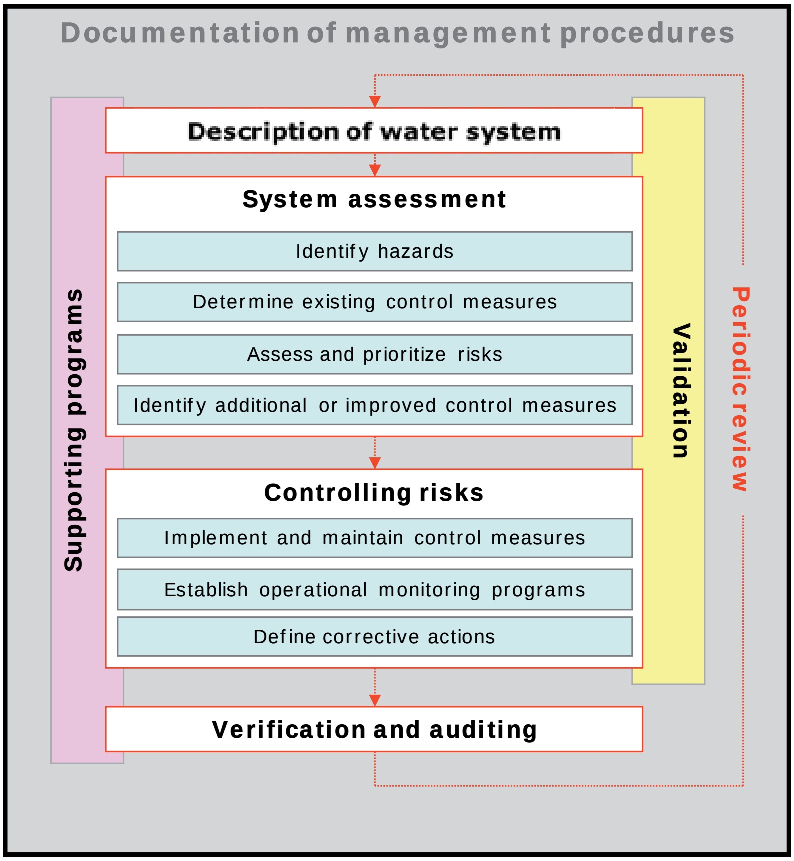


Figure 4.1 Summary of the steps involved in developing a water safety plan

4.2 Key principles of WSPs

WSPs are typically developed after the supply system has been designed and constructed. However, where possible, new or renovated systems should be designed and constructed in a way that supports implementation of WSPs. This should include identifying potential hazards, incorporating appropriate control measures (e.g. treatment processes) and considering practical aspects (e.g. ease of access for maintenance, inspection and monitoring).

Irrespective of when they are developed, WSPs should be working documents that are kept up to date and reviewed periodically to ensure that they remain current. WSPs should be reviewed if there are major changes to water supplies and uses.

The mechanisms by which WSPs are developed and applied can vary. In some cases, tasks associated with implementation could be undertaken by an owner, manager or employer. However, they could also be delegated or assigned to competent individuals employed within a building, or to specialist contractors. When tasks are either delegated or contracted, the owner, manager or employer retains the responsibility to ensure that those charged with performing designated functions are competent and that required tasks identified in the WSP are completed and documented appropriately.

4.3 Assembling a WSP team

Assembling a team is a core preparatory requirement for the development and implementation of a WSP in a building. The team will be in charge of developing and implementing the WSP—a role that includes identifying hazards, assessing risks, identifying and monitoring control measures, and developing incident protocols.

A responsible person (or WSP coordinator) needs to be identified to lead the team. This person should be either the building manager or a competent person delegated to this task by the manager. The WSP coordinator should have (or acquire) a good knowledge of the technical facilities in the building, and their daily work should be related to the building. Since the coordinator's primary task is to coordinate the process of WSP development and implementation, they should understand the principles associated with development and implementation of WSPs. However, a special technical knowledge in drinking-water and/or sanitation, while useful, is not necessarily required. The coordinator should have the authority to ensure that the WSP is implemented. A building manager is a good choice for the WSP coordinator.

The WSP coordinator needs to form a team of experts who will support WSP development and provide access to all relevant information needed. Team members should include the range of expertise needed for a thorough analysis of the building's water system. The team should include expertise in design, operation and management of drinking-water supplies; engineering; plumbing; and public health risk assessment. The team will include employees with relevant specialist expertise, as well as representatives of key users of the building water systems. Development of WSPs could also involve consultation with specialist contractors.

Some hazards that may compromise water quality in a building may be obvious to the building management; others may be more concealed. Therefore, it is essential that the WSP team is able to deal with all possible risks associated with delivering drinking-water. Managers of small buildings or facilities with simple water systems may not have "in-house" expertise. In this case, the manager or operators of the water system should coordinate development of the WSP and use health and water-quality expertise from external sources. This could include external agencies (e.g. health, water utilities), private consultants, or external specialists to provide expert advice. In some cases, health agencies may develop generic plans and guidance that can be applied.

4.4 Describing the water system

The first step of the WSP team is to compile available information on the design and operation of the water-distribution system in the building. This needs to be described in a comprehensive plan, starting with the nature and quality of water supplied to the building up to points-of-use (taps and outlets) by building occupants, users and visitors. The plan should document all components of the building water systems, including point-of-entry (PoE) and point-of-use (PoU) treatment, distribution systems (e.g. hot water, cold water, firefighting), water-using devices (e.g. swimming pools, cooling towers) and specific water uses. An accurate description of the water system is essential to support the identification of hazards, allow risks to be assessed adequately and allow appropriate control measures to be identified.

4.4.1 Functions of water networks inside buildings

Drinking-water networks inside buildings have important differences from external public water-supply networks that need to be considered when analysing potential health hazards. In many buildings, at least two different drinking-water networks operate—that is, a cold-water and a hot-water system—with the following different design features and purposes:

- Cold-water networks are typically designed to deliver water under satisfactory pressure and flow rate at all taps. Parts of the system with large flow rate demands will guide the capacity of the network. Cold-water networks may also deliver water to fire-protection systems. In some circumstances, additional treatment may be provided to supply higher water quality (e.g. in health-care buildings). Cold-water networks should be designed to be efficient, with minimal stagnation, and should be insulated and separated from hot-water networks to minimize heat gain. They should also be protected against corrosion and other damage, to maximize their lifespan.
- The primary function of hot-water networks is to deliver sufficient quantities of water at satisfactory temperatures for its intended use, while limiting energy consumption. This may be achieved by storing hot water near PoUs, responding to demand peaks for large networks, and installing recirculation loops with short branch pipes to PoU to ensure supply of water on demand. Hot-water systems may incorporate temperature-reduction devices to reduce scalding. To reduce risks from *Legionella*, these should be placed close to PoUs. Networks should be designed to minimize areas with low flow or stagnation. Insulation of the piping system will minimize temperature loss.

Buildings will also generally include a wastewater network and may include other networks for delivering other types of waters (e.g. distilled water, rainwater, water for firefighting, greywater, recycled water). All networks need to be identified and labelled clearly. Networks of different water quality need to be kept separate and isolated from both the cold- and hot-water networks. Where the drinking-water system is intentionally connected to a water system, appropriate backflow prevention is needed when delivering non-drinking-water (e.g. water for firefighting).

4.4.2 Usages and water-use patterns

A good understanding of a water network includes establishing the uses of water throughout the building. Where there are multiple supplies of water (e.g. external drinking-water, roof rainwater and recycled water), the uses of each type of water should be identified.

Therefore, all water uses (planned and actual) should be established, as well as requirements for different user groups in a building. This analysis may be based on a list of different possible uses; for example, water for drinking, showering, preparing food, washing, cleaning, toilet flushing, technical uses, watering, firefighting or leisure activities. Specific uses (e.g. medical, dental) and supply to water-using devices (e.g. cooling towers, swimming pools, water coolers, water fountains) should be identified.

Different water qualities and uses should be described clearly, using consistent nomenclature, particularly in buildings with common purposes (e.g. hospitals and health-care facilities). For example, Table 4.1 provides a description of water used in health-care facilities in France.

Water usages determine the water volume and flow rates that have to be provided at each PoU. This understanding, together with a knowledge of system capacities, is important for identifying the likelihood of low flows and areas of stagnation. Parts of buildings that have variable or seasonal occupancy rates should be identified.

Table 4.1 Nomenclature of waters used in health-care buildings in France

Quality 1. Water not submitted to any treatment within the health-care building
1.1: Water dedicated to drinking and food preparation
1.2: Water for regular care
Quality 2. Specific water treated within a health-care setting complying with defined criteria in accordance with usages
2.1: Bacteriologically controlled water
2.2: Hot water
2.3: Water from hydrotherapy pools
2.4: Water from hot tubs and shower jets
2.5: Water for haemodialysis
2.6: Purified water (drug preparation)
2.7: Highly purified water (for injection)
2.8: Drinking-water from fountains
Quality 3. Sterile waters
3.1: Diluents for injections
3.2: Water for irrigation (pouring water)
3.3: Sterilized drinking-water
Quality 4. Water for technical use[a]
4.1: Cooling network
4.2: Laundry
4.3: Boilers

[a] Water used as feed water and so on in, for example, cooling networks, boilers and laundry machines.
Note: only Quality 1, Quality 2 and Quality 3 are produced directly from the water network.
Adapted from Ministry of Health (France) (2004).

4.4.3 Understanding and documenting the design of the water system

Effective assessment of potential health hazards and risks requires a sound description and documentation of the physical structure of the building's water system (e.g. architecture, plumbing, materials, location of installations and equipment, connection to water-using devices) and its expected conditions of operation. Construction plans and any other available documentation of the building's infrastructure provide a good basis for system description. Drawing high-level, simple flow diagrams will help to capture the various elements of the building's water system, and will help to identify hazards, risks and controls.

The existing documentation and the flow diagram need to be verified by an on-site examination to confirm that they are up to date and correct. Water systems in buildings are often poorly mapped and not updated after repairs or renovations. The on-site examination should follow the delivery of water from PoE to all points of delivery or use within the building.

Elements to be examined and documented include (Figure 4.2):

- 1 point(s) of entry to the building, including possible PoE treatment;
- 2 possible building-specific sources of water and associated treatment;
- 3 water piping, storage systems and connections between drinking- and non-drinking-water systems, including intended connections (e.g. between drinking-water systems and fire systems) and unintended connections (e.g. between drinking-water systems and sewage or recycled-water systems);
- 4 devices for heating and supplying hot water;
- 5 hot-water piping systems;
- 6 equipment installed at PoU (e.g. dishwashers, washing machines, drinking- water fountains);
- 7 water treatment systems at PoU.

These elements are explained in more detail below.

1 Point(s) of entry

The most common source of drinking-water to buildings is an external piped water supply. The PoEs are often marked by a water meter on the property or building boundary. This is also the point where ownership and management responsibilities can change to the building owner. It is a critical point in terms of providing a basis for defining the physical scope of building WSPs. In some cases, buildings may have more than one PoE, and in other cases groups of buildings may be supplied through a single offtake and a shared meter. There could also be separate points of supply for firefighting. Each PoE should be identified, as well as their condition of use (permanent, intermittent, backup) and the way they are connected to the inner water system and to other entry points (i.e. whether they are interconnected or kept separate).

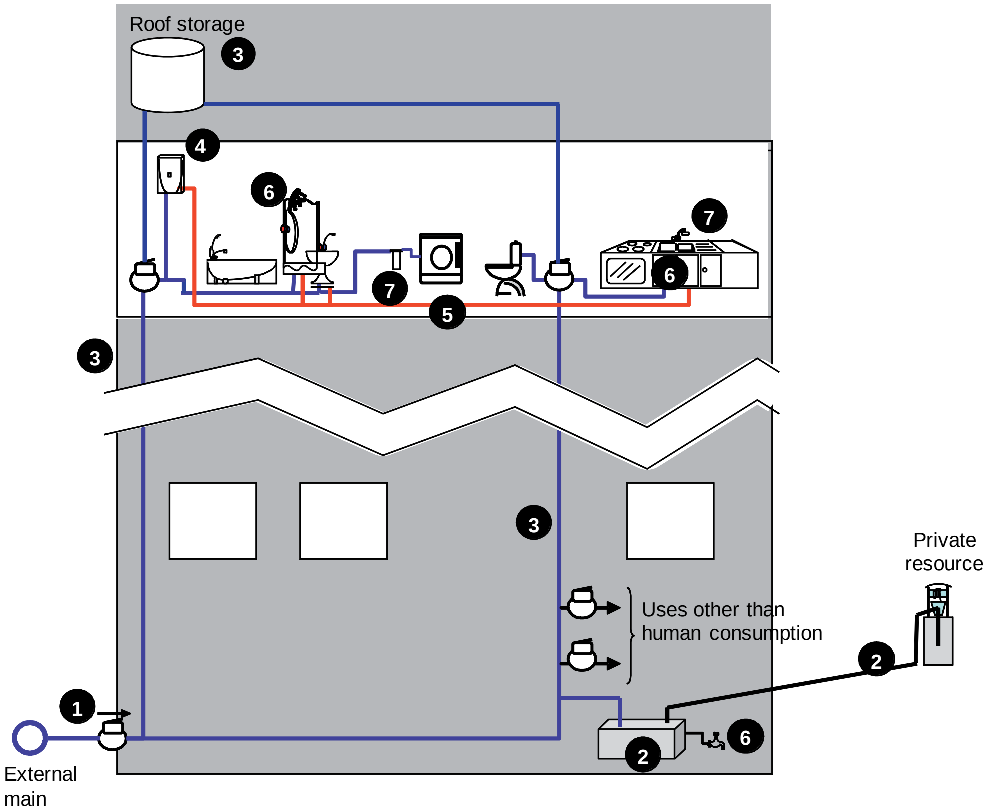


Figure 4.2 Typical components of water systems inside buildings

Issues that need to be considered include the:

- quality and composition of the delivered water (this needs to be obtained from the water supplier);
- continuity and quantity of water supply;
- conditions of accessibility to the PoE;
- presence of a water meter and of backflow-prevention systems to prevent contamination of the public network;
- responsibility of the water supplier in assuring water quality within the building; for example, it could be a requirement that the public water supply will not corrode building plumbing systems;
- treatment systems installed at the PoE (e.g. chlorinators, filters, water softeners, deionizers, activated carbon), including selection, storage, use and control of chemicals.

2 Possible building-specific sources of water and associated treatment

Buildings may use private sources of water or may augment external sources of water with building-specific sources, such as rainwater, wells, borewater and springs. If the water from the private source is not provided for human consumption (e.g. used for toilet flushing), safeguards (e.g. warning signs) must be installed to prevent this water being misused as drinking-water or being connected to the drinking-water supply.

The following questions need to be considered:

- What is the nature and location of the building-specific source?
- How is it protected from external pollution?
- How is it delivered to the building and what are the possibilities for contamination (e.g. through faults in pipework, open storage tanks, inappropriate materials in contact with water)?
- What kind of treatment is applied at the PoE?
- If the building-specific source is not used for drinking, what precautions are taken to ensure that the water is not misused or connected with the drinking-water supply?

3 Water piping, storage systems and cross-connections to non-drinking-water systems

Water piping systems in buildings vary in lengths, complexities, materials and designs. The structure of a piping system needs to be established by examining existing plans and by an on-site investigation. Plans should always be checked against reality, since they are not always updated when networks are upgraded or repaired. However, this can be difficult, particularly in large, complex buildings, because pipes are often concealed and embedded in walls or ceilings. It is important to catalogue as much of the system as possible and to document and retain all plans for future use. In particular, the following parts of the system should be identified:

- water-storage tanks (may be larger where water supplies are intermittent), including consideration of size in relation to inflow and usage requirements (total and peak flows) within the building, detention and integrity;
- points of delivery, including fixtures and connections to equipment (e.g. dishwashers, washing machines, medical equipment) and water-using devices (e.g. cooling towers, swimming pools, water fountains);
- inadvertent or unintended connections between drinking-water systems and non-drinking-water systems (lower or higher quality water);
- installation of backflow prevention between drinking-water systems and non-drinking-water systems (e.g. firefighting systems) and water-using devices;
- physical separation of cold- and hot-water systems and separation of drinking-water systems and non-drinking-water systems;
- labelling and identification of pipework;
- thermal insulation of piping systems;

- temperatures;
- antisiphonage systems or valves;
- branch pipes and dead legs;
- areas with potential for intermittent or seasonal use;
- materials used in pipes and other components, including compliance with established certification or authorization schemes for materials used in contact with drinking-water;
- access for maintenance or disinfection.

Box 4.1 provides a case study of cryptosporidiosis associated with water shortages in a multipurpose building in Japan.

Box 4.1 Cryptosporidiosis associated with water shortage

From 30 August to 10 September 1994, there was an outbreak of cryptosporidiosis among the people who visited or worked in a multipurpose building in Hitatsuka, Kanagawa Prefecture, Japan. The multipurpose building was constructed in 1970, with six storeys above the ground and one below. There were 10 restaurants or bars, a dance studio, a clothing store, a post office and accommodation for employees in the building. An epidemiological survey revealed that 461 out of 736 people investigated complained of cholera-like or influenza-like illness. An investigation of the water system in the building found that there were two separate systems: one directly connected to the public water supply served drinking-water to the first floor, while the other delivered water from the second to sixth floors through a storage tank, which was also supplied from the public water supply. The storage tank was adjacent to a night-soil tank, wastewater tank and artesian springwater tank in the basement. The tanks were concrete and separated by a wall with holes to allow connections between the tanks. (This kind of tank design is not allowed in new regulations for buildings.) Although the purpose of the holes was not clear, they might have helped to discharge excess drinking-water from the storage tank to the night-soil or wastewater tanks. Water level in the wastewater tanks was kept below the holes by pumping to the public drain.

The epidemiological survey found that there were patients from every floor except the first. Polluted drinking-water was strongly suspected as a source of infection. According to the owner of the building, the wastewater pump was broken at the time of the outbreak. Several species of pathogenic bacteria were isolated from stool and water samples, but they were not considered to be the source of the outbreak. Oocysts of *Cryptosporidium parvum* were identified in 12 (48%) of the 25 stool samples, tap water, the storage tank and other tanks. It was concluded that the cause of this outbreak was drinking-water contaminated by *Cryptosporidium* oocysts following accidental malfunction of the wastewater drainage system.

Based on Kuroki et al. (1996).

4 Devices for heating and supplying hot water

The production of hot water is a common feature in buildings. Hot-water production may be instantaneous, or based on its storage in hot-water tanks. Buildings may be served by single hot-water systems or by multiple systems to supply individual floors, sections of buildings or living units. In large systems, hot-water production can be centralized in boiler rooms or provided by multiple units. Consideration should be given to the temperature of water in storage heaters and the capacity of systems compared with water usage.

Box 4.2 provides a case study of methaemoglobinemia (a disease characterized by a higher than normal level of methaemoglobin, which does not bind oxygen, in the blood), arising from nitrite-contaminated water.

Box 4.2 Methaemoglobinemia attributable to nitrite contamination of potable water through boiler fluid additives, New Jersey, 1992 and 1996

Two outbreaks of methaemoglobinemia were reported in 1992 and 1996. In the first outbreak, acute onset of illness was reported in 49 children from one school. Onset occurred within 45 minutes after lunch. Initial symptoms were blueness of lips and fingers, followed by nausea, abdominal pain, vomiting and dizziness. Fourteen children were hospitalized and treated with supplemental oxygen and methylene blue. All children recovered in 36 hours. In the second incident, six workers reported acute onset of blueness of the skin. Two of the workers were treated with supplemental oxygen and methylene blue. All recovered within 24 hours.

An investigation of the first incident found that the children had consumed soup diluted with a mixture of hot and cold tapwater. The soup contained 459 mg/L of nitrite, while the hot water contained 4–10 mg/L of nitrite. The hot-water boiler had been returned to service that morning after earlier servicing using a commercial conditioning fluid containing nitrite and sodium metaborate. Investigations found that a backflow-prevention valve preventing flow of water from the boiler to the drinking-water system was stuck in the open position. In addition, taps for the boiler treatment solution and the hot-water coil were in the same area but unlabelled. The water system was flushed, and the school discontinued heating water through boiler coils.

An investigation of the second incident also found that a faulty backflow-prevention valve had allowed boiler conditioning fluid to contaminate hot water used to prepare coffee.

Although the potential for this type of contamination from boilers was recognized with a regulatory requirement for backflow-prevention valves, there were no requirements for routine inspection, maintenance and replacement of valves. Maintenance of backflow-prevention devices used to prevent contamination of drinking-water is essential.

5 Hot-water piping systems

Hot-water systems should be mapped and catalogued in a similar fashion to cold drinking-water systems. One of the problems associated with hot-water systems is balancing the need to maintain water temperatures above 50 °C to minimize risks from *Legionella*, while minimizing the risk from scalding. This applies particularly in aged-care and child-care facilities and health-care facilities. Hot-water piping systems can be installed as one unit at the scale of the entire building, or to serve sections of buildings.

When mapping hot-water systems, the following components and features should be identified:

- hot-water devices and storage vessels;
- thermal insulation of piping systems and physical separation from cold systems;
- the presence of looped distribution systems (circulating systems);
- temperatures throughout the system, including at most distal points and, in the case of looped systems, on point of return to heating devices;
- installation of temperature-control devices to reduce the risk of scalding (e.g. thermostatic mixing valves) and distance from these devices to PoU;
- length and numbers of branch pipes and dead legs;
- areas with potential for intermittent or seasonal use;
- materials in pipes and other components;
- access for maintenance or disinfection.

6 Equipment installed at PoU

Description of systems should identify all equipment using water.

Equipment at PoU varies in type, size and flow rates. Equipment includes sinks, taps, baths and showers, dishwashers, washing machines, medical devices, sprinkler systems, drinking-water fountains, decorative fountains and ice machines. All devices should be identified, together with frequency of use. Installation of backflow prevention should be recorded.

7 Water treatment systems at PoU

Treatment may be applied at PoU using devices such as carbon filters, membrane filters, water softeners, deionizers or ultraviolet disinfection systems. In large buildings, staff may install PoU devices such as carbon filters without approval. All PoU devices should be identified. Unauthorized equipment should be removed. Installation of backflow prevention should be recorded.

Issues to be considered include correct installation and maintenance. For example, filters need to be replaced regularly. Old carbon filters that have passed their “use-by” dates can support growth of large concentrations of microorganisms.

Existence of standards and regulations that apply to PoU equipment connected to water supplies should be determined. Where standards and regulations have been established, all equipment should be checked for compliance.

Box 4.3 provides a case study of a *Pseudomonas* outbreak in a haematology unit.

Box 4.3 Resolution of a *Pseudomonas aeruginosa* outbreak in a haematology unit with the use of disposable sterile water filters

In 2002, a high incidence of *Pseudomonas aeruginosa* bacteraemia was detected in a haematology unit in which severely neutropenic patients were admitted. A total of 61 of 1478 blood cultures were positive for *P. aeruginosa*, compared with 19 of 824 blood cultures performed in 2001.

In an initial investigation in June 2002, eight water samples were collected from bathrooms used by patients, but only one contained *P. aeruginosa*. However, when the outbreak persisted, a further 85 samples were collected. These included 46 samples of water from outlets such as taps, showers and water traps, as well as samples of detergent, air, and bathroom and toilet surfaces. Twenty-nine of the water samples contained *P. aeruginosa*, while none of the other samples were positive.

The installation of 0.2 μ membrane filters on taps and water heads significantly reduced the incidence of bacteraemia. In 2003 and 2004, *P. aeruginosa* was detected in 7 of 1445, and 11 of 1479 blood cultures, respectively.

Tapwater has been documented as a potential source of *P. aeruginosa* infections in hospital settings. Additional measures such as point-of-use treatment can reduce the risk of infection in high-risk patients.

Source: Vianelli et al. (2006).

4.5 Identifying hazards and hazardous events

In hazard identification, the WSP team is required to assess what could go wrong and where hazards and hazardous events could occur. The following sections discuss a range of possible generic hazards and hazardous events that may occur in buildings. However, it is important that hazards and related events are specifically identified for individual buildings under investigation.

Box 4.4 provides definitions of hazards, hazardous events and risk, in the context of risk management.

Box 4.4 Definitions of hazards, hazardous events and risk

Effective risk management requires the identification of potential hazards and their sources, and potential hazardous events, and an assessment of the level of risk presented by each. In this context:

- a hazard is a biological, chemical, physical or radiological agent that has the potential to cause harm;
- a hazardous event is an incident or situation that can lead to the presence of a hazard (what can happen and how);
- risk is the likelihood of identified hazards causing harm in exposed populations in a specified time frame, including the magnitude of that harm and/or the consequences.

4.5.1 Microbial hazards

Faecal contaminants

In common with most drinking-water supplies, ingress of enteric pathogens (bacteria, viruses and protozoa) associated with faecal contamination can be a significant source of hazards. Faecal contamination can enter through public water supplies provided to buildings, building-specific water supplies, faults in internal plumbing systems (e.g. unroofed water-storage tanks, cross-connections with sewage systems or with recycled-water systems) and poor hygiene at PoU.

Growth of environmental organisms

Water systems in buildings can be prone to environmental microorganism growth, including potentially pathogenic species and nuisance species, which can cause off-tastes and odours. Environmental pathogens include *Legionella*, *Mycobacterium* spp. and *Pseudomonas aeruginosa*. Water-borne *Legionella* is strongly associated with buildings, while *Pseudomonas* has been identified as a particular concern in health-care settings (Anaissie et al., 2002; Exner et al., 2005) and water-using devices such as swimming pools and hot-tub pools (Yoder et al., 2004, 2008a; Djiuban et al., 2006; WHO, 2006a). In hospitals, a broader range of environmental microorganisms have been identified as causes of nosocomial infections, including *Acinetobacter* spp., *Aeromonas* spp., *Burkholderia cepacia*, *Serratia*, *Klebsiella*, *Stentrophomonas maltophilia* and fungi such as *Aspergillus*, *Fusarium* and *Exophilia* (Annaisie et al., 2002; Sehulster et al., 2004).

Small invertebrate animals can survive and grow in distribution systems under conditions that support microbial growth and biofilms (Ainsworth, 2004). These small animals are not of health concern but can reduce the acceptability of water supplies.

4.5.2 Chemical hazards

Chemicals from environmental and industrial sources, agriculture, water treatment and materials in contact with water can contaminate building systems. Contamination could be introduced from external community supplies, building-specific water supplies or distribution systems within buildings. Chemical quality of all water supplies used in buildings should be determined. For external supplies, this information should be available from water providers, while building-specific supplies will require monitoring (WHO, 2008).

Chemicals used in water-using devices can also represent hazards, either from back-siphonage from the devices or from storages kept within buildings. These chemicals can include disinfectants, antiscalants, coolants, heating fuels, oils and other chemicals used in boilers.

Materials

Chemicals that can be leached from materials used in pipework, solders and associated fittings include aluminium, antimony, arsenic, benzo(a)pyrene, bismuth, cadmium, copper, iron, lead, nickel, organolead, organotin, selenium, styrene, tin, vinyl chloride and zinc (WHO, 2008; Health Canada, 2009). Organic substances can be released from plastic pipes and fittings, flexible hoses, glues, adhesives and tank-lining materials (plastic and bitumen based). These substances may be direct hazards or may cause indirect problems by supporting microbial growth (e.g. from polymeric or elastomeric compounds).

In addition to potential health impacts, materials can contain chemicals that cause aesthetic problems. For example, iron and zinc do not produce health impacts, but rust will discolour water, while elevated levels of many metals such as zinc will add a metallic taste to water. Users will often assume that discoloured or poorly tasting water is unsafe.

If the materials are suitable for use in drinking-water systems and corrosion is controlled (see section 4.6), the concentrations of hazardous chemicals released into water supplies should not represent a health risk. However, hazardous concentrations could be released by unsuitable materials. Some countries have established programmes to certify products and materials used in drinking-water distribution systems.

Water-treatment chemicals

Water treatment is used in some buildings to either improve untreated water supplies or to supplement treatment applied by the drinking-water provider. It may also be used to produce water of higher quality required for specialist purposes (e.g. renal dialysis or manufacturing processes). Common forms of treatment include filtration, disinfection and softeners. Water-treatment chemicals, such as disinfectants and coagulants, and chemicals used to maintain treatment processes, such as membrane-cleaning agents, can represent hazards.

Annex 2 provides a summary of microbial and chemical hazards that can present a risk to building water supplies, including potential outcomes of infection or exposure as well as sources of exposure and methods for identification.

4.6 Hazardous events

4.6.1 Contaminated or intermittent water supply

The quality or quantity of external sources of piped water supplied to a building may be compromised due to intermittent supply, contaminated water or poor condition of the distribution system.

Those responsible for water supplies in buildings should liaise with operators of external piped water supplies to review the performance and previous history of the supply. This review should consider the quality (including contamination events) and quantity (volume, reliability, frequency and length of interruptions) of the supply. The presence of buffering storages and alternative sources of water will influence the impact of interruptions to external supplies.

In cases where information on water quality of external supplies is inadequate, building managers may need to consider monitoring.

4.6.2 Ingress of contamination

Water sources

Contamination of building water systems can be caused by ingress of hazards into sources of external or building-specific supplies. Further information is provided in the supporting texts on protecting groundwater (Schmoll et al., 2006) and the GDWQ (WHO, 2008). Ingress of microbial and chemical contaminants can be caused by a range of hazardous events, including contamination of water sources by human and animal waste, industrial spills and discharges, inadequate treatment, inappropriate storage, pipe breakages and accidental cross-connections. Water utilities should provide warnings to building owners and managers when incidents threaten the safety of water delivered to buildings. Building owners should ensure that mechanisms have been established for notifications to be received and for appropriate responses to be initiated.

Building systems

Possible events leading to ingress of contamination can be determined by a systematic review of the system components, taking a “what-can-happen” brainstorming approach. The input of plumbing specialists, together with water microbiologists, is important in hazard identification. Any break or disruption to the integrity of drinking-water distribution systems can lead to ingress of microbial contamination. The likelihood of contamination events is increased where drinking-water and wastewater networks are installed in close proximity.

Box 4.5 provides a case study of water quality in rural health-care facilities.

Box 4.5 Water quality at rural South African health-care facilities

Water quality problems at health-care facilities in developing areas are often not only the result of on-site microbial deterioration but start with the quality of the water supplied to the facility. In South Africa, rural facilities have to rely on boreholes or surface water for their source of potable water. The water is often supplied without treatment, or after only limited treatment. The quality of the potable water used in health-care facilities in rural areas in South Africa is not monitored routinely. During 2006, a small study was conducted at 21 clinics in the Limpopo province in the north of South Africa to determine the microbial water quality of the drinking-water. Water was tested for *Escherichia coli*. General information on water supply and sanitation issues at the clinics was also collected.

Water availability was one of the most pressing problems experienced by many of the clinics. In many cases, this was blamed on inadequate technical support and maintenance. A significant percentage of the clinics studied used water that did not comply with South African drinking-water standards. This may have been partly due to the variety of sources upon which they need to rely, particularly when their primary source fails. A significant health risk to users was indicated by positive *E. coli* counts found in 14 of the 49 samples (29%), representing 38% of the clinics. This study highlighted the fact that health-care facilities in rural areas often receive water of inadequate microbial water quality, which could jeopardize the health of both patients and staff at the clinics.

Source: M du Preez, Council for Scientific and Industrial Research, South Africa.

Events that can lead to ingress of contamination include the following:

- Cross-connection of different water qualities (e.g. drinking-water and water of other quality) (USEPA, 2002) may not be readily apparent, because differences in physical appearance may not be recognized by users. Inadvertent connections may be introduced during maintenance and repair.
- Inadequate backflow prevention on PoU equipment can allow contaminated water or chemicals used in the equipment to flow back into and contaminate drinking-water systems.
- Leakage of chemicals or fluids, and cross-connections with chemical storages (e.g. heat transporters or corrosion-preventing additives associated with hot-water devices) can contaminate drinking-water (USEPA, 2002).
- Inadequate protection of building storage tanks can lead to contamination from the water supply. Similarly, unprotected tanks are at risk of faecal contamination from birds and vermin.
- Water supplies can be deliberately contaminated (Ramsay & Marsh, 1990).
- Hydrophobic compounds can migrate through plastic piping. Storing or using hydrocarbons or solvents close to plastic piping that is porous to hydrophobic compounds can contaminate drinking-water. Storing such products in boiler rooms can lead to increased migration of organic substances due to elevated temperatures.

Box 4.6 provides a case study of poor water-supply management in a health-care facility.

Box 4.6 Poor management of a hospital water supply

A hospital in Eastern Europe with 400 beds has two separate water sources of water: an intermittent community supply that provides sufficient water, and a shallow on-site bore that provides salty water. The community supply is sourced from a well about 5 km from the hospital. This community supply is treated using a rudimentary, manually controlled chlorination device. The community supply is poorly protected from contamination at both the source and during distribution. Supply from the community system is limited by the availability of power to the whole system, coupled with inadequate pumping and storage capacity at the hospital.

As a result, the hospital has two internal systems. The first system distributes a mixture of water from the community supply and the on-site bore. This water is too salty to drink (it is classified as being non-drinkable), and is used for toilet flushing and to supply firefighting equipment. The second system delivers drinking-water from the community supply to about half the building. There is no labelling to distinguish between the two systems, even in rooms that have outlets from both systems. There is no evidence of backflow prevention in any parts of the plumbing systems.

When water is available from the community supply (about twice a day), it is collected and stored for later use in bathtubs, buckets and any other available containers. There is no hot-water system, no bathing facilities in the hospital, and no hand-washing facilities near toilets. Drainage pipes from some sinks are not sealed at the point of entry into floors. The plumbing system is prone to freezing, because the central heating system has not operated for more than 15 years.

A number of measures could lead to large improvements. The quality, management and constancy of the community supply could be greatly improved, but this is beyond the control of the hospital. The most pressing need at the hospital is to ensure that there is sufficient pump capacity and storage at the hospital to provide greater security of supply of water from the community system. This would allow disconnection of the on-site bore and reduce the need to collect water in open containers. Constant pressure in the hospital system would also reduce the likelihood of backflows and ingress of contaminated water. Sanitation at the hospital could be improved by providing more hand-washing facilities, ensuring that toilet facilities are functional and ensuring that drainage systems are maintained. The system should be examined for cross-connections, and, where necessary, backflow-prevention devices should be installed.

Alternative sources of water such as deep bores could be investigated.

Source: Prospal (2010).

4.6.3 Poorly controlled treatment

Installing water-treatment systems should improve water quality, if they are managed properly. However, potential hazards may arise from:

- lack of validation that treatment systems will be effective;
- incorrect installation (e.g. softening systems should be calibrated so that they do not produce water that could be corrosive);
- operation by staff with insufficient training and knowledge;

- inadequate monitoring and poor control;
- insufficient maintenance;
- inadequate response to equipment failures or poor monitoring results (e.g. inadequate disinfectant residuals);
- excessive doses of treatment chemicals (e.g. disinfectants) and poor control of chemicals used in maintenance of treatment processes (e.g. cleaning agents for membrane filters).

Disinfection by-products are likely to increase if disinfection is applied. While excessive doses of chlorine should be avoided, it is important that microbial control is maintained.

4.6.4 Microbial growth and biofilms

Water supplies in buildings connected to public or external supplies represent end-of-pipe systems. As such, they can often provide environments and conditions (e.g. low flows, stagnation) that are favourable for microbial growth and biofilm formation.

Environmental pathogens are often adapted to grow in biofilms, and growth can be greater in conditions that support biofilm development. In well-managed systems, biofilms will be thin and relatively well contained. Concern arises when these biofilms become too thick and start to disseminate throughout the system. Organisms in established biofilms can be difficult to remove. Poorly managed building water systems are prone to colonization, and biofilms can develop within pipes and on components such as washers, thermostatic mixing valves and outlets. Biofilms are extremely difficult to remove from all parts of the system once they are established, and they can be resistant to disinfectants, such as chlorine. Well-managed disinfection regimes that maintain disinfectant residuals through water systems can inactivate potential pathogens released into the aqueous phase, but this protection is lost if disinfectant residuals fall below effective levels.

Factors associated with microbial growth and biofilm formation in cold-water systems include:

- stagnation and low water flows;
- poor temperature control, which creates conditions supporting microbial growth; several environmental pathogens (e.g. *Legionella*) grow more quickly at body temperature (37 °C), and hot and cold water should therefore be kept above 50 °C and below 25 °C, respectively (inadequate separation and insulation of cold- and hot-water systems can lead to warming of cold water);
- scaling (because of its impact on hydraulics);
- scaling and corrosion, which provide rough surfaces that promote development of biofilms;
- suspended matter, which can provide nutrients favouring microbial growth, and create deposited sludges that support biofilms;
- source water that contains a high organic load (i.e. high total organic carbon);

- inappropriate materials containing microbial nutrients in contact with water;
- poor maintenance and intermittent use of PoU equipment and devices (e.g. ice machines, cooling towers, old carbon filters past their "use-by" date), which can support microbial growth (e.g. *Listeria*, *Pseudomonas*, *Legionella* and fungi); for example, filters need to be replaced regularly.

The case study in Box 4.7 describes what can happen when a cold-water system fails.

Box 4.7 Outbreak of legionellosis due to failure in cold-water system

A hospital in Brandenburg, Germany, with more than 900 beds opened a new building and began to move patients from some older wards to the new one. The management of the hospital changed with the opening of the new building. Soon after starting operation of the new wards, seven patients were diagnosed with legionellosis. Samples had been collected from the hot-water distribution system before moving patients and had not contained *Legionella*. As soon as the outbreak was detected, the water distribution system was inspected. Use of water from showers and other utilities was restricted, filters were installed, and patients were subjected to stricter surveillance.

At the same time, alterations were made to the water-system operations, particularly the disinfection regimes. Details of theses alterations remain unclear due to the simultaneous change of management and limited availability of documentation. Afterwards, the system was checked again and was considered safe.

Six months later, another new building was opened, and again patients were moved from old wards to the new building. Again, the hot-water distribution was examined before the move, with no detection of *Legionella*. And again, five patients fell ill with legionellosis shortly afterwards.

A more in-depth inspection of the whole water system was conducted, along with immediate measures such as installing filters and carrying out disinfection procedures. Both new buildings had separate hot-water distribution systems. Both were only sparsely contaminated with *Legionella*. However, both buildings shared the same cold-water distribution system, and the temperature in these pipes was shown to be higher than allowed by technical standards (25 °C maximum allowed for cold water). Apart from insufficient insulation of the cold-water pipes, the hydraulics of the whole system had not been optimized, leading to stagnation. There were cross-connections with fire hydrants and pipe sizes that were inadequate.

Corrective measures introduced following the initial response (disinfection and installation of filters) comprised installation of regulation valves and recirculation pipes to avoid stagnation and heating of cold water. Changes in management had been associated with poor documentation associated with planning, construction and modifications. Documentation of the water distribution system and disinfection procedures was improved. A more detailed risk assessment was performed.

The two outbreaks following the opening of the biggest new hospital buildings in the region drew major public attention, and the new management faced severe criticism. Costs for corrective action to avoid closing the hospital (or at least the buildings affected) were remarkably high. Two of the twelve patients who were confirmed cases of legionellosis died. Legal action was pursued.

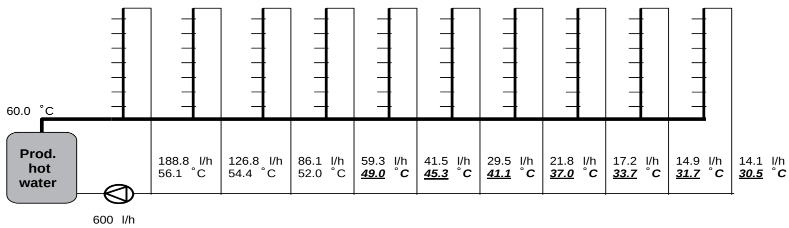
Adapted from Robert Koch Institute (2004).

Factors associated with biofilm formation and growth of environmental pathogens in hot-water systems include:

- insufficient heating capacity to cope with demand;
- poor temperature control, leading to reduction of hot-water temperatures below 50 °C; factors can include
  - poor insulation of hot-water systems
  - poor design, leading to low flow or stagnant areas (long branch pipes and dead ends)
  - installation of high-volume storage tanks that support stagnation and stratification (stratification can lead to lower water temperatures at the bottom of storage vessels)
  - failure to maintain water at sufficiently high temperatures in storage vessels (in some cases, temperatures in storage vessels may be reduced in a bid to save heating costs or to reduce risks of scalding by cooling the whole hot-water system)
  - insufficient equilibrium of permanent flow in looped systems or insufficient total flow rates to feed all parts of the piping system (see Box 4.8)
  - incorrect positioning or operation of temperature-reduction measures (e.g. thermostatic mixing valves); the main fault is locating these devices too far away from taps and outlets, creating long lengths of pipework containing warm water;
- corrosion and scaling, resulting in the accumulation of sediments and microorganisms at the bottom of storage tanks;
- inadequate cleaning and maintenance.

Box 4.8 *Legionella* hazard due to unbalanced looped hot-water systems

Looped hot-water networks are designed in such a way that the temperature in the loops is maintained because the loops are insulated and a minimum flow rate is maintained in each loop. For a given loop, the difference in temperature between the two points where it is connected to the main distribution circuit ("departure" and "arrival") is inversely proportional to the flow rate in the loop. For example, in a typical building with six levels, a 5 °C temperature difference may be maintained only under the condition that the flow rate in the loop is equal to or above 40 litres per hour. Very often, this condition can be attained only by specific valves that equilibrate flows among the loops. However, if the design or construction of such networks is poor, flows may not be balanced—that is, the first loops take the largest part of the flow rate, so that there is not enough flow for the last loops. As the figure below shows, this frequent type of fault can directly affect the temperature of the last loops, which can then become incubators of *Legionella* and other environmental pathogens at temperatures below 50 °C.



Example of unbalanced flow rates in a looped hot water system and its consequences on the temperature of circulated water

4.6.5 Release of hazards from materials and equipment

Unsuitable materials and equipment used in water systems may release hazardous substances into drinking-water (Health Canada, 2009). The chemicals could be contaminants in the materials (see section 4.5.2), be leached during initial use, or be leached due to elevated corrosion.

Stagnation of water within the building system can increase concentrations of hazardous chemicals released from materials. Intermittent use of end-of-plumbing fixtures (e.g. drinking-water coolers in schools) can result in the presence of elevated concentrations of heavy metals such as copper from copper piping or lead from brass fixtures.

Corrosion and scaling

A wide range of materials can be potential sources of chemicals through corrosion, including pipes, solders and fittings (Health Canada, 2009). Corrosion of materials in contact with water is natural and will eventually cause leakages or failures, allowing ingress of contamination. In addition, the formation of corrosion product layers can promote microbial growth. The aim is to keep corrosion to a minimum; however, it can be accelerated by a number of factors, including water quality (particularly pH, chloride and sulfate, disinfectant concentrations, organic materials), poor material quality, use of materials that are incompatible with the given water quality, poor installation (poor welding, interconnection of different types of metal piping), water stagnation and temperature (Health Canada, 2009). Some waters, particularly those with low levels of dissolved minerals, can be corrosive for metal pipes and fittings, including copper, lead and brass (which often contains lead). Water utilities should be able to supply information on the characteristics of water supplied to buildings, including the likelihood of corrosion.

Water with high levels of hardness can cause increased scaling. Again, water utilities should be a source of information on hardness of incoming water supplies. Hot-water devices are particularly susceptible to scaling.

Scaling can cause energy losses (due to increased pumping and heating costs), resistance to disinfection, and premature failure of appliances (e.g. boilers and hot-water systems).

4.6.6 Specific uses

Sources of specific hazards can arise from specific uses (e.g. medical, dental), or from water-using devices, such as cooling towers, swimming pools, water coolers, water fountains or misting systems (e.g. in garden centres and conservatories).

Hazardous events associated with specific uses include:

- inadequate backflow prevention, allowing contaminated water or chemicals used in water-using devices to flow into drinking-water systems;
- aerosol formation (from showers, decorative fountains, etc.), providing potential exposure to respiratory diseases (e.g. legionellosis, mycobacterial hypersensitivity pneumonitis);
- poor maintenance and intermittent use, providing conditions that support microbial growth (e.g. *Listeria*, *Pseudomonas*, *Legionella* and fungi), corrosion (e.g. copper leaching from piping in drinking-water coolers) or leaching of chemicals from materials (e.g. plasticizer from plastic piping and tubing);
- inadequate treatment in swimming pools and hot-tub pools, allowing survival of enteric pathogens (e.g. *Giardia*, *E. coli* 0157, *Norovirus*) or growth of environmental pathogens (e.g. *Legionella* and *Pseudomonas*) (Craun et al., 2005; Pond, 2005; Sinclair et al., 2009).

4.6.7 Poor management (intermittent use)

Water distribution systems require proper management. Where parts of buildings and associated plumbing are not used for extended periods (e.g. months), the water system should be physically disconnected to avoid stagnation. Stagnant water can support growth of biofilms and environmental pathogens, such as *Legionella* and mycobacteria, and can contain elevated concentrations of chemicals released from pipework, such as copper and lead.

4.6.8 Construction work, renovations and repairs

If not properly planned and managed, renovation, repairs and modifications to buildings and associated water supplies can lead to introduction of microbial and chemical hazards. Where water distribution systems are extended, modified or repaired, there will be periods when flow is stopped and when pipework is intentionally cut and left open for periods, allowing potential ingress of contamination.

Hazardous events that could occur during construction, extension or repairs of systems include:

- the use of inappropriate materials—this can include using metallic products that are incompatible with existing materials in the system, causing corrosion;
- microbial or chemical contamination during repair or maintenance;
- accidental cross-connection between systems delivering different water qualities—renovation work may highlight deficiencies in labelling of existing pipework, which should be rectified;
- temporary switching to alternative supplies during construction, as well as introduction of temporary stagnation, dead legs and blind ends;
- failure to upgrade heating capacity when hot-water systems are extended;
- changes to the established equilibrium of operation in terms of hydraulic conditions, thermal capacity and corrosion risks; for example, renovating or altering the type of system described in Box 4.8 (above) could change performance, and extending the system may increase the total pressure too much for regulation valves to counterbalance, making equilibrium among loops impossible.

Extensions and renovations should not be assessed as separate entities from the existing system. Modifications can have wide-ranging ramifications on performance of the existing system through changing flow patterns, increasing capacity requirements and complexity. Renovations leading to change of use (e.g. from a commercial building to an apartment block) can be particularly complex and involve substantial changes to water systems and water usage. After construction, the existing system and extension should be considered as a single “new” system to be reassessed for potential hazardous events. WSPs will need to be reviewed and amended following any significant modifications.

Changes need to be recorded in system descriptions and distribution system maps.

4.6.9 Emergencies leading to contamination of external supplies

Major events such as flooding and other faults leading to contamination of external supplies (e.g. leading to a boil-water advisory) can contaminate building water supplies, including end-of-plumbing and PoU devices such as ice machines, beverage dispensers, drinking-water coolers and other water-using devices.

Alternative water supplies used in the event of an emergency may be a source of hazards and should be used with care.

4.7 Risk assessment

Risk assessment is a process by which identified hazards and hazardous events are evaluated to decide whether they represent a significant risk that needs to be controlled. The type of information that should be considered in a risk assessment is shown in Figure 4.3.

Risk assessments should take into account the number and vulnerability of exposed people and the type of exposure.

In the risk-assessment process, the important issue is to identify and prioritize unacceptable risks that need to be controlled. It is important not to get caught by identifying all risks and providing them with equal weighting.

Risk assessments can be applied at the time of planning or constructing a system; they can also be applied to an existing system. The preventive approach to include risk assessment with planning and construction is always preferable. Modifying existing systems, including retrofitting additional monitoring and control measures, is typically more expensive. Reactive risk assessments and modifications taken after harm has been caused can be complicated by political and legal influence, and time constraints.

Assessments for new buildings will identify risks that need to be controlled and the measures that need to be incorporated in the new water systems. Therefore, risk assessments should be conducted as early as possible within planning and design phases.

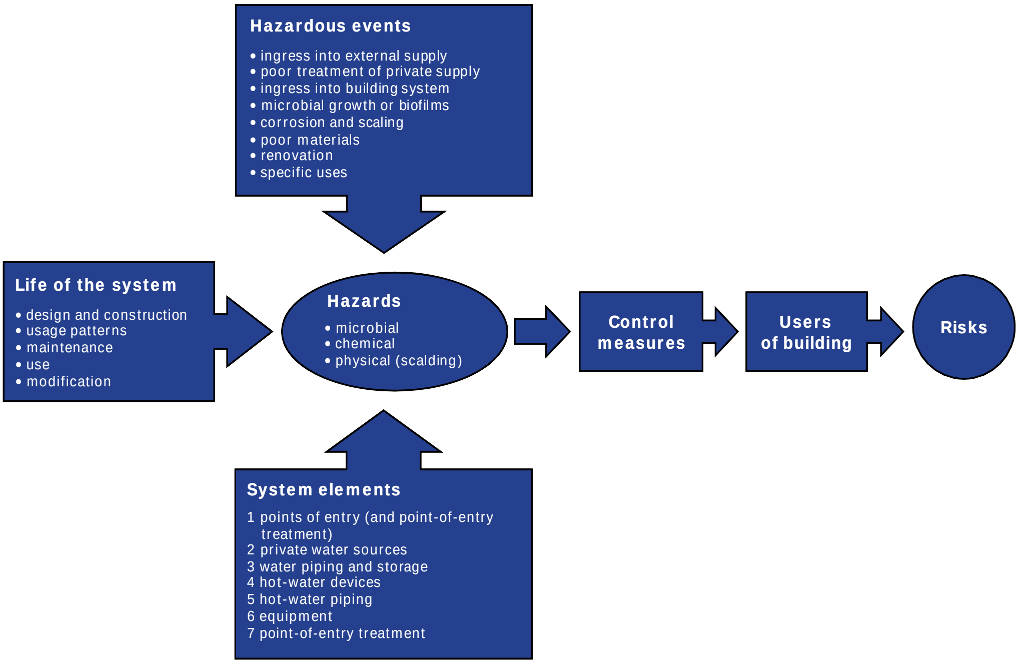


Figure 4.3 Types of information to consider in risk assessment

Risk assessments for existing buildings should identify and consider the effectiveness of established control measures. If the control measures are either insufficient or not effective, the risk-assessment process will identify significant risks and point to system modifications required to achieve water-quality targets. Therefore, the outcome of risk assessment is a plan of action that documents necessary additional or improved control measures, including time lines and responsibilities for their implementation. This should include establishing priorities for action.

Risk assessment and prioritization methods range from relatively simple team decision approaches, through semiquantitative, matrix-based approaches, to fully quantitative risk assessments (WHO, 2009). Which method is best in a given situation will depend on the complexity of the building water system assessed. The method of choice for a small or simple structured building may be qualitative team decisions based on the judgement and experience of the WSP team. For example, risks could be classified as significant, uncertain or insignificant. Those classified as significant should be considered as clear priorities for further action that could include application of additional control measures, while risks classified as uncertain may require further investigation.

Similarly, this type of approach could be applied to assess the risks from contamination or failure of external supplies. Where data are available on performance in the preceding years (e.g. over the past 5–10 years), a risk assessment could be based on:

- one or no major contamination or water-shortage events in the past 5–10 years, safe supply resumed after less than two days (= reliable public distribution);
- one to two major contamination or water-shortage events per year, resumed after less than two days (= generally satisfactory public distribution; PoE treatment may be considered for high-risk buildings or populations); or
- frequent major contamination or water-shortage events (= public distribution is not sufficiently reliable; PoE treatment or alternative sources should be considered).

Risk assessments for more complex buildings with a range of different water usages and technologies may benefit from a more formal and structured approach. In all cases, the WSP team needs to decide on a consistent risk-assessment methodology.

Tables 4.2 and 4.3 illustrate one approach for assessing and ranking risks. In this approach, the likelihood of a hazard occurring is combined with the severity of consequences to provide a risk matrix and is particularly applicable to hazardous events. The tables can be varied to meet the needs of the organization undertaking the risk assessment. For example, the numbers of categories for likelihood and consequence could be reduced.

Table 4.2 Example of a simple risk-scoring matrix for ranking risks

	Severity of consequences				
Likelihood	**Insignificant**	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost certain					
Likely					
Moderately likely					
Unlikely					
Rare					

Table 4.3 gives an example of descriptors that can be used to rate the likelihood of occurrence and severity of consequences. A "cut-off" point must be determined above which all hazards will require immediate attention. There is little value in expending large amounts of effort to consider small risks. For example, in the first instance, a cut-off point could be those risks above the bold line. Once these risks are managed, the cut-off point could be lowered.

For some hazards, it may be possible to incorporate a quantitative risk assessment. This assessment can provide a numerical estimate of whether the risk is tolerable or unacceptable. For chemicals, this estimate can include guideline values. For microbiological quality, quantitative risk assessment can be applied using a four-step process involving hazard identification, dose–response determination, exposure assessment and risk characterization. Hazardous events that lead to chemical guideline values being exceeded, or to high levels of microbial risk, should be considered unacceptable and hence require management.

The risk assessment should consider the effectiveness of existing control measures. Where risk remains unacceptably high, alternative or additional controls will be required (after existing measures have been considered). These additional measures must be evaluated in a supplementary risk assessment after additional control measures have been put in place.

Table 4.3 Examples of definitions of likelihood and severity categories that can be used in risk scoring

Item	Definition
Likelihood categories	
Almost certain	Once per day
Likely	Once per week
Moderately likely	Once per month
Unlikely	Once per year
Rare	Once every five years
Severity categories	
Catastrophic	Potentially lethal to all people using the building, including vulnerable groups (e.g. immunocompromised patients, infants and the elderly), following acute exposure
Major	Potentially harmful to all people using the building following acute exposure
Moderate	Potentially harmful to vulnerable groups (e.g. immunocompromised patients, infants and the elderly) following chronic exposure
Minor	Potentially harmful to all people using the building following chronic exposure
Insignificant	No impact or not detectable

Regardless of which method is preferred, any decision taken in the risk assessment needs to be documented to ensure that decisions are sufficiently transparent for external examination (e.g. in audits) and to allow reassessment in periodic reviews.

Further information on hazards, risks and responses is provided in Box 4.9.

Box 4.9 Example of a risk assessment

A water safety plan (WSP) team investigated the water system in a school building for 600 pupils. The building included a gymnasium with two shower rooms (40 showers in total). The WSP team found the following problems:

- One distribution pipe within the building was made of lead. This pipe delivers water to three bathrooms and one small kitchen.
- One small leakage in a pipe in the basement was identified.

Hot water was prepared from a centralized system in the main building at a temperature of 60 °C. There was no circulation loop. The hot-water pipes supplying water to the showers in the gymnasium were not insulated properly. Cold-water pipes were close to the hot-water pipes.

The WSP team prepared the following table for the risk assessment and for the decision about additional control measures.

Risk assessment and additional control measures for an example water system

	Hazard 1	Hazard 2	Hazard 3
Hazard or hazardous event	Lead pipe	Leaking pipe	Temperature loss from heater to shower; maximum water temperature at shower at 48 °C
Hazard type	Chemical contamination by lead	Chemical and microbial contamination	Microbial growth (Legionella)
Current control measure	None	None	Thermostatically controlled water heating
Basis for risk assessment	Daily consumption of lead-contaminated water at the taps in the bathrooms and in the small kitchen by children is likely	A breakdown of the water supply is not considered likely in the near future	It is very likely that there are long stagnation periods of the warm water supplying the showers. Temperatures below 60 °C will occur, and the potential for the growth of Legionella is high. Also, elevated temperatures in cold-water pipes are likely. These could support growth of Legionella.
Risk	**Major**	**Low–minor**	**Major**
Further investigations	Water analysis for lead	Check integrity of distribution system Check material compatibility Check corrosion	Temperature profiling of the system Check water heaters Check water system usage Water analysis for Legionella

Box 4.9 Example of a risk assessment *continued*

Risk	Major	Low–minor	Major
New or modified control measures	Short term: • Provide information to the teachers and pupils that water can only be drunk at certain taps • Label the taps that deliver lead-contaminated water Long term: • Replace all lead pipes	Replace with appropriate material	Short term: • Close showers Long term: • Install a warm-water circulation system, proper thermal insulation of warm-water and cold-water pipes

4.8 Control measures

Control measures are barriers to risks. They need to be identified and implemented for hazards identified as a significant priority. In the context of a WSP, control measures are defined as those steps in drinking-water supply that directly affect drinking-water quality, either by preventing the occurrence of significant hazards or by inactivating, removing or reducing them to acceptable levels.

Control measures can include a wide range of activities and processes. They can be:

- preventive (and be incorporated in design, planning, construction and commissioning)
- treatment (e.g filtration, disinfection, softeners)
- technical (e.g. temperature control, maintenance procedures)
- behavioural (e.g. measures that influence how water is used).

Control measures must be defined specifically and precisely for all significant risks, and adapted to the local conditions. They should never be imprecise or vague.

While the type and number of control measures will vary for each supply system, their collective implementation and maintenance is essential to ensure that water quality is controlled effectively.

Adequate control measures may already be established in many buildings. However, after reviewing their effectiveness in the course of system assessment, additional measures may need to be identified or existing measures may need to be modified. Improvement plans should be designed to deal with significant risks. Optimum solutions may not be economically, technically or socially feasible in the short term, and improvement plans may need to set short-, medium- and long-term goals.

Table 4.4 (at the end of this section) provides examples of control measures. Some of the control measures are applied during design and installation, while others involve a range of practical measures, including flushing, cleaning, disinfection and other routine maintenance procedures. Simple systems will require fewer control measures than more complex systems in large buildings.

While control measures are directed at ensuring water quality, there may also be preventive actions and responses applied to maintain constancy of supply. These could include installation of sufficient buffering storage tanks or identification of alternative sources of water. Examples are included in Table 4.4.

4.8.1 Validation

All control measures should be validated to ensure effectiveness. Validation is the process of obtaining evidence that control measures are effective and achieve the required results. Validation can take the form of intensive monitoring during commissioning or initial implementation of a new or modified control. Alternatively, validation can take the form of assessing technical data from published studies or data provided by manufacturers (preferably confirmed by independent certification). This is a common approach used in assessing treatment processes. Validation can also be informed by successful implementation in other buildings.

Validation will typically only apply under certain conditions and these will typically be defined by operational limits. For example, chlorination could be validated (confirmed) as being effective if a minimum chlorine residual of 0.5 mg/l is achieved. In this case, 0.5 mg/l is used as a lower limit in operational monitoring (see section 4.9).

4.8.2 Ingress of contamination

Microbial contamination

Control measures to reduce ingress of microbial contamination from water sources can include water treatment at the PoE. This is particularly important where the quality of the source water cannot be guaranteed or where improved quality water is required—for example, in health-care facilities that accommodate patients with increased risk of infection.

Water treatment can be used:

- at PoE to
  - supplement treatment applied by the drinking-water provider
  - improve untreated building-specific water supplies or supplementary sources of water (e.g. rainwater);
- before devices such as hot-water systems or specialized equipment to improve water quality;
- at PoU (e.g. carbon filters, membrane filters).

Common forms of treatment include filtration, disinfection, softeners and carbon filters. Selection of PoE devices will be based on the nature of the source water (surface water, groundwater, rainwater, etc.), susceptibility to contamination (e.g. by human and livestock waste), the intended use of the water and the vulnerability of users.

Within buildings, control measures include ensuring the physical separation of systems transporting different qualities of water (e.g. drinking-water from sewage). These systems should be clearly marked to ensure that the possibility of inadvertent cross-connections is minimized during maintenance, repairs and renovations. Where systems and devices are connected to drinking-water systems (e.g. firefighting supplies, cooling towers), backflow devices need to be installed to prevent ingress of contaminated water. Many countries have technical guides on how this should be achieved.

Where possible, positive pressure should be maintained to reduce the likelihood of ingress of external contamination. Pressure fluctuations should be minimized for the same reason.

Chemical and physical contamination

Control measures to ensure the physical and chemical quality of water entering buildings can include treatment at PoE. This could apply to either public or building-specific water supplies. The selection of appropriate solutions will depend on the nature of the chemical contamination. Selection of PoE devices should be based on expert advice.

Common forms of treatment include water softeners, deionizers, activated carbon and filtration.

Microbial growth and biofilms

Pathogen-control strategies inside buildings should prevent the development of conditions that can foster growth of hazardous environmental pathogens, such as *Legionella* and *Pseudomonas aeruginosa*.

Control measures should focus on good design principles and temperature management, and limit the development of biofilms. Systems should be designed and operated to maximize circulation and flows (avoiding stagnation, low flows, long branch pipes and dead ends, poor distribution of flow among branch pipes, etc.). Water temperatures should be kept below 20 °C in cold-water systems and above 50 °C in hot-water systems. Pipes carrying hot water should be insulated, while cold-water systems should be protected from heat sources. Ideally, hot water should be stored at above 60 °C and circulated at 50 °C or higher. In tropical and hot climates, keeping cold-water systems below 20 ºC during summer months is difficult. In these cases, using alternative controls (e.g. reducing stagnation, low flows and other risk factors) will have a higher priority.

Temperature reduction to reduce the risk of scalding in hot-water systems (e.g. by using thermostatic mixing valves) should be applied as close as possible to PoU. Distribution systems that incorporate multiple loops should be designed to ensure that flow rates can be equilibrated among the various loops. The capacity to disinfect hot-water systems using elevated temperatures or chemical processes should be considered. If PoE disinfection is installed to reduce the risk of microbial growth, it should be maintained and monitored to ensure effectiveness.

Additional safety measures may be applied in buildings or parts of buildings used by higher risk populations. This could include PoU devices (e.g. filters or ultraviolet disinfection units) installed on showers and taps. Effectiveness of these devices has been demonstrated in high-risk areas of health-care facilities, such as intensive-care units, for control of *Legionella* and *Pseudomonas* (Exner et al., 2005; Trautmann et al., 2008). Use of these devices should also be considered as a general measure where there are concerns about the quality of water entering buildings. Installation should be accompanied by ongoing maintenance and replacement programmes. Poorly maintained devices will not perform effectively and may support growth of biofilms.

4.8.3 Materials and equipment

Degradation, corrosion and scaling

The aim is to minimize corrosion and hence control the release of chemical hazards and extend the life of pipework and associated equipment. In many countries, water suppliers are required to provide water that is not aggressive (likely to cause corrosion in internal plumbing systems). However, this is not always the case, and building owners may need to implement control measures.

Corrosion can be controlled by:

- selection of suitable materials (i.e. not only more “resistant” material but also a better quality of the same material);
- minimizing water stagnation;
- preventing galvanic corrosion by avoiding contact between different metals;
- preventing bacterial regrowth (biofilm formation);
- treating water (e.g. removing corrosive ions such as chloride);
- adding corrosion inhibitors (e.g. polyphosphates, sodium silicates);
- encouraging corrosion “competition” with cathodic protection (e.g. using sacrificial galvanic anodes that dissolve instead of the piping material, or using inert electrodes powered by an external source of direct current in water-storage tanks).

Water with high levels of hardness can cause increased scaling. Increased temperature can exacerbate scaling, and hot-water devices and heating elements are particularly susceptible. A common control measure to reduce scaling is installation of water softener to reduce hardness.

4.8.4 Specific uses and water-using devices

Risks associated with specific uses (e.g. medical, dental) and water-using devices can be controlled by measures directed towards reducing contamination and preventing direct exposure to contaminated water or aerosols. Where devices are connected to drinking-water systems, the ingress of contamination to the main supply should be prevented by installing appropriate backflow-prevention devices.

All devices need to be maintained to minimize microbial growth and biofilm formation. Control measures for these types of devices should be based on regular cleaning, flushing of piping and tubing, and disinfection. Where devices produce sprays, possible exposure to fine aerosols should be minimized. This can be achieved by reducing release from devices such as cooling towers (e.g. by installing drift eliminators) or, where possible, reducing public exposure by operating systems outside opening hours (e.g. irrigation systems in garden centres).

Many countries have regulations and standards that apply to water-using devices. These regulations and standards can include general requirements such as requiring installation of backflow prevention on equipment connected to drinking-water supplies. Regulations may also specify application of control measures, including water treatment, disinfection and regular cleaning for specific devices such as cooling towers, swimming pools, hot-tub pools and hot-tub baths. Further information on control measures for these devices can be found in *Guidelines for safe recreational water environments volume 2: swimming pools and similar environments* (WHO, 2006a) and *Legionella and the prevention of legionellosis* (Bartram et al., 2007).

4.8.5 Management, maintenance and repair

Water treatment devices at PoE and PoU and water-using devices should be cleaned regularly to minimize microbial growth and corrosion (softeners and carbon filters may be colonized if not adequately maintained). Water-using devices should be decommissioned when not in use, and drained where possible. Water-using devices such as cooling towers and evaporative condensers will often require cleaning and decontamination before being returned to service. Devices such as drinking-water fountains should be flushed following periods of non-use (e.g. school holidays).

4.8.6 Construction and renovation

In new buildings and upgraded parts of buildings, appropriate planning, construction and commissioning provides the first opportunity to apply control measures for preventing hazards and minimizing risks.

Planning

Initial planning of new buildings and upgrades for existing buildings often give little attention to water quality and hygiene issues. Functional and aesthetic features of a new building are generally given higher priority. Planning and designing safe water systems normally has to adapt to a physical framework that is already set. Planning of water systems is commonly left to subcontractors or subordinates in teams of designers. If not integrated in early stages of planning, there can be major consequences for the functionality and safety of water distribution within the building. Malfunction of water installations and subsequent retrofitting and remedial action can be very expensive and can interrupt construction or commissioning. Therefore, it is important to include specialists for water utility planning as soon as possible.

Definitions of water usage in new buildings are often imprecise, particularly in multipurpose buildings. This can be exacerbated where the intended uses of a new building are not known or are subject to substantial changes during the planning phase. Owners may not have decided where to put certain devices and end-of-use equipment, and can often be unaware of consequences and associated risks. Calculations of water usage and appropriate dimensions of the water distribution system are essential to ensure that systems are designed with appropriate capacities. This involves consideration of how the system and any associated equipment are to be used (e.g. numbers of users, frequency). Both over- and under-estimation of water capacity can compromise safety. As much detail as possible about projected water use and equipment requirements must be obtained from owners or intended users of buildings. Dual plumbing systems incorporating recycled water for toilet flushing and other non-drinking uses are becoming more popular. Installation of these systems will reduce water usage through drinking-water systems, and unless this taken into account it will lead to over-capacity and increased risks of stagnation.

In some cases, building owners are not the users or managers of buildings. For example, hotel buildings are quite often built and owned by companies other than those responsible for operating and managing the hotel. Early consultation between the various parties, including documentation of water-installation issues, is recommended to prevent the need for modifications during commissioning.

It may help to learn from existing buildings and transfer this experience to new, comparable projects. In most cases, pre-existing examples of safe water distribution systems are available. Dealing directly with manufacturers and providers of equipment (e.g. dimensions for water boilers or tanks) is useful, but design engineers may be a better source of information, because water hygiene depends on the whole system, rather than on individual components.

Construction phase

The initial plan for water distribution facilities should be followed wherever practical. If changes are made, they need to be incorporated into an amended plan; this includes changes to materials or dimensions of pipework and equipment. It is not appropriate to use working sketches from the planning office that do not reflect the actual installation.

Risks of biofilm formation or corrosion can be reduced by using only materials that are certified for use with drinking-water. Using incorrect or inferior—and possibly cheaper—alternatives will generally incur high costs for subsequent corrective measures.

Special care must be taken with procedures that are known to be crucial for system performance. It is essential that only water of drinking quality comes in contact with fittings and materials, even during construction. Alternatively, measures should be taken to ensure that the dead water is completely removed and the new fittings are flushed before being commissioned.

Pressure tests for distribution systems can be critical. Sometimes, water of lower quality is used for this purpose. While draining, flushing and high-dose chlorination can reduce risks from contamination, they may not always be completely successful. The pressure test should be used (with air, oil-free gas or drinking-water) to avoid this risk of residual contamination. If lower quality water is used, the system must be thoroughly drained and disinfected afterwards.

Timing also needs to be considered. Construction of a large building is often done in several phases. It is important to keep all finished parts of the water installation dry until the whole system is commissioned for routine operation. Introducing water into the system too early (e.g. weeks or months before a system becomes fully operational) can cause long-term problems. Retained water will become stagnant and support growth of biofilms, which are difficult to remove. Wherever possible, water should only be added to the system as a final step before it becomes operational. If this is not possible, sections that remain stagnant for extended periods should be thoroughly drained and disinfected before the system is commissioned.

4.9 Operational monitoring of control measures

A key requirement in identifying control measures is that performance can be monitored. Thus, operational monitoring procedures need to be established for each newly identified or existing control measure. Operational monitoring is used to assess the performance of individual control measures to ensure that they are working effectively, as designed. Monitoring frequencies should be selected to ensure that corrective actions can be introduced in a timely fashion to prevent loss of control and development of hazardous situations.

WSPs should incorporate a monitoring plan to answer the following questions:

- What will be monitored?
- How will it be monitored?
- Where will it be monitored?
- When and how often will it be monitored?
- Who will do the monitoring?
- Who will receive the results for analysis and, where necessary, ensure appropriate remedial responses are implemented?

Operational monitoring does not necessarily involve complex and time-consuming microbial or chemical tests. It rather takes the form of a planned sequence of inspections of observable features. As summarized in Table 4.4, many of the operational monitoring requirements involve regular inspection (e.g. checking structural integrity of storage tanks) or auditing of maintenance procedures (e.g. checking that PoU devices have been maintained according to manufacturers' instructions). Operational monitoring can include relatively simple field measurements, such as monitoring for turbidity, the appearance of the water, temperature and chlorine residuals. The general principle is that frequent performance of quick field tests is preferable to infrequent and expensive laboratory-based testing. Poor performance of hot-water systems can be detected more quickly and on an ongoing basis through monitoring of water temperatures, rather than by testing for pathogens such as *Legionella, Pseudomonas* or mycobacteria.

For each control measure, operational limits defining acceptable performance need to be identified and applied to operational monitoring parameters. These limits are typically identified during validation of control measures and can take the form of upper or lower limits or tolerance ranges. For example, this could include identifying a minimum temperature of 50 °C for hot-water systems and a maximum temperature of 20 °C for cold-water systems to prevent the growth of environmental pathogens, such as *Legionella*. Control measures are considered to be effective if monitoring results comply with the limits. If these limits are not met, corrective actions need to be taken immediately to bring the measure back under control. Corrective actions must be specific and predetermined, where possible, to enable rapid implementation. For hot-water systems, this includes identified actions to ensure that temperatures above 50 °C are restored and maintained. In some cases, it can be useful to set preliminary targets that provide an early warning if control measures are not be performing as well as possible. If these targets are not met, corrective actions can be implemented before control is lost. For example, if the low temperature limit in a hot-water loop is 50 °C, a preliminary target at which action is initiated could be 53 °C.

4.10 Management procedures and corrective responses

All aspects of WSPs need to be documented in a management plan. This includes system mapping, hazard identification, risk assessment, identification of control measures, monitoring programmes, corrective actions, improvement plans and communication strategies. Much of the management plan will describe monitoring and maintenance procedures that will be routinely followed on a day-to-day basis during normal performance. Many of these procedures will relate to sensible and practical measures to maintain cleanliness, hygiene, integrity and performance of systems. The key is to ensure that procedures are precisely described, with clear directions on what needs to be done and who will do it. However, documentation should also include corrective actions and response to incidents and failures. Many potential incidents are predictable (e.g. ingress of contamination, microbial growth and biofilms), and specific responses can be identified. A procedure also needs to be developed to deal with unpredictable events. This should take the form of an incident-response plan dealing with general principles, including responsibilities and communication requirements.

4.10.1 Ingress of contamination from external water sources

Chemical and microbial contamination may enter the distribution system of the buildings from external water supplies. If contamination is detected in a public water supply, advice should be provided to building owners or managers by the water supplier. This should include advice on recommendations for users of the water, alternative sources, responses implemented by the water utility, and estimated time frames for return to normal operation.

Depending on the contamination and potential impacts, the following measures could be considered for building water supplies:

- **Prevent the consumption of contaminated water.**
  - Provide advice to all users of the building that water from the building system should not be consumed. Label taps and outlets with appropriate advice.
  - Consider the need to provide bottled, packaged or tankered water to the building users. The building owner should ensure that the alternative source of water is safe and, if tankers are used, that they are suitable for delivering safe drinking-water.
  - Switch to an uncontaminated source of water to the building, if possible.
  - Use mobile treatment units (e.g. temporary chlorinators) to produce safe drinking-water, if contamination is likely to persist for an extended time. Monitor the operation of treatment devices to ensure that they produce safe drinking-water.
- **Disinfect the system.**
  - If microbially unsafe water is or was supplied to the building, it will be necessary to disinfect and flush the whole water system. This process should be monitored by on-line and field measurement of disinfectant concentrations at outlets throughout the building. The effect of the disinfection should be verified by microbiological analysis.
- **Flush the system.**
  - If chemically contaminated water is or was supplied to the building, it will be necessary to flush the whole water system. The effect of flushing should be verified by chemical analysis.

4.10.2 Ingress of contamination from building systems

If ingress of contamination in the building is identified, the source must be eliminated. Other corrective actions and responses could include the following:

- **Prevent the consumption of contaminated water.**
  - Issue advice to all users of the building or users of mains water in the affected section of the building that the water supply should not be consumed. Label taps and outlets with appropriate advice.
  - Consider the need to provide bottled, packaged or tankered water to building users while remedial action is taken. The building owner should ensure that the alternative source of water is safe and, if tankers are used, that they are suitable for delivering drinking-water.
- **Disinfect the system.**
  - In the event of microbial contamination, it will be necessary to disinfect and flush the whole water system or the affected sections of the system, depending on the type and extent of the contamination. This process should be monitored by on-line and field measurement of disinfectant concentrations at outlets throughout the building. The effect of disinfection should be verified by microbiological analysis.
- **Flush the system.**
  - In the event of chemical contamination, it will be necessary to flush the whole water system or the affected sections of the system. The effect of flushing should be verified by chemical analysis.

Failure of point of entry

PoE treatment devices need to be monitored to ensure that they function effectively. Non-compliance with critical limits should lead to an immediate assessment of impacts and remedial action. Further actions will depend on the nature and significance of the treatment (e.g. disinfection of a building-specific water supply compared with secondary disinfection of a treated external water supply).

Where PoE treatment is required to produce safe drinking-water from unsafe private or public supplies, responses and actions could be similar to those applied to contaminated external supplies. If the PoE treatment (e.g. water softeners) improves water quality but is not critical for safety or the performance of other control measures, the responses will not be as substantial and warnings about consuming the water will not be required.

4.10.3 Microbial growth and biofilms

If impacts from microbial growth are detected (e.g. discoloured water, odours, off-tastes, and slimes and sludges in water-using devices), it is likely that water systems will require disinfection and flushing. Hot-water systems can be “pasteurized” by flushing with water at temperatures greater than 60 °C (preferably greater than 70 °C). Users should be notified when disinfection or “pasteurization” is implemented. Water hotter than 60 °C can cause severe scalding, while water containing high levels of disinfectants can have objectionable tastes and odours for some users. Water-using devices will also require cleaning and disinfection.

The source of microbial growth should be examined. For example, the performance of treatment used in water-using devices should be checked. Where water temperatures are too high in cold-water systems or too low in hot-water systems, the cause should be investigated and corrected. This could include examining separation of systems, insulation, temperatures produced by water heaters, location and performance of thermostatic mixing valves, and flow rates in all branches—particularly in return mains.

The operation of the system should be checked to determine whether usage patterns have changed and whether areas of water stagnation have been introduced.

4.10.4 Release of hazards from materials and equipment

Improvement programmes should be established to reduce or stop the release of hazards by replacing the responsible components within the distribution system. Where this involves large amounts of pipework and fittings, this may need to be a staged process. For example, if there are large numbers of lead-based pipes (in some cases, most pipes in a building could contain lead), it is often impractical to replace it all at once. Depending on the extent and significance of contamination and potential impacts, the following measures should be considered:

- **Prevent the consumption of contaminated water where the water is considered unsafe.**
  - Issue advice to all users of the building or users of mains water in the affected section of the building that the water supply should not be consumed. Label taps and outlets with appropriate advice.
  - Consider the need to provide bottled, packaged or tankered water to the users of the building while remedial action is taken. The building owner should ensure that the alternative source of water is safe.
- **Flush the system.**
  - It may be necessary to flush the whole water system or the affected sections of the system. It may be appropriate to implement regular flushing programmes (e.g. for lead contamination; USEPA, 2002; Ontario Ministry of the Environment, 2010). The effect of flushing should be verified by chemical analysis.
- **Prevent corrosion.**
  - Corrosion can lead to chemical contamination. If the contamination includes hazardous chemicals, then similar management procedures applied to ingress of chemical contamination (see above) should be considered. Corrosion can affect the taste and appearance of water. If this occurs, building water supplies should be flushed to reduce concentrations of corrosion products.
  - Corrosion can also lead to faults that allow microbial contamination. Faults should be immediately repaired following standard maintenance procedures. This should include flushing and disinfection of affected parts of distribution systems.

4.10.5 Specific uses and water-using devices

Corrective actions and responses associated with incidents and failures detected in water for specific uses normally focus on taking remedial action and preventing exposure.

Where faults and contamination are detected, a standard response is to stop use or operation of the device until remedial action has been taken. Procedures describing when and how to shut down devices, and how to clean and decontaminate them, should be documented and made available. These procedures should include monitoring requirements that must be met before devices are returned to service.

Advice should be issued to users of the building or users of specialized equipment when the devices are not available. Devices should be labelled with appropriate advice.

Where water is used for specific medical or dental procedures, alternative sources may be required. Procedures should be established to ensure that alternatives are available.

Box 4.10 provides a case study of *Legionella* infection from a private hot tub.

Box 4.10 *Legionella* infections from a private whirlpool (hot tub) in Sweden

In mid-February, a middle-aged Swedish man fell severely ill with legionellosis. The cultivation of his sputum sample showed growth of *Legionella bozemanii*, an unusual species in Sweden.

Since the patient had not recently travelled abroad, an investigation to find the source of infection was initiated by the department of communicable disease control and prevention in Stockholm County. The man was staying at his summer cottage during the incubation time. The water supply to his cottage was delivered through a long pipe via his neighbour's property. Water in the pipe was suspected to be the source of infection, and so the water was sampled and analysed for the presence of *Legionella*, but none was detected. On further questioning, the patient recalled that he had visited a friend and they had bathed in the friend's whirlpool bath.

The owner of the whirlpool was contacted and was found to be suffering from protracted symptoms of a respiratory tract infection. He had taken a course of penicillin for about two months, with no effect on his symptoms. Serological results later showed raised titres of antibodies to *Legionella bozemanii*.

At the end of April, samples were taken from the whirlpool, and very high concentrations of *Legionella bozemanii/anisa* were detected in the whirlpool water (3 600 000 cfu/l). The bacteriological analysis also showed high numbers of *Pseudomonas aeruginosa* and very high numbers of heterotrophic bacteria (>30 000 cfu/ml). These results indicated that the whirlpool had not been maintained correctly.

The owner of the whirlpool stated that he had maintained the whirlpool according to the manufacturer's maintenance instructions, although he had changed the filter more often than was recommended. The whirlpool has a volume of about 3 m^3; the owner changed the water every second week, and added chlorine (manually) as a disinfectant. The owner of the whirlpool contacted people who had visited him previously and had bathed in the whirlpool. He reported that about 40 people had developed mild respiratory symptoms after their visit.

The growth of the unusual *Legionella bozemanii/anisa* may have been due to the fact that the water used in the household was a mixture of well water and water from a nearby lake. Outbreaks caused by whirlpools distributing *Legionella* are becoming more frequent. Outbreaks of Pontiac fever with high attack rate are more common, but legionellosis outbreaks also occur.

Whirlpools are commonly installed in public places such as hotels, gyms or hot tubs, and poor maintenance of whirlpools is common. This was the first time that a private whirlpool had been found to be the vehicle of legionellosis in Sweden, but it is likely that the number of people contracting an infection with milder symptoms from their private whirlpools is underestimated.

Guidelines have been produced for hotels and public places to help reduce the risk of whirlpools becoming sources of *Legionella*.

Source: de Jong et al. (2004).

4.10.6 Emergencies affecting external supplies

The quality of alternative water supplies provided in emergencies should be verified. Where treatment of these supplies is implemented, operational procedures and monitoring will be required to ensure that acceptable performance is achieved.

As part of remediation following a contamination event, the entire distribution system, including water-using devices, PoU and end-of-pipe devices will need to be flushed and possibly disinfected or decontaminated. Treatment systems such as water softeners, deionizers and filtration systems will need to be regenerated, backwashed or recommissioned before being returned to service. Small PoU filters could harbour contamination and may need replacing.

4.11 Management procedures for new buildings or major upgrades

Water systems, particularly in major buildings, tend to be complex in terms of both their geometry and the technical elements being installed. It is challenging to operate such systems correctly. In addition, personnel who will take responsibility for the new building may not have extensive expertise or training.

Thus, commissioning of water systems in buildings can have a critical influence on the quality of water. The design, construction and function of water systems, as well as management procedures, need to be documented by the constructer of the building and by manufacturers of specific devices and specialized equipment installed in buildings. Operating instructions and maintenance plans should be included. The instructions must cover details about the proper operation of the drinking-water supply system and about adequate functional checks. The nature, scope and frequency of inspections should be specified.

For buildings with specific requirements and potentially vulnerable users (e.g. hospitals, residential homes for the elderly, nursery schools), a specific hygiene plan should be established in cooperation with a hospital hygienist, the responsible public health authority and, if necessary, the water supplier.

A complete documentation folder of management plans and procedures should contain detailed plans of the system and technical fact sheets for all installed components (e.g. water filters, disinfection systems, drinking-water heaters), water-using devices (e.g. cooling towers) and specialized equipment (e.g. medical equipment, dental chairs).

Commissioning should incorporate a management and instruction protocol, which must be signed by both parties (manufacturer and operator of the system). There must also be an appropriate handover process to ensure that the building manager or operator is aware of all features and technical specifications of water systems, devices and associated equipment in the building. The responsible operator has to be informed about reporting requirements, legal obligations, codes of practice, national standards, technical rules and training requirements. Hygiene training may be required.

At the time of commissioning, water quality should be documented by hygienic testing of microbial and chemical quality in an adequate set of drinking-water samples. Initial higher intensity monitoring (additional samples and parameters) might be necessary, depending on intended use of the facility, outcomes of inspection, any irregularities during construction or commissioning, and delays in beginning of regular use (see section 4.8.5). In these cases, a water-quality expert should be consulted.

4.12 Verification

Verification is required to provide reassurance that WSPs are effective and water systems as a whole operate safely. Verification typically includes two components:

- testing water quality
- auditing WSPs.

4.12.1 Water-quality testing

The extent of water-quality testing will be influenced by the size and characteristics of the building, and the reliability and quality of the external water supply. In most buildings that have reliable, high-quality water supplies, there will be limited requirements for independent verification. Part of the responsibilities of the water utility is to ensure that the chemical and microbiological quality of water delivered to buildings is safe. The water utility should provide results on request.

Testing of water-quality safety in buildings is generally only required where:

- additional building-specific sources of water are used to augment the external supply;
- the building has specific purposes that increase potential risks (e.g. hospitals and other health-care facilities);
- water-using devices such as cooling towers, swimming pools and hot tubs are installed;
- management actions are established to minimize ongoing sources of contamination (e.g. flushing to deal with lead contamination).

Where additional building-specific sources of water are used, verification should include traditional indicators of faecal contamination, such as *E. coli*, and chemical parameters. The range of chemical parameters and frequency of testing will depend on the source of the water supply. Guidance on verification of microbial and chemical quality is provided in the GDWQ (WHO, 2008). In health-care buildings, particularly those incorporating intensive-care units, verification may include testing for specific microorganisms such as *Legionella* in hot-water systems. Further guidance is provided in *Legionella and the control of legionellosis* (Bartram et al., 2007). Verification of water quality in water-using devices such as cooling towers and swimming pools may also include testing for specific organisms. Further guidance is provided in *Guidelines for safe recreational water environments volume 2: swimming pools and similar environment* (WHO, 2006b). In some countries, verification of water-using devices may be a regulatory requirement.

The quality of water allocated to specific uses may also need to be verified. The parameters included in monitoring will depend on the specific requirements of the end use.

4.12.2 Water safety plan audits

Verification should include audits of WSPs to demonstrate that the plans have been properly designed, are being implemented correctly and are effective. As described in the GDWQ (WHO, 2008), factors to consider include:

- all significant hazards and hazardous events have been identified
- appropriate control measures have been included

- appropriate operational monitoring procedures have been established
- appropriate operational limits have been defined
- corrective actions have been identified
- appropriate verification monitoring procedures have been established.

Audits should be included in internal reviews by building managers. Audits by independent experts should also be considered. Independent audits may be required by regulatory authorities or accreditation agencies for certain types of buildings (e.g. health-care facilities) or where buildings use independent sources of water.

4.13 Supporting programmes

Supporting programmes are activities that support implementation of WSPs and assurance of water quality. Operators, maintenance staff, employees and users of buildings may have limited knowledge of WSP principles, technical aspects and good practice associated with water supplies in buildings. Therefore, an important component is developing training and education programmes for personnel who are involved in activities that influence the delivery of safe water, and personnel for whom it is critical to use water safely (e.g. health-care professionals).

Section 5 provides further information on training.

Codes of good operating practices and hygiene are also important components of supporting programmes. These can be captured in standard operating procedures that include but are not limited to:

- hygienic use of water supplies
- hygienic practices in maintaining water supplies, water-using devices and equipment
- hygienic practices in performing repairs
- calibration of monitoring equipment
- instructions on access to equipment and modification of systems
- training requirements for maintenance staff.

The case study in Box 4.11 describes the response to a hospital water supply after contamination with *Pseudomonas aeruginosa*.

Box 4.11 Contamination of a hospital water supply with *Pseudomonas aeruginosa* in Germany

Pseudomonas aeruginosa in concentrations up to and above 100 organisms per 100 ml were detected in the water supply to a new hospital building in a number of locations and on repeated occasions during 2005–06. The colonization could not be eliminated, despite repeated thermal disinfection and implementation of continuous chlorine dioxide disinfection. As a result, the building was vacated, and an expert consultant was engaged to provide advice.

An ultraviolet plant was installed at the point of entry to the water system. The water system was intensively flushed and decontaminated with higher doses of chlorine dioxide disinfection for three days. This was augmented by intermittent dosing with hydrogen peroxide, as recommended in guidelines of the German Association for Gas and Water. After decontamination, there were only isolated detections of *Pseudomonas* (downstream of the pressure-increasing system).

Further measures included replacing and disinfecting the pressure-increasing system, and placing the ultraviolet plant before the pressure-increasing system.

Following these actions, it was decided to:

- move patients and employees into the building to avoid further stagnation (regular water throughput);
- establish an incident plan;
- continue microbiological testing.

Ongoing testing has shown that the strategy has been successful, with no further contamination. The alternative was to completely replace the water distribution system at a projected cost of approximately €2 million.

Source: Exner, Pleischl & Koch (personal communication, 2007).

4.14 Periodic review

Periodic review is a key requirement of effective WSPs; for example, after every three to five years or after significant changes of the supply system. Periodic review ensures regular updates of system assessment and management procedures, and also allows for the inclusion of incremental improvement strategies in system upgrades.

WSPs can become out of date due to modifications to water systems, changes in water uses, and changes in building ownership or tenancies. Therefore, WSPs should be reviewed whenever substantial changes occur.

Table 4.4 Examples of hazards, hazardous events and responses

Hazards and hazardous events	Control measures	Operational monitoring	Management procedures, protective actions	Supporting programmes
Intermittent supply				
Loss of water supply (isolated event)	• Back up water systems (e.g. alternative supply, standby disinfection facilities) • Ensure carted water is available	• Measure disinfectant residuals (e.g. chlorine concentration), pH • Monitor levels of water in storage tanks • Monitor integrity of storage	• Develop contingency plans to deal with emergencies • Establish procedures for activating back-up systems • Establish procedures before resuming the water supply or use	• Inform building occupants or users on what to do during interruption • Communication protocol with water utility • Train operational and maintenance staff in use of back-up systems
Intermittent supply (regular event)	• Back up water systems (e.g. alternative supply, standby disinfection facilities) • Ensure carted water is available • Provide large storages for supply during interruptions	• Monitor water pressure or water availability • Record times of water availability and water usage • Measure disinfectant residuals (e.g. chlorine concentration), pH • Monitor levels of water in storage tanks • Monitor integrity of storage	• Establish procedures for activating back-up systems • Establish procedure before resuming the water supply or use	• Inform building occupants or users on what to do during interruptions • Discuss the communication protocol with water utility • Train operational and maintenance staff in use of back-up systems

Table 4.4 Examples of hazards, hazardous events and responses *continued*

Hazards and hazardous events	Control measures	Operational monitoring	Management procedures, protective actions	Supporting programmes
Contamination of external supply entering the building				
Poor microbial quality (long term)	• Install PoE treatment systems (e.g. filtration and disinfection) • Install PoU devices (e.g. filtration) • Back up systems (alternative supply, standby disinfection facilities) • Ensure carted water, packaged water or bottled water supplies are available • Issue advice to boil water • Isolate building from external supply	• Measure disinfectant residuals (e.g. chlorine concentration), pH • Monitor turbidity if PoE treatment includes filtration • Monitor performance of PoU devices and equipment • Monitor use of carted or bottled water • Ensure water is boiled before use • Monitor cross-connection control preventing ingress of external supply	• Develop procedures for operating PoE systems and treating back-up supplies • Develop procedures for maintaining PoU devices (these should be consistent with manufacturers' instructions) • Identify sources of bottled, packaged or tankered water supplies • Restore disinfection • Restore filtration if provided • Monitor water quality (verification)	• Develop communication procedures for informing building occupants or users • Discuss communication protocol with water utility • Establish contracts with bottled, packaged or tankered water suppliers • Train operational and maintenance staff in use of back-up systems
Poor chemical quality (long term)	• Install PoE treatment systems (e.g. deionizers, softeners, activated carbon) • Install PoU devices (e.g. filtration) • Provide an alternative supply • Ensure carted water, packaged water or bottled water supplies are available • Isolate building from external supply	• Monitor operation of PoE treatment • Monitor performance of PoU devices and equipment • Monitor treatment of back-up supply • Monitor use of carted or bottled water • Monitor cross-connection control preventing ingress of external supply	• Develop procedures for operating PoE systems and treating back-up supplies • Develop procedures for maintaining PoU devices (these should be consistent with manufacturers' instructions) • Monitor water quality (verification)	• Train operational and maintenance staff in use of back-up systems

Table 4.4 Examples of hazards, hazardous events and responses *continued*

Hazards and hazardous events	Control measures	Operational monitoring	Management procedures, protective actions	Supporting programmes
Contamination of external supply entering the building *continued*				
Poor microbial quality (short term) (e.g. treatment failure, pipe breakage, natural disasters)	• Back up systems (alternative supply, standby disinfection facilities) • Ensure carted water, packaged water or bottled water supplies are available • Issue advice to boil water	• Measure disinfectant residuals (e.g. chlorine concentration), pH • Monitor appearance (turbidity, colour) and odour of water • Monitor use of carted or bottled water • Ensure water is boiled before use	• Develop contingency plans to deal with emergencies • Provide alternative sources of water (bottled, packaged water or tankered supplies) • Issue advice to boil water • Liaise with water utility on repair of external system • Develop a procedure for flushing and disinfecting internal supply when the water quality of external supply is restored • Verify water quality after normal supply is restored	• Communicate with water utility, including about incident protocol • Establish communication procedures for informing building occupants or users during incident and recovery • Develop a communication protocol with water utility • Train operational and maintenance staff in use of back-up systems
Poor chemical quality (short term) (e.g. treatment failure, pipe breakage, natural disasters)	• Back up water systems (e.g. alternative supply, with standby disinfection facilities) • Ensure that carted water, packaged water or bottled water supplies are available	• Monitor appearance (turbidity, colour) and odour of water	• Develop contingency plans to deal with emergencies • Provide alternative sources of water (bottled, packaged water or tankered supplies) • Activate back-up systems • Develop a procedure for flushing the system when the water quality of external supply is restored • Verify water quality after normal supply is restored	• Establish communication with water utility, including incident protocol • Develop communication procedures for informing building occupants or users during incident and recovery • Develop a communication protocol with water utility • Train operational and maintenance staff in use of back-up systems

Table 4.4 Examples of hazards, hazardous events and responses *continued*

Hazards and hazardous events	Control measures	Operational monitoring	Management procedures, protective actions	Supporting programmes
Contamination of internal supply				
Pipe breaks or entry of contamination into storage tanks	• Regularly inspect systems, including water-storage tanks • Minimize pressure fluctuations • Ensure that the water distribution system is designed properly • Install pressure-reducing valves	• Monitor water pressure • Check turbidity, signs of corrosion or unusual taste	• Develop procedures for repairing or replacing broken pipes • Develop a procedure for disinfecting and flushing affected areas • Develop a procedure for inspecting, repairing and disinfecting storage • Identify sources of bottled or packaged water, or tankered supplies	• Develop procedures for building occupants or users to report loss of supply or changes in appearance, taste and odours • Use materials and pipes that are certified as being suitable • Train operational and maintenance staff on selection of materials and procedures for repairing faults
Cross-connection of different water qualities (chemical or microbial contamination)	• Physically separate and label water systems delivering different water types or removing sewage/greywater • Minimize accidental or unintended cross-connections and provide backflow prevention where required • Maintain positive pressure in the distribution system	• Monitor integrity of system separation and inspect system labelling • Monitor operation of backflow-prevention devices	• Develop procedures for installing or replacing pipework and fittings • Remove unintended cross-connections. • Develop a procedure for disinfecting and flushing affected areas	• Develop communication procedures for informing building occupants or users • Provide instructions for maintenance staff and plumbers or fitters installing new or replacement pipework and equipment
Connection with PoU devices and equipment	• Install appropriate backflow-protection systems • Prevent huge pressure variation in pipe network • Maintain continuous pressure	• Monitor performance of PoU devices and equipment • Monitor operation of backflow-prevention devices	• Develop procedures for installing and connecting devices and equipment to distribution systems	• Provide instructions for people who install equipment • Follow plumbers' codes of practice

Table 4.4 Examples of hazards, hazardous events and responses *continued*

Hazards and hazardous events	Control measures	Operational monitoring	Management procedures, protective actions	Supporting programmes
Contamination of internal supply *continued*				
Poor maintenance of equipment and PoU devices, leading to microbial growth or corrosion	• Monitor performance of equipment and PoU devices • Ensure that the system is maintained in accordance with manufacturers' instructions • Install appropriate backflow-protection systems	• Monitor performance of PoU devices and equipment • Monitor appearance of water for signs of growth (discolouration, turbidity, odours) or corrosion	• Develop procedures for maintaining devices (consistent with manufacturers' instructions)	• Train maintenance staff
Backflow from chemical storages Inadequate backflow prevention on equipment	• Minimize connections and provide backflow prevention where required	• Monitor operation of backflow-prevention devices • Monitor use of chemicals	• Develop procedures for installing and connecting storages to distribution systems	• Provide instructions for people who install chemical storages • Follow plumbers' codes of practice

Table 4.4 Examples of hazards, hazardous events and responses *continued*

Hazards and hazardous events	Control measures	Operational monitoring	Management procedures, protective actions	Supporting programmes
Sewerage or septic systems				
Aerosol contamination	• Install water traps in sewage lines • Filter double traps in high-risk environments • Prevent contamination from septic tanks	• Monitor integrity of system separation	• Develop procedures for installation during construction and upgrades	• Follow plumbers' codes of practice
Cross-connection with drinking-water system	• Ensure separation from water systems and appropriate labelling and marking of pipework and fittings	• Monitor separation of system	• Develop procedures for installation during construction and upgrades • Remove unintended cross-connections. • Develop a procedure for disinfecting and flushing affected areas • Identify sources of bottled or packaged water, or tankered supplies	• Follow plumbers' codes of practice
PoE treatment				
Incorrect operation and interruption to treatment	• Assign staff to perform maintenance • Monitor operation of processes (e.g. that ultraviolet lights and chlorinators are functioning) • Install alarms on key processes • Have a standby generator	• Measure disinfectant residuals (e.g. chlorine concentration), pH • Monitor turbidity if PoE treatment includes filtration	• Develop procedures for operating PoE systems • Restore disinfection • Restore filtration if provided	• Train operational and maintenance staff

Table 4.4 Examples of hazards, hazardous events and responses *continued*

Hazards and hazardous events	Control measures	Operational monitoring	Management procedures, protective actions	Supporting programmes
PoE treatment *continued*				
Inadequate maintenance	• Assign staff to perform maintenance • Ensure processes are maintained according to manufacturers' instructions	• Monitor the effectiveness of maintenance procedures	• Develop maintenance procedures	• Train operational and maintenance staff
Overdosing with treatment chemicals or release of treatment chemicals into distribution systems	• Ensure dosing equipment and storages are maintained • Avoid overdesigning chemical storage capacities • Minimize cross-connections and provide backflow prevention where required	• Monitor use of chemicals	• Develop procedures for operating PoE systems, including calibration of dosing systems • Restore correct doses	• Train operational and maintenance staff
Microbial growth and biosystems				
Complex systems	• Apply additional disinfection at PoE • Sanitize or disinfect hot-water systems regularly • Install PoU devices (e.g. filtration)	• Measure disinfectant residuals (e.g. chlorine concentration), pH, after PoE device, and monitor disinfectant residuals in system • Monitor disinfectant residuals and temperature during sanitization • Monitor performance of PoU devices and equipment	• Restore disinfection • Develop procedures for sanitization and flushing • Develop procedures for maintaining PoU devices (consistent with manufacturers' instructions)	• Develop communication procedures for informing building occupants and users during sanitization • Train operational and maintenance staff in use of PoE treatment and sanitization procedures

Table 4.4 Examples of hazards, hazardous events and responses *continued*

Hazards and hazardous events	Control measures	Operational monitoring	Management procedures, protective actions	Supporting programmes
Microbial growth and biosystems *continued*				
Stagnation and low water flows (cold systems)	• Avoid overdesigning capacities • Remove the causes of fluctuation (e.g. high peak water demand, fire drills) • Prevent negative pressure • Flush systems that are not used frequently • Isolate areas that are not used for extended periods • Remove dead legs and minimize length of branch pipes	• Monitor appearance, taste and odour of water • Monitor use of water throughout the building	• Develop procedures for isolating sections of water systems that are not in use • Develop procedures for sanitization and flushing	• Develop procedures for building occupants or users to report loss of supply or changes in appearance, taste and odours • Train operational and maintenance staff
Stagnation and low water flows (hot systems)	• Avoid overdesigning capacities • Flush systems that are not used frequently • Isolate areas that are not used for extended periods • Remove dead legs and minimize length of branch pipes	• Monitor appearance, taste and odour of water • Monitor temperature • Monitor use of water throughout the building	• Develop procedures for isolating sections of water systems that are not in use • Flush all taps on weekly basis if not being used regularly • Develop procedures for sanitization and flushing	• Develop procedures for building occupants or users to report loss of supply or changes in temperature, appearance, taste and odours • Train operational and maintenance staff
Intermittent/ seasonal use/closed hospital wards	• Isolate areas not in use • Drain system and disinfect on return to service	• Monitor occupancy and use of water throughout the building	• Develop procedures for isolating sections of water systems that are not in use • Develop procedures for returning supply before reopening closed sections • Develop procedures for sanitization and flushing	• Train operational and maintenance staff

Table 4.4 Examples of hazards, hazardous events and responses *continued*

Hazards and hazardous events	Control measures	Operational monitoring	Management procedures, protective actions	Supporting programmes
Microbial growth and biosystems *continued*				
Poor temperature control (cold systems)	• Insulate cold- and hot-water pipes. • Keep systems physically separate	• Monitor temperature	• Investigate and remove sources of elevated temperatures	• Follow plumbers' codes of practice
Low water temperatures in hot-water storage vessels	• Adjust heater temperature • Ensure sufficient energy delivery (e.g. with distant hot-water supply) • Check heater thermostat • Maintain temperatures above 50 °C in distribution system • Maintain temperatures above 60 °C in storage vessels • Install temperature-reduction devices as close as possible to PoU • Insulate system • Avoid stagnation and low flow areas (minimize branch pipes, dead ends, etc.) • Ensure sufficient capacity for maximum flows	• Monitor temperatures in storage vessels, distribution systems and at PoU • Monitor maintenance of temperature-reducing devices	• Develop procedures for operating hot-water systems, including remedial action if temperatures are too low	• Develop procedures for building occupants or users to report low temperatures • Train operational and maintenance staff • Follow plumbers' codes of practice
Inappropriate materials	• Select appropriate materials (where certification schemes have been established, use only authorized materials)	• Check that only authorized materials are used	• Develop procedures for selecting materials • Replace unsuitable materials	• Train operational and maintenance staff on selection of materials • Follow plumbers' codes of practice

Table 4.4 Examples of hazards, hazardous events and responses *continued*

Hazards and hazardous events	Control measures	Operational monitoring	Management procedures, protective actions	Supporting programmes
Microbial growth and biosystems *continued*				
Poorly maintained PoU devices	• Assign staff to perform maintenance • Ensure devices are maintained according to manufacturers' instructions • Check and/or install appropriate backflow-protection systems	• Monitor performance of PoU devices and equipment • Monitor appearance of water for signs of growth (discolouration, turbidity, odours) or corrosion • Monitor production and release of aerosols	• Develop procedures for maintaining devices (consistent with manufacturers' instructions)	• Train maintenance staff
Poor control of looped water supplies	• Check design and operation of pipe loops • Check flow rates in circulated loops, and recalculate equilibrium conditions among loops	• Monitor water pressures and temperatures	• Repair systems so that flows are balanced	• Train operational and maintenance staff
Materials				
Release of organic substances	• Select appropriate materials • Where certification schemes have been established, use only authorized materials	• Check that only authorized materials are used • Where solvents are used during installation, monitor application and curing	• Develop procedures for selecting materials and using solvents • Replace unsuitable materials	• Develop procedures for building occupants or users to report odours • Train operational and maintenance staff on selection and use of materials • Follow plumbers' codes of practice

Table 4.4 Examples of hazards, hazardous events and responses *continued*

Hazards and hazardous events	Control measures	Operational monitoring	Management procedures, protective actions	Supporting programmes
Materials *continued*				
Entry of organic substances through plastic piping	• Select appropriate pipe material, particularly in areas where solvents or hydrocarbons are stored • Avoid inappropriate materials in areas where solvents or hydrocarbons are stored or manipulated	• Check that only authorized materials are used • Monitor chemical storages	• Develop procedures for selecting materials • Replace unsuitable materials • Develop procedures for storing chemicals	• Follow procedures for building occupants or users to report odours and tastes • Train operational and maintenance staff on selection of materials • Follow plumbers' codes of practice
Corrosion and scaling				
Poor installation	• Choose quality materials • Follow national or international choice and construction rules • Use active protection of pipes (e.g. sacrificial anodes, anticorrosion products)	• Check appearance of water (red-brown for rust, blue-green at outlets for copper)	• Develop procedures for installing piping and fittings	• Develop procedures for building occupants or users to report changes in appearance, taste and odours • Follow plumbers' codes of practice
Dissolution or corrosion of metals (from pipework, fittings, drinking-water fountains, etc.)	• Follow correct installation • Select appropriate materials • Avoid interconnection of incompatible metal materials • Use PoE chemical treatments to reduce corrosion • Flush pipework regularly • Flush drinking-water fountains regularly after interruptions to use (weekends, holidays, etc.) • Install PoU devices	• Check appearance of water (red-brown for rust, blue-green at outlets for copper) • Monitor performance of PoE and PoU devices and use of chemicals • Monitor performance of flushing programmes	• Develop procedures for installing piping and fittings • Develop procedures for operating PoE and PoU devices • Develop procedures for implementing flushing programmes	• Train operational and maintenance staff in the operation of PoE and PoU equipment • Follow plumbers' codes of practice

Table 4.4 Examples of hazards, hazardous events and responses *continued*

Hazards and hazardous events	Control measures	Operational monitoring	Management procedures, protective actions	Supporting programmes
Corrosion and scaling *continued*				
Incompatibility with incoming water quality	• Check incoming water quality and recommendations relating to materials used in distribution systems • Install water softeners to reduce water hardness	• Monitor development of scale (particularly on hot-water elements) • Check appearance of water	• Develop a procedure for consulting with water supplier about materials compatible with water quality • Develop procedures for operating PoE devices	• Train operational and maintenance staff in the operation of PoE equipment • Follow plumbers' codes of practice • Follow advice from water utilities on characteristics of external water supply
Specific uses				
Contamination of dental hygienic equipment, dental assembly (water for mouth washing, wash basin, cooling dynamic tools, auxiliary uses)	• Ensure effective disinfection • Allow easy cleaning and disinfection of the assembly and the material in contact with water • Install adequate backflow prevention • Use suitable material in contact with water (no natural rubber, no nickel plating)	• Monitor implementation of disinfection and cleaning • Check operation of backflow prevention	• Document procedures • Repeat cleaning and disinfection if there are doubts about cleanliness	• Train staff to ensure that procedures are understood and applied

Table 4.4 Examples of hazards, hazardous events and responses *continued*

Hazards and hazardous events	Control measures	Operational monitoring	Management procedures, protective actions	Supporting programmes
Specific uses *continued*				
Exposure to aerosols from contaminated cooling towers and evaporative condensers	• Maintain devices (check to see if regulations or standards have been developed) • Maintain cleanliness • Decontaminate regularly (e.g. twice per year) • Decontaminate on return to service • Drain system when not in use • Install biocide dosing • Install drift eliminators • Install outlets away from fresh air inlets to air-conditioning systems	• Monitor cleanliness of devices • Monitor operation of treatment systems (antiscalant, disinfection) • Monitor implementation of maintenance procedures • Inspect and maintain drift eliminators	• Make sure the system is designed according to established standards • Develop procedures for operating and maintaining devices • Develop procedures for cleaning and decontamination • Develop procedures for shut-down and reactivation	• Follow codes of practice for installation, operation and maintenance • Train operational and maintenance staff
Contamination of hot tubs, whirlpools, water display	• Drain and clean regularly • Ensure continuous filtration and disinfection	• Measure disinfectant, pH, turbidity	• Develop procedures for operating and maintaining devices • Develop procedures for cleaning and decontamination	• Follow codes of practice for operation and maintenance • Train operational and maintenance staff
Contamination of respiratory system equipment	• Drain and clean regularly • Disinfect at PoU (ultraviolet radiation) • Ensure backflow prevention is adequate • Wash nebulizers with sterile water and dry thoroughly	• Inspect the system and equipment regularly • Monitor disinfection procedures • Monitor implementation of maintenance procedures	• Develop procedures for operating and maintaining devices • Develop procedures for cleaning and decontamination	• Train operational and maintenance staff

Table 4.4 Examples of hazards, hazardous events and responses *continued*

Hazards and hazardous events	Control measures	Operational monitoring	Management procedures, protective actions	Supporting programmes
Specific uses *continued*				
Contamination of humidifiers	• Maintain droplets separator • Maintain and clean the generator, and disinfect the PoU (e.g. using ultraviolet radiation) • Ensure air catchments are far from polluted area (e.g. cooling towers) • Avoid condensed water recovery • Ensure that the system design separates droplets of critical size, and does not allow stagnation	• Inspect humidifiers regularly • Monitor disinfection procedures • Monitor implementation of maintenance procedures	• Develop procedures for operating and maintaining devices • Develop procedures for cleaning and decontamination	• Train operational and maintenance staff
Drinking-water coolers	• Ensure that coolers are used or flushed regularly to prevent excessive corrosion or leaching of metals, particularly in buildings with seasonal use or extended closures (e.g. schools)	• Inspect drinking-water coolers regularly • Monitor implementation of maintenance procedures	• Develop procedures for maintaining devices, including flushing after periods of low or no use	• Develop procedures for building occupants or users to report changes in taste and odours • Train operational and maintenance staff
Contamination of decorative fountains	• Clean and maintain regularly • Completely drain system for cleaning • Use appropriate water disinfectant	• Inspect fountains regularly • Monitor implementation of maintenance procedures	• Develop procedures for operating and maintaining devices • Develop procedures for cleaning and decontamination	• Train operational and maintenance staff
Contamination of eye wash stations and safety showers	• Flush stagnant water frequently • Disinfect the system regularly • Replace with bottles for eye wash	• Inspect regularly • Monitor implementation of maintenance procedures, including flushing and disinfection	• Develop procedures for operating and maintaining devices • Develop procedures for cleaning and disinfection	• Train operational and maintenance staff

Table 4.4 Examples of hazards, hazardous events and responses *continued*

Hazards and hazardous events	Control measures	Operational monitoring	Management procedures, protective actions	Supporting programmes
Construction work				
Use of inappropriate materials	• Select appropriate materials (where certification schemes have been established, use only authorized materials)	• Check that only authorized materials are used	• Develop procedures for selecting materials	• Train designers and builders on selection of materials • Follow plumbers' codes of practice
Microbial or chemical contamination events during repair or maintenance works Temporary switching to alternative supply Temporary stagnation, dead legs and blind ends Extensions of existing installations (which may change the established equilibrium of operation in terms of hydraulic conditions, thermal capacity and corrosion risks)	• Pre-plan extensions to ensure that they are appropriately designed and installed (design should take into account the characteristics and requirements of the existing system) • Isolate new sections from existing systems until integrity can be ensured • Flush and disinfect new construction before it is connected • Ensure that new work is inspected and certified by a qualified plumber or engineer before use • Thoroughly test the operation of the new system in combination with existing infrastructure	• Ensure that design requirements are followed, and that installation procedures are monitored • Monitor isolation of the sections under construction.	• Develop rocedures for constructing and installing new systems, equipment and devices	• Train designers and builders • Follow plumbers' codes of practice • Follow auditing and certification procedures for completed work before commissioning

Table 4.4 Examples of hazards, hazardous events and responses *continued*

Hazards and hazardous events	Control measures	Operational monitoring	Management procedures, protective actions	Supporting programmes
Construction work *continued*				
Accidental or unintended cross-connection between systems delivering different water qualities	• Ensure that new work is inspected and certified by a qualified plumber or engineer before use • Check connections with existing systems • Ensure that all new work is labelled appropriately • Install backflow-prevention devices where required to protect drinking-water systems	• Ensure that design requirements and installation procedures are followed • Monitor isolation of the sections under construction	• Develop procedures for constructing and installing new systems, equipment and devices	• Train designers and builders • Follow plumbers' codes of practice • Follow auditing and certification procedures for completed work before commissioning

PoE = point of entry; PoU = point of use.

5 Supporting environment

This section describes the roles of supporting personnel to ensure the smooth running of water safety plans (WSPs). This includes surveillance, inspection, outbreak detection, regulatory and policy frameworks, and capacity building and training.

5.1 Independent inspection and surveillance

5.1.1 Inspection

Independent inspection and surveillance of drinking-water systems is essential for ensuring that systems are well designed and are managed and operated in a manner that protects public health. Independent inspections and surveillance can be undertaken during construction and major renovations of buildings, or can be applied to existing buildings.

Independent technical inspections are often required as part of construction and renovation of buildings. For example, engineering inspections and certification of plumbing systems can be required under building and plumbing codes. These inspections should include assessments of public health impacts of drinking-water systems and associated devices. Public health agencies should also be consulted as early as possible during design and construction to assess the suitability of water systems, including the selection, installation and monitoring of control measures. Where possible, public health agencies should assess and approve WSPs developed for new buildings and new or renovated water systems, particularly in buildings where potential health risks can be high (e.g. health facilities).

Independent technical inspections of existing buildings can be undertaken by auditors or specialists with expertise in areas such as WSPs, plumbing, water treatment, operation of water devices (e.g. water-cooled air-conditioning, swimming pools, hot tubs), water microbiology, infection control, and occupational health and safety. Technical inspections can be commissioned by building managers to provide assurance that systems are being operated so that they protect public health and are consistent with regulatory requirements. Remedial action or improvements identified by such independent inspections should be documented and implemented. In some circumstances, independent inspections may be included as part of accreditation activities. For example, accreditation of facilities such as hospitals or hotels can include independent inspection of drinking-water systems and WSPs. Independent inspections can also be a regulatory requirement. Outcomes of these inspections should be documented within WSPs.

5.1.2 Surveillance

Surveillance is one of the five key components of the *Framework for safe drinking-water* (WHO, 2008) and is necessary to verify that WSPs are well designed and correctly implemented. Surveillance is a specific and ongoing activity that should be undertaken by public health agencies to assess and review the safety of drinking-water systems. As well as being a measure of compliance with regulatory requirements, surveillance helps to protect public health by promoting ongoing improvement, and by contributing to the early detection of water quality risk factors and the subsequent selection of appropriate remedial actions. Ensuring timely implementation of corrective action and targeted improvement can prevent waterborne disease.

Surveillance of drinking-water systems in buildings can involve audits, direct assessment or, ideally, a combination of these two approaches. Audits will generally include reviewing and approving new WSPs, as well as routine auditing of implementation of individual WSPs. Direct assessment involves testing of water quality. The advantage of audits is that they assess the capability to consistently produce safe drinking-water, while direct assessment assesses whether safe drinking-water was produced at the time of testing. Direct audits are more useful when they are included as part of broad surveys.

Both approaches require the surveillance agency to understand drinking-water systems and the way in which WSPs are applied, as well as the capability to undertake audits and respond to significant water incidents. In addition, direct assessments require the surveillance agency to have expertise in identifying appropriate monitoring locations and parameters, and collecting samples. They must also have access to testing facilities, be able to interpret results, and provide reports to building managers.

There are large numbers of buildings in urban centres, and routine surveillance of all building water systems will generally be impossible. Effective planning and development of surveillance programmes should identify priorities based on levels of risk. This requires an analysis of the types of buildings to be included in surveillance programmes, together with information on building characteristics and risk factors associated with building occupiers and users. Characteristics to be considered include:

- building types (hotels, apartments, hospitals, aged-care facilities, hospices, clinics, schools, child care, recreation centres, etc.);
- size and location of buildings and numbers of people potentially exposed;
- vulnerability of occupiers or users of buildings (residents, workers, patients, elderly or very young people, etc.);
- type and size of water systems (drinking-water supplies, hot-water systems, water-cooled air-conditioning systems, swimming pools, hot tubs, etc.);
- expertise of building operators and employees;
- availability of specialist service providers;
- geographical and climatic conditions (e.g. temperature, humidity, climate variability).

In many cases, surveillance may be based on occasional surveys. However, buildings such as hospitals and aged-care facilities should be audited at least once per year. Specific surveillance may be conducted for buildings that are closed for extended periods and reopened (e.g. schools and seasonal hotels). Targeted surveillance may be performed for specific devices and equipment, such as cooling towers, evaporative condensers, swimming pools and hot tubs. In some countries, this type of targeted surveillance may be required by specific legislation.

Surveillance can be undertaken or coordinated by central public health authorities in conjunction with regional and local offices, or with environmental health departments within local government. Programmes should be based on practical considerations, taking into account the capability of surveillance agencies. Greater attention should be focused on buildings that have potentially higher risks.

When designing surveillance programmes, consideration should be given to whether surveillance will be the responsibility of public health agencies or third parties (e.g. specialist auditors), certified or approved by these agencies, or a combination of both. Where third parties are used, the public health agency needs to retain responsibility for implementing the surveillance programmes. The public health agency should also provide directions on the frequency of inspections and audits, as well as the procedures to be applied. Public health agencies should receive and assess third-party reports and communicate assessments with building owners and managers.

Audits

Audits are on-site assessments, from intake to tap, of the whole water system—including sources, transmission infrastructure, treatment processes, storage, distribution systems, maintenance and monitoring programmes, and water uses within the building. Audits should embrace all water systems existing within the building, such as cold-, hot- and warm-water treatment and distribution systems; water-cooled air-conditioning systems; swimming pools; hydrotherapy pools; and hot-tub pools. The objective is to evaluate the ability of building management to produce and deliver safe drinking-water, as well as water of quality suitable for other specific uses within a building (e.g. in clinics, dental surgeries).

Audit-based approaches rely on data and information being provided by building owners and managers. This will include descriptions of water systems and end uses, results of operational monitoring to check that control measures are working effectively, results of monitoring at point of delivery to assess compliance with water-quality requirements, and evaluation of consumer satisfaction and complaints. Information should also be provided on independent inspections, internal audits, previous surveillance audits, and implementation of remedial action and improvement programmes.

Audits will normally focus on the design and implementation of WSPs. This could include:

- reviewing the building's water systems to examine whether all systems and uses are included and described accurately in WSPs;
- ensuring that WSPs consider all appropriate regulations, codes, guidelines and accreditation requirements;
- examining records to ensure that the system is being managed according to the WSP;
- assessing whether operational monitoring parameters have been kept within operational limits, that compliance was maintained, and that appropriate action was taken to respond to non-compliance, where necessary;
- ensuring that verification programmes are in place, that results demonstrate effectiveness of WSPs, and that appropriate action was taken to respond to non-compliance;
- examining maintenance records;
- assessing whether systems have been operated by appropriate personnel or appropriate service providers;
- ensuring that regulatory requirements have been met;

- examining reports of independent inspections and internal audits;
- ensuring that all actions and results have been documented and reported according to the WSP;
- assessing incident plans, contingency measures, and communication and reporting protocols;
- assessing supporting programmes and strategies for improving and updating the WSP.

Audits may involve interviewing building managers, operators and technical staff involved in water-system management. A final report should be completed at the end of the audit to formally notify the building owner or manager of the findings. The report may be used for future compliance actions and inspections and should summarize the findings of the survey, remedial action and recommended improvements, together with timelines for implementing actions and improvements.

Targeted audits should be conducted after substantial changes to the source, distribution system or treatment process, and in response to significant incidents.

Audits conducted in response to significant incidents detected by building operators should focus on verifying that:

- the incident was investigated promptly and appropriately
- the incident was reported to appropriate authorities in a timely fashion
- the cause was determined and corrected
- the incident and corrective actions were documented
- the WSP was reassessed and amended, where necessary, to avoid a similar situation.

Direct assessment

Direct assessment involves the collection and analysis of water quality by the surveillance agency. It does not replace requirements for audits, and should not be used to reduce the frequency of audits. Results should always be reported to building managers and should complement verification testing.

5.1.3 Incidents, emergencies and outbreaks

Additional inspections will be required in the event of incidents, emergencies (including natural disasters) and waterborne outbreaks. This will involve inspection of WSPs and of associated water systems. Investigations will normally require immediate collection of water samples. Wherever possible, samples should be collected before remedial actions are taken—as long as this does not cause unnecessary delays. This is important in trying to establish the cause of outbreaks.

The types of systems inspected will depend on the nature of the incident or outbreak. For example, investigations of waterborne gastroenteritis will be different from investigations of waterborne legionellosis. The former will focus on systems delivering water for ingestion, either directly or through food production; the latter will focus on systems containing water between 20 °C and 50 °C, and producing aerosols.

Following an outbreak, a further inspection will be required to ensure that any required remedial action has been taken, and that WSPs have been amended to minimize the likelihood of recurrence. The effectiveness of remedial action and amended WSPs should be verified by water-quality testing.

5.1.4 Supporting programmes

Surveillance should incorporate complementary health promotion and educational components. It should be seen as an activity to maintain or improve public health standards in a collaborative approach. Regulations should allow for penalties and sanctions, but these should only be imposed as a last resort.

Building owners and managers should be aware of the standards required by surveillance agencies, the purpose of audits and inspections, how audits will be performed, what features will be examined, and what information is required from building managers during an audit.

5.1.5 Reporting and communication

Reporting and feedback are essential elements of a successful surveillance programme and should support the development of effective remedial strategies. Outcomes of surveillance should always be reported to building managers. Annual reports should be prepared by coordinating authorities and distributed to all agencies involved in surveillance activities (e.g. national, regional and local agencies).

Agencies responsible for surveillance should also develop strategies for disseminating and explaining outcomes of surveillance to building occupiers and users.

5.1.6 Use of information

Information gained from surveillance programmes should be collated and assessed. This information is an invaluable source of data on effective management of water systems, and can help to identify recurrent causes of problems. Analysing collated data may identify common factors associated with potential water contamination, such as inadequate or ineffective treatment processes, structural conditions (e.g. impacts of water-main breaks, faulty valves or hydrants), hydraulic capacity (e.g. low-pressure complaints, rusty or coloured water occurrence), leakage (e.g. pro capita water demand), or water quality deficiencies due to cross-contaminations or to unintended uses.

Collated information can also be used to review relative health risks presented by different types of buildings and circumstances; it can also be used to refine surveillance programmes.

5.2 Disease surveillance and detection of outbreaks

5.2.1 Purpose of disease surveillance programmes

Establishing and verifying effective disease-control programmes, including WSPs, requires effective surveillance programmes. These surveillance programmes should provide:

- accurate and timely information on disease occurrence
- early detection and notification of outbreaks
- assessment of responses to outbreaks
- efficient monitoring of intervention programmes.

The World Health Organization (WHO) *Guidelines for drinking-water quality* (WHO, 2008) define the reduction of disease and outbreaks as health outcome targets. Reducing disease provides the most direct evidence of the success of WSPs, while continued disease provides evidence that WSPs are inadequate and require modification. While the immediate response to detection of disease is necessarily reactive, the subsequent responses can be proactive in identifying and eliminating building-specific and systemic risks.

Many countries have mechanisms for surveillance and reporting of communicable diseases. The importance of these mechanisms is reinforced by the International Health Regulations (IHR) (WHO, 2005), which call for Member States to apply and—where necessary—strengthen capabilities for surveillance, reporting, notification and communication of infectious disease. While surveillance programmes often include waterborne organisms, specific surveillance of water as a source of disease is generally not well developed or coordinated. This includes waterborne disease associated with buildings.

5.2.2 Structure of disease-surveillance systems

The structure of disease-surveillance systems is governed by a number of factors, including legislation, the strategy for implementing surveillance, responsible agencies, and stakeholders and communication (WHO, 2006c).

Legislation

Public health legislation, including the IHR, provides the regulatory framework governing the identification, reporting and communication of notifiable diseases.

Public health legislation can also include requirements for health-care facilities to implement infection-control capabilities, while legislation dealing with occupational health and safety can include requirements relating to control of specific diseases, such as legionellosis.

Strategy

Disease-surveillance strategies depend on the nature of the diseases under investigation, the objectives of surveillance, the methods for conducting surveillance, and the application of data in informing public health practice. Countries may have multiple disease-surveillance systems operating simultaneously. Some will be aimed at early detection and response to outbreaks; others will focus on monitoring longer term disease trends, or the impact of interventions and control programmes. Each type of surveillance has specific characteristics. Disease surveillance used in health-care facilities is typically more active and immediate than surveillance of the outcomes of interventions, such as disease-control regulations or longer term public health programmes.

Disease-surveillance strategies can include:

- ongoing monitoring of reporting of communicable diseases by medical practitioners and laboratories;
- short-term and long-term analysis of results;
- investigation of clusters of illness or increased incidence of disease.

Monitoring of waterborne disease generally lags behind general disease surveillance (Bartram et al., 2002; Hunter et al., 2003). One of the principal factors is that most of the diseases transmitted by ingestion of contaminated water are transmitted in higher frequencies from other sources, such as food and person-to-person contact. This makes assessing the contribution of water difficult. In Europe, only 2% of gastrointestinal disease between 1986 and 1996 was linked to water (Bartram et al., 2002). Based on epidemiological investigations and intervention studies, estimates for the United States of America have placed the contribution at 8–12% (Colford et al., 2006; Messner et al., 2006).

Hence, while national and regional surveillance systems typically incorporate enteric organisms that can be waterborne, confirming association with water supplies is generally limited to outbreaks.

Some countries have established systems for detecting and reporting waterborne outbreaks. These data indicate that waterborne disease outbreaks associated with large water supplies have been substantially reduced, and that the proportion of outbreaks associated with buildings has increased (Blackburn et al., 2004; Yoder et al., 2004, 2008ab; Djiuban et al., 2006; Liang et al., 2006). In 2003–2004, the classification of waterborne disease by the United States Centres for Disease Control and Prevention was modified to include specific categories dealing with plumbing deficiencies (Liang et al., 2006).

Some diseases are exclusively waterborne; for example, legionellosis (caused primarily by *Legionella pneumophila*) and dracunculiasis (caused by *Dracunculus medinensis*). For these organisms, disease surveillance has been an important tool in supporting implementation of control measures. Waterborne legionellosis is strongly associated with building water supplies.

Initially, improved surveillance can detect an increased prevalence of disease. This has been reported for legionellosis in Europe (Bartram et al., 2007). Furthermore, improved surveillance provides a more accurate basis for establishing the need for, effect of and benefit of interventions. For example, in Australia, disease surveillance has demonstrated the effectiveness of *Legionella* regulations in reducing both the occurrence of the organism in cooling towers and the frequency of disease (Vic DHS, 2007).

Disease surveillance strategies can be tailored to deal with specific issues. For example, surveillance in health-care facilities is likely to involve a different spectrum of diseases from those included in general surveillance schemes, due to the increased and varied vulnerabilities of patients and residents. As described in section 2, organisms such as *Acinetobacter*, *Aspergillus*, *Burkholderia*, *Klebsiella* and *Pseudomonas* have been associated with disease in health-care facilities.

Priority diseases and case definitions

It is not economically possible or practical to monitor all diseases. General surveillance systems should include diseases of national public health importance. WHO has produced guidance for selection of priority diseases, including waterborne diseases (WHO, 2006d, 2006e).

Specific disease-surveillance systems, such as those in health-care facilities, should target diseases of public health concern within the setting in question. The range of agents can vary within buildings; for example, within health-care facilities, renal dialysis patients are more susceptible than other patients to endotoxins, toxins and chemical contaminants in water used for dialysis.

Disease surveillance of water supplies in buildings will generally involve microbial pathogens, but should also consider chemical agents such as corrosion products (e.g. copper, lead, nickel and cadmium). Surveillance for chemicals is uncommon; prevention is by far the preferable approach. However, surveillance has been performed for lead (in blood) in certain circumstances (CDC, 2010).

Case definitions should be identified and documented for all priority diseases. A national register of case definitions should be developed and applied in all disease-surveillance schemes.

Responsible agencies and stakeholders

Public health surveillance is typically coordinated at a national level by ministries of health, and operates at national, regional and local levels. Coordination and oversight of operations by a central agency is essential.

Infection-control teams in health-care facilities play a key role in public health surveillance. Similarly, in commercial and industrial buildings, occupational health services play a role in disease surveillance. In some countries, control of legionellosis is regulated at least in part by occupational health legislation (Bartram et al., 2007).

Coordination of all disease surveillance activities is important to support efficiency and to avoid duplication.

Reporting and communication

Reporting and communication support the collection of disease information, dissemination of outcomes, implementation of immediate responses, and longer term interventions.

Reporting systems should be established to ensure that information moves from the point of generation (i.e. disease detection) to collection and coordination agencies. Standard operating procedures should be established for reporting. The procedures should deal with transmission of routine data, as well as data on suspected and confirmed outbreaks. Procedures should be communicated to everyone involved in disease surveillance.

Communication between all stakeholders involved in disease surveillance is essential. Coordination of all disease-surveillance activities undertaken by national, regional and local authorities, infection-control teams and occupational health services is required to ensure effective reporting of disease, timely detection of outbreaks, implementation of responses and longer term control measures.

Disease-surveillance strategies typically involve reporting by medical practitioners and laboratories. Timeliness and accuracy of reporting are crucial. In addition, systems should be established to ensure that results of disease surveillance undertaken by infection-control teams are routinely reported to coordinating agencies. Outbreaks detected in health-care facilities should be reported immediately.

Communication of outcomes is required. This can include routine reports, as well as issuing of warnings and advice to health practitioners, the public and managers of buildings. It is important to have communication procedures in place to deal with suspected or confirmed outbreaks of potentially waterborne disease. For example:

- the detection of outbreaks of legionellosis could result in communication with building owners during the outbreak about immediate action (e.g. precautionary decontamination of cooling towers);
- outbreaks of waterborne cryptosporidiosis could lead to issuing of advice to operators of leisure centres and swimming pools regarding practices to avoid primary and secondary transmission;
- increased incidence of nosocomial disease will require communication with staff and managers of health-care facilities.

Mechanisms should be established to facilitate this communication before outbreaks occur.

After a disease outbreak, communication should be widened to include information on the lessons learnt, and how practices will be used or applied to minimize the likelihood of recurrence.

Communication should also include sharing of information between agencies and stakeholders. For example, this should include establishing communication networks for infection-control teams, to help identify common problems, causes and interventions. Disease surveillance at a regional level should be supported by a national communication system. Higher levels of travel have increased the spread of diseases across boundaries; therefore, communication should be extended across borders to meet obligations of the IHR (2005) and also to share experiences and lessons learnt.

Disease-surveillance guidelines and standards

Effective disease-surveillance systems are underpinned by comprehensive standards and guidelines. These standards and guidelines should define priority diseases, and include case definitions, notification and reporting requirements, responsibilities, data management, evaluation, immediate and long-term responses, outbreak preparedness and training.

Guidelines should deal with related aspects, such as infection control in health-care facilities (WHO, 2002; Sehulster et al., 2004) and laboratory procedures such as standard methods and quality control.

5.2.3 Disease surveillance for water supplies in buildings

Disease surveillance for disease associated with buildings is a subset of general surveillance. However, building water supplies have some specific characteristics:

- The water systems and hence the sources of disease are typically discrete and defined.
- Buildings such as hospitals, medical clinics, aged-care facilities and child-care centres can cater for subgroups with increased vulnerabilities.
- In health and aged-care facilities, infection-control teams play a central role in surveillance.

Microbial pathogens represent the greatest risk associated with building water supplies, but toxic chemicals such as heavy metals, industrial compounds, coolants and boiler fluids can also cause illness.

Microbial disease and outbreaks associated with buildings can be detected by active surveillance by national or regional agencies and infection-control teams, by passive processes such as reporting by medical practitioners and other health-care professionals, or through anecdotal reporting by building users.

Acute disease caused by building-specific chemicals (e.g. boiler fluid) is generally detected by passive processes, while chronic and acute disease caused by heavy metals (e.g. copper and lead) can be detected by either passive processes or broader investigations. The latter could be implemented where there is evidence of systematic issues such as corrosion of plumbing systems caused by public water supplies.

5.2.4 Disease-surveillance strategies for waterborne disease

Surveillance of waterborne disease can be included in a range of programmes with different functions and characteristics. These can include surveillance of:

- national and regional incidence of infectious disease
- waterborne disease outbreaks
- specific diseases, to measure incidence and the need for intervention
- disease in specific settings, such as health-care facilities.

National and regional incidence of infectious disease

National and regional surveillance programmes can include specific waterborne diseases such as cholera, legionellosis and dracunculiasis. For these diseases, the outcomes of disease surveillance can be used to assess longer term trends as well as the outcome of intervention programmes.

National and regional programmes typically include diseases that may be waterborne. General surveillance does not identify endemic waterborne disease without the addition of ancillary epidemiological studies (Calderon & Craun, 2006), but can detect waterborne outbreaks—although the sensitivity is poor (Padiglione & Fairley, 1998; Craun et al., 2004).

Waterborne disease outbreaks

The likelihood of detection of waterborne disease outbreaks can be increased by augmenting infectious-disease programmes with specific mechanisms to promote reporting of such outbreaks. The data from outbreaks can be used to identify important pathogens, water-system deficiencies and interventions to reduce waterborne disease (Craun et al., 2006). The best example of outbreak detection is in the United States of America, where statistical data on waterborne disease outbreaks have been collected and reported since the 1920s (Djiuban et al., 2006; Yoder et al., 2008ab). Recent surveillance data indicate that a substantial proportion of outbreaks in recreational water and drinking-water was associated with buildings such as sports centres, hotels, schools, child-care centres, nursing homes, hospitals and restaurants. Diseases were caused by a range of agents, including *Cryptosporidium*, *Giardia*, *Shigella*, *Legionella*, *Pseudomonas*, *Norovirus*, copper and ethylene glycol (Blackburn et al., 2004; Yoder et al., 2004, 2008ab; Djiuban et al., 2006; Liang et al., 2006).

The reports have highlighted water-system deficiencies, such as cross-connections in buildings and the need for improved control of opportunistic pathogens such as *Legionella* and *Pseudomonas*.

Specific diseases

Surveillance for legionellosis is a good example of a targeted monitoring programme and has been well documented elsewhere (Bartram et al., 2007). Surveillance has been used to identify the prevalence of disease, the need for improved control, and the success of intervention programmes (WHO, 2006c; Vic DHS, 2007).

Infection control

Infection rates in health-care facilities are an indicator of the quality of care, including the safety of the environment. Surveillance is used to monitor incidence of disease, identify risk factors and evaluate the impact of interventions. Waterborne disease involving organisms such as *Acinetobacter*, *Aspergillus*, *Burkholderia*, *Klebsiella*, *Legionella*, mycobacteria, *Pseudomonas* and *Stenotrophomonas* has been identified as cause for increased concern in health-care facilities (Annaisie et al., 2002; Sehulster et al., 2004).

Results of disease-surveillance programmes have been used to identify control measures to minimize the risk of infection associated with building water supplies (Sehulster et al., 2004; Bartram et al., 2007).

Review

The results of disease-surveillance programmes should be subject to regular review to identify trends, including increases and decreases in disease rates, changes in patterns of disease, the occurrence of emerging disease and the impacts of control measures. Outcomes and any recommendations arising from reviews should be reported.

5.2.5 Detection of outbreaks

Outbreaks are generally defined as two or more cases linked in location and time. Waterborne outbreaks associated with water supplies in buildings represent preventable failures in WSPs. All outbreaks should be investigated to confirm occurrence, identify the source, implement immediate control measures, and identify the need for longer term and general changes in management programmes.

Agencies and teams involved in disease surveillance should establish investigation protocols to respond to outbreaks. Early detection of outbreaks and appropriate, timely responses will reduce the size and impact of outbreaks. Pre-planning promotes rapid responses and avoids planning on the run, which is very likely to lead to poor coordination, mistakes and delays.

Outbreak investigations follow a sequence of activities that includes:

- pre-planning
- outbreak confirmation
- case definition
- outbreak description
- hypothesis generation and confirmation
- control and prevention
- communication.

Pre-planning

Pre-planning should identify who should be involved in the investigation of outbreaks. This should include responsibilities, leadership and coordination. Methods for investigating outbreaks and basic requirements (e.g. case definitions, data transfer and communication procedures) should be identified.

Outbreak confirmation

An increase in reported cases or detection of specific pathogens in clinical samples is generally the first sign of an outbreak. However, it is important to confirm that the apparent outbreak is real. Factors that have been shown to contribute to "pseudo-outbreaks" have included increased detection due to increased testing, contamination of clinical samples, false positive tests and coincidence of unrelated cases (CDC, 1995, 1997b, 2009; Regan et al., 2000; Kressel & Kidd 2001; Blossom et al., 2008).

Case definition

Once an outbreak is confirmed, a case definition should be developed to establish criteria for inclusion. The definition should include descriptions of place and time of onset, and specific biological and clinical criteria (symptoms and test results). Cases could be categorized as definite, probable or possible, based on the level of data available. Case definitions may also change during investigations as new information becomes available.

Outbreak description

A detailed description of the outbreak should be generated as investigations progress. The description could include information on numbers of cases, place, time, sex, age and movement. Epidemic curves and mapping of geographical distribution can provide evidence of sources of contamination and whether they are from single, intermittent or ongoing events (WHO, 2002; Hunter et al., 2003).

Hypothesis generation and confirmation

As the outbreak description develops, it should be possible to formulate hypotheses on sources of infection and routes of transmission, and identify possible control measures. Confirmation is necessary, even in cases that appear to have an obvious source. Hypotheses will be strengthened, refined, modified or discarded as the investigation continues. For waterborne outbreaks, confirmation will generally involve collecting and analysing water samples, and assessing the design and implementation of WSPs for failures. Genetic typing of isolates is an important tool for identifying sources of cases, and can support or reject hypotheses (Heath et al., 1998; Hunter et al., 2003; Gilmour et al., 2007). Epidemiological methods such as case–control studies are also used to test hypotheses by comparing risk factors between groups of cases and controls without disease (WHO, 2002).

It is important to identify the correct source of disease and to avoid going public with unconfirmed hypotheses. Pressure to identify sources quickly should not be allowed to compromise accuracy. Failure to identify the correct source can lead to expensive and ineffective interventions.

Control and prevention

A priority in all investigations is to identify and implement effective control measures. The aims are to:

- interrupt the chain of transmission and minimize the magnitude of the outbreak
- prevent future outbreaks.

The selection of control measures will require consultation with appropriate experts such as environmental microbiologists and water-treatment specialists. Outbreak investigations should assess the success of control measures, while ongoing disease surveillance should be implemented to monitor continued effectiveness. This type of surveillance will include monitoring of disease and the efficacy of the control measure. In the long term, monitoring of preventive control measures will take precedence.

Communication

During investigations, timely and accurate information should be provided to public health authorities (if not leading the investigation), building owners and managers, patients and, where appropriate, the public. Where there is uncertainty—for example, in the identification of sources—this should be communicated.

Full reports should be prepared at the end of outbreaks, describing events, interventions, lessons learnt and recommendations to prevent further occurrence. These reports should be made available to appropriate agencies, authorities, and building owners and managers involved in operation of water supplies.

5.2.6 Lessons learnt from disease surveillance and investigations

Results of disease-surveillance activities and outbreak investigations must be used to inform practices, and measures applied to reduce waterborne disease. The decrease in drinking-water waterborne outbreaks in the United States of America since the 1980s has been attributed to more stringent regulation (NRC, 2006). Events such as the Milwaukee outbreak of cryptosporidiosis in 1993 (MacKenzie et al., 1994) contributed to the development of regulations. At the same time, the proportion of outbreaks and illness associated with buildings has increased (Blackburn et al., 2004; Yoder et al., 2004, 2008ab; Djiuban et al., 2006; Liang et al., 2006). Water supplies in buildings are typically not included within the scope of national drinking-water regulations.

However, lessons learnt from disease surveillance and outbreak investigations have been used to reduce risks associated with building water supplies. The clearest example of this is the development of guidelines and regulations for controlling waterborne legionellosis (see *Legionella and the prevention of legionellosis*; WHO, 2007). Other examples include increased attention on cross-connection control and backflow prevention (USEPA, 2002; NRC, 2004) and the development of guidelines for preventing waterborne disease in health-care facilities (WHO, 2002; Sehulster et al., 2004).

On a national, regional and local level, it is important to learn from the application of control measures to deal with waterborne disease. Documentation, reporting and communication networks should support cataloguing of incidents and the sharing of experience in detecting deficiencies and implementing responses. Where appropriate, these can be translated into guidance and regulation to minimize risks of disease.

5.3 Regulatory and policy frameworks

National governments, together with regional and local authorities, are generally deemed to be responsible for ensuring that consumers are provided with safe and wholesome water in sufficient quantity. Typically, this responsibility will lie within the ministry of health, although sometimes other agencies, such as those responsible for environmental protection, may play a role. The actions and responsibilities of these authorities and agencies need to be supported by legislative and regulatory tools. However, the diversity of constitutional and legal systems makes it impossible to define a single accepted way for developing and implementing legislation. Nevertheless, there are a number of common principles that should be applied.

5.3.1 Purpose of legislation

Legislation should define responsibilities, functions and obligations of agencies charged with ensuring compliance with drinking-water quality requirements. Legislation should also provide these agencies with necessary powers to administer laws and regulations. For instance, the requirements of surveillance within buildings can be hindered by difficulties for national, regional or local authorities in gaining access to undertake inspections and audits. This needs to be considered in regulatory frameworks. Responsibilities for water quality also need to be identified. This should include responsibilities of drinking-water suppliers and the managers, operators or owners of water systems in buildings.

As discussed throughout this document, the most effective way of assuring drinking-water safety in buildings is the application of WSPs that cover all issues, from planning and construction to surveillance of tapwater quality. The central role of WSPs should be reinforced and supported by regulatory and policy frameworks.

In addition to drinking-water legislation, many countries have established standard-setting bodies and certification systems. Standards and codes of practice can apply to a broad range of activities that can influence construction and management of drinking-water systems in buildings. These can include standards relating to construction of buildings, installation of plumbing, water systems and sewage systems, as well as the design, installation, maintenance and operation of devices such as cooling towers and evaporative condensers, swimming pools, hot-tub pools, hot-water systems and plumbing devices. Standards could also apply to sampling, testing and accreditation of technical experts (e.g. plumbers) and auditors.

Tables 5.1–5.3 summarize the tools needed by legislators for addressing WSP implementation in accordance with national legislation, technical regulations, standards and codes of practice.

Table 5.1 Management legislation

Area of management legislation	Issues for legislator or regulator	Issues for standard-setting and certification agencies
Building construction and commissioning (as far as the water distribution system is concerned)	• Award the right of inspection entry, at building stages, to those responsible for regulating and certifying water systems • Enforce the WSP-in-building approach • Enforce by law the certification scheme for everyone involved, and their role	• Provide construction and plumbing standards • Provide codes of good practice for each category of work • Provide commissioning procedures and testing methods for water distribution systems and individual components, as required • Establish training and certification programmes for everyone involved
Maintaining required water quality	• Enforce mandatory WSPs for buildings of specified characteristics (size; kind of occupancy; public or open to public, etc.) • Identify responsibilities for at least the following: – owners – building managers – WSP managers • Identify independent regulatory agencies for performing technical inspection • Establish procedures for monitoring and reporting for health protection (implemented by the building manager and an independent health authority; for health-care premises, this is implemented by infection-control teams)	• Prepare general and specific WSPs according to the characteristics of the building (size; type); these should include definitions of major risks (microbiological, chemical, hydraulic) and responses to major events (natural catastrophes) • Provide a training and certification programme for those involved (identified in legislation) • Develop standards, guidance and a code of good practice for the operation and maintenance of water distribution systems in general, and for individual components and devices, as required
Surveillance	• Set the minimum surveillance requirements for WSPs • Identify independent entities for implementing the surveillance programme (public and/or third party) and specify their scope and given authority • Ensure independent entity has right of access and inspection of WSPs • Ensure the independent entity has the authority to order actions deemed necessary for protecting consumer health and safety	• Define WSP surveillance programmes (frequency, required analyses, etc.) • Establish accreditation scheme for independent entities performing surveillance of WSPs • Establish accreditation schemes for laboratories

WSP, water safety plan.

Table 5.2 Technical regulations

Area of technical regulation	Issues for legislator or regulator	Issues for standard-setting and certification agencies
Building permission	• Set minimum requirements for water supplies and specifications in buildings (e.g. pressure, flow rate) • Set minimum requirements for the sewage system connection • Set requirements for alternative water sources (private wells, etc.)	• Set standards for water supplies • Set standards for sewage systems
Materials and products intended for contact with drinking-water	• Define criteria based on: – mechanical characteristics related to safety and performance (durability, energy consumption, noise) – fitness for contact with drinking-water	• Set standards for testing: – mechanical characteristics – fitness for contact with drinking-water (migration or release of hazardous chemicals, support of microbial growth, etc.)
Surveillance of water quality at the consumer tap	• Define water-quality standards, and keep them up to date • Define criteria for collecting representative water samples • Define appropriate analytical methods	• Identify methods for taking water samples for chemical, physical and microbial analyses
Installation of water systems inside buildings	• Define requirements per product standards, including, if available, those related to safety, hygiene, energy savings • Define requirements for preventing unintended cross-connection and installation of backflow prevention, where required	• Set standards for internal installations, including: – general requirements – design principles – piping system design – installation – operation and maintenance • Set standards for connecting appliances and equipment to water distribution systems (washing and dishwashing machines, humidifiers, etc.) • Set standards for PoE and PoU devices, including operation and maintenance instructions
Installation of swimming pools, hot tubs, and other recreational water devices	• Define and update the water-quality standards • Define safety rules • Identify roles and responsibilities • Define “public” and “private” swimming pools • Ensure rights of inspection to regulatory entities for public pools	• Set standards for designing, operating and maintaining pools and accessories • Set standards for water treatment (filters, disinfection, etc.)

Table 5.2 Technical regulations *continued*

Area of technical regulation	Issues for legislator or regulator	Issues for standard-setting and certification agencies
Installation of systems conveying water for special purposes (e.g. in health-care facilities, child care)	• Define criteria for assessing the compatibility of activities within buildings with occupancy • Set general requirements for water systems intended for special purposes (e.g. increased safety levels and protection) • Set specific requirements, as needed or advisable	• Develop quality standards for each type of special water • Set standards for water-treatment devices
Hot-water and cold-water storage within dwellings	• Define requirements for independent technical inspection	• Set standards for storage tanks and associated equipment, including design, operation and maintenance
Hot-water systems	• Define requirements for preventing health risks (e.g. from *Legionella*) and suitable water specifications (e.g. temperature) • Define requirements for independent technical inspection	• Set standards for designing, operating and maintaining heating, storage and delivery, including temperature control
Water-using cooling devices (cooling towers, evaporative condensers)	• Define requirements for preventing health risks (e.g. from *Legionella*) • Define requirements for independent technical inspection	• Set standards for designing, operating and maintaining cooling systems

PoE, point of entry; PoU, point of use.

Table 5.3 Links between legislation, regulations and standards

Area of regulation	Major issues for legislators	Major issues for standard-setting and certification agencies
Suitability of equipment for purpose	• Define requirements for establishing and operating certification schemes	• Define and manage certification scheme
Materials and products intended for the contact with drinking-water	• Establish a certification scheme	• Test schemes
Management of building system for safety, including maintenance and servicing	• Assign responsibilities of owner and manager	• Provide guidance and codes of good practice on cleaning, disinfection for systems and associated devices (e.g. swimming pools)
Independent oversight of building water safety	• Provide for independent oversight (surveillance) • Define scope of authority of independent agency (different types of building) • Ensure right of access and inspection for independent entity • Require analysis by accredited laboratories • Require that sampling and analyses comply with recognized methods	• Define frequency of inspections or audit • Define criteria for audits • Establish and operate accreditation schemes for inspectors and auditors • Establish and operate accreditation schemes for laboratories • Establish processes for accrediting sampling and analytical methods
System installation and commissioning	• Oversee licensing or industry self-regulation of plumbers	• Set standards and codes of good practice for plumbing • Set accreditation scheme for plumbers
Construction of buildings, including requirements for ensuring water-related environments are safe	• Set requirements for an entity to establish and update construction standards	• Establish a body to provide and maintain standards
Health-care settings	• Identify special provisions in high-risk environments • Identify responsibilities of health service providers	• Establish a body to provide and maintain standards and ongoing guidance on good practice
Drinking-water quality standards	• Assign authority to a suitable body to establish and update standards • Specify consultation requirements • Assign enforcement requirements	• Develop criteria for standard setting • Oversee the consultation process • Process enforcement

5.4 Capacity building and training

A wide range of responsibilities is associated with ensuring safety of water within buildings. The principles, including WSPs, are captured within the *Framework for safe drinking-water*. The risk-management principles described in the framework also apply to other devices, such as water-cooled air-conditioning plants, swimming pools and hot-tub pools (WHO, 2006a; Bartram et al., 2007).

All the stakeholders identified in section 3 need to have the appropriate skills to perform their specific functions related to provision of safe water supplies. This includes building commissioners and designers, building managers, employees, public health agencies, auditors, professional bodies and infection-control practitioners.

It is not practical or realistic to expect that all stakeholders will have the capacity to perform all functions. Training will need to be tailored for each group of stakeholders. Training provided to employees responsible for drinking-water systems will differ from training provided to employees responsible for water-cooled air-conditioning plants, swimming pools or hydrotherapy pools. However, all stakeholders need to have a basic understanding of risk-management principles associated with WSPs, including the identification of hazards, the assessment of risks and management strategies applied to control these risks. Each stakeholder should be aware of how their specific responsibilities fit within and contribute to the design and implementation of WSPs. They also need to be aware of the consequences of failure. Too often, this is not the case (Hrudey & Hrudey, 2005).

Overall, therefore, training programmes must be coordinated to ensure consistency of intent and understanding. In this way, all activities associated with water systems can contribute to a consistently high standard of design, construction, operation, maintenance and management.

General training should be available on:

- risk-management principles;
- development and application of WSPs; this should include training on applying WSPs in specialized settings (e.g. for infection control in medical and dental surgeries and renal dialysis clinics);
- risk assessment;
- control measures, including treatment;
- operational procedures, including monitoring and maintenance;
- emergency actions and responses.

In addition, specialized training may include the following components:

- For professionals involved in designing or modifying buildings and water networks
  - water-quality regulation, standards and guidelines
  - information on the importance of water quality and implications of failure
  - setting water-quality targets (e.g. environmental and building quality labels, certification)

    - prevention of microbiological and chemical contamination, including major mistakes to be avoided (e.g. poor-quality water resources; accidental or unintended cross-connections; poor design of water distribution networks, waste systems and venting systems; poor design of storage systems)
    - maintenance and sampling requirements.
- For plumbers
    - water-quality regulations, standards and guidelines
    - responsibilities and legal obligations
    - evidence of links between construction practices and water quality at the tap (e.g. impacts of welding practices on resistance to corrosion, use of incompatible materials, inappropriate pipe diameters, accidental or unintended cross-connections)
    - water-system design, construction rules and good practices.
- For auditors
    - detailed knowledge of national and local water standards and guidelines applying to system design and construction
    - detailed knowledge of all aspects of WSPs
    - auditing practices applied to the domain of water quality.
- For regulators
    - understanding determinants of other disciplines that affect WSPs in their domain (e.g. health regulators should have an understanding of the main determinants of building design and construction)
    - building and plumbing regulations, standards and codes of practice.
- For building managers
    - importance of water quality and implications of failure
    - water-quality regulation, standards and guidelines
    - responsibilities and legal obligations
    - water-system design and construction
    - WSPs
    - maintenance and surveillance of water systems
    - supervision of water-system audits and risk assessments
    - event and incident management
    - audits of contractors' qualifications and competence.

- For employees responsible for specific installations (e.g. water-cooled air-conditioning plants, swimming pools, hydrotherapy pools)
  - importance of water quality and implications of failure
  - detailed knowledge of national and local design, construction, auditing and maintenance standards and guidelines for such installations
  - prevention of microbiological and chemical contamination specific to such installations
  - periodic feedback from others' field experience and major mistakes to be avoided (e.g. through specialist workshops, industry associations).

Mechanisms for providing this training and building capacity include formal courses that are accredited by national educational agencies, professional associations, industry-operated training courses, in-house training and mentor programmes, workshops, seminars and conferences. Training could be provided in stand-alone courses or within broader training programmes provided for specialists such as infection-control practitioners or plumbers. Where possible, training should be supported by provision of manuals, fact sheets and guidelines on websites. Contact details for appropriate experts or appropriate agencies should also be provided.

Feedback from field experience should be organized and documented to support training programmes, so that professionals can benefit from others' experience. Training and information sessions based on the presentation of field experience have been found to attract high levels of interest and increase the recognition and appreciation of water-quality issues and shared responsibilities. This type of networking and sharing of experiences can be valuable and effective. It should be encouraged.

Training should be documented, and records of all employees who have participated in training should be maintained. Skills and knowledge need to be maintained through attendance at refresher courses or at workshops and seminars that can reinforce existing qualifications.

Annex 1 Model water safety plan—daycare facility for children

I Hazard identification, hazard assessment and risk characterization

Position	Potential hazard	Cause	Risk (likelihood and consequences)	Preventive or control measures
1.1	Contamination of the system with chemicals and/or microorganisms	Using cross-connections to other systems	High	• Avoid cross-connections • Design inspection records • Ensure that only appropriately qualified people are permitted to carry out connection work • Ensure that external professionals inspect or maintain the system
1.2		Flooding	Moderate–high	• Install adequate backflow-prevention devices • Establish an emergency plan • Train staff for flooding situation
1.3		Backflow resulting from reduced pipe pressure	Moderate	• Install adequate backflow-prevention devices • Ensure mandatory functionality check of backflow devices
1.4		Corrosion of pipes, valves, etc.	Moderate	• Install fine filter after water meter • Install adequate material, pipe dimension and system design
1.5		Do-it-yourself repairs in the system	Moderate	• Target educational activities to building owners or managers • Ensure that external professionals inspect or maintain the system

I Hazard identification, hazard assessment and risk characterization *continued*

Position	Potential hazard	Cause	Risk (likelihood and consequences)	Preventive or control measures
2.1	Microbial growth (e.g. *Legionella*, *Pseudomonas*) in the system	Stagnation of water in pipes with dead end	High	• Ensure a regular flushing of all pipes • Avoid dead pipes and long pipes • Identify areas at risk of stagnation • Reduce the length of tap pipes to minimize stagnation volume
2.2		Intermittent use (shower, hosepipe, social room, office, vacation)	High	• Ensure regular use of the system • Ensure regular flushing of the system • Construct shut-off valves near main pipes or near frequently used pipes and drainpipes after shut-off • Cut off unused pipes
2.3		Inadequate temperature in the warm-water system (heater temperature too low)	High	• Ensure adequate heater temperature and adequate supply of circulation pump • Construct adequate insulation of pipes and heaters
2.4		Inadequate temperature in cold-water system	High	• Ensure adequate cold-water temperature in the system • Separate cold-water pipes from heater and warm-water pipes • Ensure adequate insulation of pipes
2.5		Inadequate system material used	Moderate	• Use material according to current guidelines and standards
2.6		Warm-water flows are not hydraulically balanced	High	• Ensure adequate pipe dimension • Ensure that adequate flows are maintained through all parts of the distribution system • Replace simple valves with temperature-adjustable valves
2.7		Heater sludge (forces growth of microorganisms)	Moderate	• Inspect, maintain and clean the heater regularly

I Hazard identification, hazard assessment and risk characterization *continued*

Position	Potential hazard	Cause	Risk (likelihood and consequences)	Preventive or control measures
2.8	Local microbial contamination of the system	Inadequate tap hygiene (e.g. contaminated showerhead, aerator)	High	• Inspect and maintain tap hygiene • Ensure that work practices for maintenance comply with standard procedures
3.1	Leach-out of organic compounds into drinking-water	Inappropriate materials used, or stagnation	Moderate	• Use certified materials • Record material requirements
4.1	Biofilm growth	Water flow is too low, resulting in colonization of surfaces	Moderate	• Inspect the zones of concern, and put in place a plan to increase flows in these areas • Flush pipework
4.2		Poor chemical water quality leaving the treatment plant (e.g. post-treatment precipitation of floc, iron/manganese precipitation)	Moderate	• Ensure a regular cleaning and flushing programme is in place, especially through low-flow and dead-end areas
4.3		Poor microbial water quality leaving the treatment plant and introduced in the distribution system	Moderate	• Install filter to reduce some pathogens (e.g. protozoa) • Ensure a regular cleaning and flushing programme is in place, with additional chlorination especially through low-flow and dead-end areas
4.4		Inadequate material used	Moderate	• Use certified materials • Use materials according to current guidelines and standards
5.1	Sediment deposits	Inadequate cleaning programme	Moderate	• Install sediment filters to reduce sediments • Ensure an adequate cleaning programme is in place (particularly for fine filters, etc.)
5.2		Water velocity is too high	Moderate	• Ensure that pipes are of adequate dimension • Control the opening and closing valves, and starting pumps
6.1	Damage of the supply system	Natural disaster	Moderate	• Establish an emergency plan • Create an emergency communication schedule • Train staff for this situation

II Operational monitoring and management

Position	Hazard	Cause	Monitoring procedures	Critical or operational limit (reference value)	Validation or verification	Management procedures, including corrective actions
1.1	Contamination of the system with chemicals or microorganisms	Cross-connections to other systems	• Provide job sheets and procedures to staff • Check security devices (safety valves like backflow prevention devices, etc.) at cross-connections	• Sufficient quality of job sheets • Security devices installed adequately	• Installation of cross-connections complies with guidelines, codes of practice and accepted standards • Backflow-prevention devices installed according to guidelines, codes of practice and accepted standards • Tapwater quality conforms with national drinking-water guideline values after cross-connection	• Maintenance procedures for backflow-prevention devices • Avoidance of cross-connections and removal of inadequate installation of cross-connections
1.2		Flooding	• Ensure that emergency plan is up to date and that responsible staff have been instructed on its use	• Update intervals of emergency plan (e.g. annual updating) are kept and responsibilities are checked	• Emergency plan complies with guidelines, accepted standards and references	• Emergency plan providing essential information for flooding situation (e.g. pipe materials, security devices, responsibilities, emergency numbers) • Review and update of emergency plan and assignment of responsibilities following incidents

II Operational monitoring and management *continued*

Position	Hazard	Cause	Monitoring procedures	Critical or operational limit (reference value)	Validation or verification	Management procedures, including corrective actions
1.3	Contamination of the system with chemicals or microorganisms (continued)	Backflow resulting from reduced pipe pressure	• Inspect and maintain the functionality and security of devices regularly (e.g. backflow-prevention devices) • Monitor pressure and flow in the system	• Inspection every six months; maintenance at least once a year • Backflow-prevention devices leak-proofed, functional • Normal fluctuation of pressure and water flow	• Installation and maintenance of backflow-prevention devices according to guidelines, accepted standards and references	• Maintenance procedures for backflow-prevention devices
1.4		Corrosion of pipes, valves, etc.	• Record pipe material and pipe dimension, date of installation • Inspect pipes for corrosion damage	• Inspection intervals are kept • Corrosion damage is not observable	• Recording and maintenance of pipe material comply with guidelines, accepted standards and references	• Purchasing specifications for pipes and fittings • Immediate inspection of pipes • Replacement of heavily damaged pipes with adequate pipe material
1.5		Do-it-yourself repairs in the system	• Inspect and maintain the system regularly • Provide regular training to building owners and managers	• Inspection or maintenance occurs at least once a year • Do-it-yourself repairs are well conducted • Certification of training	• Plumbers' certification complies with national standards • Installation, construction of pipes, as well as tapwater quality, comply with guidelines, accepted standards and references	• Procedures for inspection, management and training • Employment of only those plumbers with certification • Immediate shut-down of pipes and tap devices followed by reinstallation of pipes

II Operational monitoring and management *continued*

Position	Hazard	Cause	Monitoring procedures	Critical or operational limit (reference value)	Validation or verification	Management procedures, including corrective actions
2.1	Microbial growth (e.g. *Legionella*, *Pseudomonas*) in the system	Stagnation of water in pipes with dead ends	• Record length of dead-end pipes and pipes at risk of stagnation • Monitor regular flushing programme	• The length of water pipes' dead ends are ≤10 times of the pipe diameter or ≤3 litres in volume	• Construction of pipes complies with guidelines, accepted standards and references	• Procedures and programmes for regular flushing • Disconnection of dead ends
2.2		Intermittent use (shower, hosepipe, social room, office, vacation)	• Ensure regular use of tap devices • Inspect and maintain shut-off valves regularly, and check drainage pipes • Monitor a regular flushing programme	• Tap devices are used at least every third day • System is flushed regularly (take pipe volume) if system is out of use for more than four weeks • Shut-off valves are inspected at least every six months, and maintenance occurs at least once per year	• Inspection, maintenance, installation and construction of pipes and tapwater quality comply with guidelines, accepted standards and references	• Inspection, maintenance and flushing programmes and procedures • Totally shut off areas with intermittent use
2.3		Inadequate temperature in warm-water system (e.g. temperature in heater too low)	• Monitor warm-water temperature	• Warm-water temperature in heater at least 60 °C and in the whole system only temporarily below 60 °C • Circulation system not more than 5 °C below heater temperature in backflow of circulation	• Construction of pipes (insulation) and water temperature comply with guidelines, accepted standards • Tapwater quality follows national guideline values for drinking-water quality	• Programme and procedures for temperature monitoring • Pipes, heater and valves are insulated • Increased heater temperature • Adequate circulation

II Operational monitoring and management *continued*

Position	Hazard	Cause	Monitoring procedures	Critical or operational limit (reference value)	Validation or verification	Management procedures, including corrective actions
2.4	Microbial growth (e.g. *Legionella*, *Pseudomonas*, *Aeromonas*) in the system (continued)	Inadequate temperature in cold-water system	• Monitor cold-water temperature	• Cold-water temperature in the whole system below 20 °C, only temporarily below 25 °C (European standard)	• Construction of pipes (insulation) and water temperature comply with guidelines, accepted standards • Tapwater quality follows national guideline values for drinking-water quality	• Programme and procedures for temperature monitoring • Renew al of pipe insulation, or reinstall or pipes moved in the system
2.5		Inappropriate system material used	• Check and document pipe, valves and additional equipment material regularly, and update knowledge • Check microbial parameters and indicator parameters	• Regular check and documentation of pipe material is carried out	• Pipe material that complies with guidelines, accepted standards is used • Tapwater quality follows national guideline values for drinking-water quality	• Purchasing specifications for system materials • Immediate check and documentation of pipe material • Replacement of critical system components
2.6		Warm-water supply hydraulically unbalanced	• Inspect and maintain temperature of adjustable valves regularly • Monitor temperature in the system	• Inspect valves every six months, and maintain at least once per year • Keep temperature above 58 °C in the warm-water system	• Certification of temperature-adjustable valves • Water quality after valves follows national drinking-water guideline values	• Inspection, maintenance and monitoring programmes and procedures • Replacement of defective, damaged valves

II Operational monitoring and management *continued*

Position	Hazard	Cause	Monitoring procedures	Critical or operational limit (reference value)	Validation or verification	Management procedures, including corrective actions
2.7	Microbial growth (e.g. *Legionella, Pseudomonas, Aeromonas*) in the system (continued)	Heater sludge (forces growth of microorganisms)	• Inspect and maintain the heater annually, and monitor the cleaning programme	• Inspect and maintain intervals at least once per year • Ensure that sediment deposit in heater is not observable	• Inspection and maintenance of heater comply with guidelines and accepted standards • Microbiological parameters and indicator parameters follow national guideline values after heater maintenance at heater exit	• Maintenance and cleaning programmes and procedures • Cleaning and removal of sludge • Thermal or chemical disinfection
2.8	Local microbial contamination of the system	Inadequate tap hygiene (e.g. contaminated showerhead, aerator)	• Inspect showerheads, aerators, etc. regularly • Check microbiological parameters and indicator parameters after maintenance of tapwater devices	• Inspection of showerheads, aerators, etc. at least once per year • Turbidity < 1 NTU; *E. coli*, coliforms = 0, normal trend of colony counts after tapwater devices	• Inspection complies with guidelines, accepted standards and references • Tapwater quality follows national guideline values for drinking-water quality	• Inspection, maintenance, cleaning and testing procedures and programmes • Thermal or chemical disinfection • Replacement of tap devices
3.1	Leach-outs of organic compounds from pipe materials into drinking-water	Inappropriate material used or stagnation	• Check material requirements • Authorize only experienced staff (checking job sheets)	• Sufficient knowledge of staff about material used in the system and update of knowledge about system materials	• Use of material complies with guidelines, accepted standards and references	• Purchasing specifications for system materials • Procedures for selecting staff (including qualifications) • Searching for experienced staff and replacement of inappropriate material

II Operational monitoring and management *continued*

Position	Hazard	Cause	Monitoring procedures	Critical or operational limit (reference value)	Validation or verification	Management procedures, including corrective actions
4.1	Biofilm growth	Water flow is too low, resulting in colonization of surfaces	• Monitor water flow and pressure in the system	• Adequate water flow in the system	• Water flow complies with references and national standards	• Procedures and programmes for monitoring water flows and pressures • Adjustment of pipe dimension to the system • Check of functionality of temperature-adjustable valves, and replacement of defective valves
4.2		Poor chemical water quality leaving the treatment plant (e.g. post-treatment precipitation of floc, iron/ manganese precipitation)	• Monitor the flushing programme of the system regularly • Monitor iron, manganese, chloride, etc.	• Electrical conductivity and pH are normal • Turbidity <1 NTU after flushing programme	• Water treatment solutions comply with guidelines, accepted standards and references • Tapwater quality follows national guidelines for drinking-water quality	• Flushing and monitoring programmes and procedures • PoU water treatment before entering installation system (activated carbon filter, pH regulation)
4.3		Poor microbiological water quality leaving the treatment plant and in the distribution system	• Inspect and maintain the filter regularly • Check microbiological parameters or indicators in the system	• Inspection or maintenance intervals at least every six months • Turbidity <1 NTU and *E. coli*, coliforms = 0	• Tapwater quality complies with national guidelines for drinking-water quality	• Inspection, maintenance and monitoring programmes and procedures • Thermal or chemical disinfection • Boiling of tapwater

II Operational monitoring and management *continued*

Position	Hazard	Cause	Monitoring procedures	Critical or operational limit (reference value)	Validation or verification	Management procedures, including corrective actions
4.4	Biofilm growth (continued)	Inappropriate material used	• Check and document pipe, valves and additional equipment material regularly, and update knowledge • Check microbiological parameters and indicator parameters	• Regular check and documentation of pipe material is carried out	• Pipe material used complies with guidelines, accepted standards • Tapwater quality follows national guideline values for drinking-water quality	• Purchasing specifications for system materials • Immediate check and documentation of pipe material • Replacement of critical system components
5.1	Development of sediments	Inadequate cleaning programme (e.g. maintenance of filter)	• Check elements of cleaning programme according to current standards (e.g. regular maintenance of filters)	• Essential system elements in cleaning programme included	• Cleaning programme complies with guidelines, accepted standards and references	• Inspection, maintenance and monitoring programmes and procedures • Update of cleaning programme according to guidelines, accepted standards and references
5.2		Water velocity too high	• Check pipe dimension • Inspect or maintain controlled openings and closing valves and pumps	• Adequate system flow	• Inspection and maintenance comply with guidelines, accepted standards and references	• Design specifications • Inspection, maintenance and monitoring programmes and procedures • Removal of sediments by cleaning procedures • Replace pipe with inadequate dimensions

II Operational monitoring and management *continued*

Position	Hazard	Cause	Monitoring procedures	Critical or operational limit (reference value)	Validation or verification	Management procedures, including corrective actions
6.1	Drainage of the supply system	Natural disaster	• Ensure that emergency plan is up to date, and that responsible staff have been instructed in its use	• Emergency plan completed and updated	• Emergency plan complies with guidelines, accepted standards and references	• Emergency plan providing essential information for disasters (e.g. responsibilities, emergency call numbers) • Update and audit of emergency plan

NTU, nephelometric turbidity unit; PoE, point of entry; PoU, point of use.

Annex 2 Potential biological and chemical hazards in building water supplies

Etiologic agent	Incubation period	Clinical symptoms	Source of exposure	Confirmation of waterborne disease
Bacteria				
Acinetobacter	Variable, depending on type of infection	Nosocomial infections, including urinary tract infections, pneumonia, bacteraemia, secondary meningitis and wound infections. Diseases are predisposed by factors such as malignancy, burns, major surgery and weakened immune systems, particularly in neonates and elderly people.	Free-living organisms that grow in distribution systems. Conditions such as low flows that promote biofilms are likely to support growth. Exposure through contact or inhalation of aerosols.	Cultures from cases and isolation from implicated water.
Campylobacter	1–10 days (usually 2–4 days)	Abdominal pain, diarrhoea (with or without blood or faecal leukocytes), vomiting, chills and fever. The infection is self-limited and resolves in 3–7 days. Relapses may occur in 5–10% of untreated patients. Other less common clinical manifestations of *C. jejuni* infections include reactive arthritis and meningitis. Several reports have associated *C. jejuni* infection with Guillain-Barré syndrome, an acute demyelinating disease of the peripheral nerves.	Contamination caused by ingress of faecal contamination through faults in treatment or distribution of water supplies. Exposure through ingestion of faecally contaminated water.	Cultures from stools and isolation from implicated water.

Etiologic agent	Incubation period	Clinical symptoms	Source of exposure	Confirmation of waterborne disease
Bacteria *continued*				
Escherichia coli (enteroinvasive or enterotoxigenic)	10–12 hours seen in outbreaks up to 24–72 hours	Profuse watery diarrhoea without blood or mucus; abdominal cramping and vomiting.	Contamination caused by ingress of faecal contamination through faults in treatment or distribution of water supplies.	Demonstration of *E. coli* isolates from stools that are enterotoxigenic or enterohaemorrhagic.
E.coli O157:H7 (enterohaemorrhagic)	2–10 days with a median of 3–4 days	Bloody or non-bloody diarrhoea, severe abdominal cramps and occasional vomiting, fever infrequent. Between 2% and 7% of cases can develop the potentially fatal haemolytic uraemic syndrome, which is characterized by acute renal failure and haemolytic anaemia. Children younger than five years are at most risk of developing haemolytic uraemic syndrome.	Exposure through ingestion of faecally contaminated water.	Demonstration of *E. coli* of same serotype in implicated water and stools in persons.
Klebsiella and other Gram-negative bacteria (*Serratia marcesans, Stentrophomonas maltophilia, Aeromonas, Burkholderia cepacia, Enterobacter*)	Variable depending on organism and type of infection	*Klebsiella* spp. and other Gram-negative bacteria can cause invasive infections in hospitals, involving the bloodstream, urinary tract, respiratory tract, eyes and wounds. On rare occasions, *Klebsiella* spp., notably *K. pneumoniae* and *K. oxytoca*, may cause serious infections, such as destructive pneumonia. Patients at highest risk are those with impaired immune systems, such as the elderly or very young, patients with burns or excessive wounds, those undergoing immunosuppressive therapy, or those with HIV infection.	Free-living organisms that grow in distribution systems. Conditions such as low flows that promote biofilms are likely to support growth. Exposure through contact or inhalation of aerosols.	Cultures from cases and isolation from implicated water.

Etiologic agent	Incubation period	Clinical symptoms	Source of exposure	Confirmation of waterborne disease
Bacteria *continued*				
Legionella spp.	2–10 days (usually 5–6 days) 5 hours to 3 days (usually 1–2 days)	Legionellosis (pneumonic illness). Fever, non-productive cough, headache, abdominal pain, nausea, diarrhoea, respiratory failure. Pontiac fever is a milder, self-limiting disease with a high attack rate and an onset (five hours to three days) and symptoms similar to those of influenza: fever, headache, nausea, vomiting, aching muscles and coughing.	Free-living organisms that grow in water between 25 °C and 50 °C. Growth promoted by low flows and development of biofilms. Sources include: • cooling towers, evaporative condensers; • domestic hot-water systems that include sections that operate between 25 °C and 50 °C; • humidifiers; • hot tubs and spas; • dental water lines at a temperature above 25 °C; • ice machines; • other water sources, including stagnant water in fire sprinkler systems that contain water between 25 °C and 50 °C. Exposure through inhalation of aerosols or aspiration.	Identification of urinary antigen, serum antibodies or *Legionella* from the case. Isolation of *Legionella* from implicated water matching the type found in the case.

Etiologic agent	Incubation period	Clinical symptoms	Source of exposure	Confirmation of waterborne disease
Bacteria *continued*				
Non-tuberculous or atypical *Mycobacterium* spp. (*M. gordonae, M. kansasii, M. marinum, M. xenopi, M. scrofulaceum, M. avium, M. chelonae, M. intracellulare* and *M. fortuitum*)	1 week to 2 months	Atypical *Mycobacterium* spp. can cause a range of diseases involving the skeleton, lymph nodes, skin and soft tissues, as well as the respiratory, gastrointestinal and genitourinary tracts. Manifestations include pulmonary disease, Buruli ulcer, osteomyelitis and septic arthritis.	High densities can form in biofilms on the insides of pipes and taps. Non-tuberculous *Mycobacterium* can colonize, survive, persist, grow and multiply in tapwater. Sources include distribution systems, hot- and cold-water taps, ice machines, heated nebulizers, hot tubs, footbaths and showerhead sprays. Multiple routes of transmission, including ingestion, inhalation and contact.	Cultures from cases and isolation from implicated water.

Etiologic agent	Incubation period	Clinical symptoms	Source of exposure	Confirmation of waterborne disease
Bacteria *continued*				
Pseudomonas aeruginosa	Ranges from 8 hours to 5 days, depending on type of infection	*Pseudomonas aeruginosa* can cause a range of infections, but rarely causes serious illness in healthy individuals without some predisposing factor. It predominantly colonizes damaged sites such as burn and surgical wounds, the respiratory tract of people with underlying disease, and physically damaged eyes. From these sites, it may invade the body, causing destructive lesions or septicaemia and meningitis. Cystic fibrosis and immunocompromised patients are prone to colonization with *P. aeruginosa*, which may lead to serious progressive pulmonary infections. Water-related folliculitis and ear infections are associated with warm, moist environments such as swimming pools and hot tubs. Diseases are predisposed by factors such as malignancy, burns, major surgery and weakened immune systems, and groups such as the elderly or neonates are particularly at risk.	Common environmental organism with growth promoted by conditions that support biofilm development (low flows or stagnant water). Commonly associated with poorly maintained and disinfected hot tubs, whirlpools, swimming pools or saunas. Multiple routes of transmission, including ingestion, inhalation and contact.	Isolation of *P. aeruginosa* from cases and implicated water or demonstration of presence by specific immunodiagnostic test (e.g. direct fluorescent antigen) or by PCR.
Salmonella	6–72 hours (usually 12–36 hours)	Diarrhoea lasting three to five days accompanied by fever and abdominal pain. Usually the disease is self-limiting. Other less common manifestations include reactive arthritis, endocarditis, meningitis, pericarditis, pyoderma or pyelonephritis.	Contamination caused by ingress of faecal contamination through faults in treatment or distribution of water supplies.	Cultures from cases and isolation from implicated water.
Salmonella Typhi	3 to more than 60 days (usually 8–14 days)	Insidious onset of fever, headache, malaise, constipation or diarrhoea, anorexia.	Exposure through ingestion of faecally contaminated water.	Cultures from cases and isolation from implicated water.

Etiologic agent	Incubation period	Clinical symptoms	Source of exposure	Confirmation of waterborne disease
Bacteria *continued*				
Shigella	12 hours to 1 week (usually 1–3 days)	Abdominal cramps, fever and watery diarrhoea occur early in the disease. All species can produce severe disease, but illness due to *S. sonnei* is usually relatively mild and self-limiting. In the case of *S. dysenteriae*, clinical manifestations may proceed to an ulceration process, with bloody diarrhoea and high concentrations of neutrophils in the stool. The production of Shiga toxin plays an important role in this outcome.	Contamination caused by ingress of faecal contamination through faults in treatment or distribution of water supplies. Exposure through ingestion of faecally contaminated water.	Cultures from cases and isolation from implicated water.
Vibrio cholerae 01 or 0139	A few hours to 5 days (usually 2–3 days)	The initial symptoms of cholera are an increase in peristalsis followed by loose, watery and mucus-flecked “rice-water” stools that may cause a patient to lose as much as 10–15 litres of liquid per day. Non-toxigenic strains of *V. cholerae* can cause self-limiting gastroenteritis, wound infections and bacteraemia.	Contamination caused by ingress of faecal contamination through faults in treatment or distribution of water supplies. Exposure through ingestion of faecally contaminated water.	Isolation of toxigenic *V. cholerae* 01 or *V. cholerae* 0139 from implicated water and from stool or vomit of ill persons, or significant rise (fourfold) in vibriocidal antibodies.
Viruses				
Adenoviruses	1–12 days, depending on illness	Adenoviruses cause a wide range of infections, including gastroenteritis, acute respiratory diseases, pneumonia, pharyngoconjunctival fever, cervicitis, urethritis, haemorrhagic cystitis, epidemic keratoconjunctivitis (“shipyard eye”), and pharyngoconjunctival fever (“swimming pool conjunctivitis”). Different serotypes are associated with specific illnesses; for example, types 40 and 41 are the main cause of enteric illness.	Contamination caused by ingress of faecal contamination through faults in treatment or distribution of water supplies. Multiple routes of exposure, including ingestion, inhalation or contact with faecally contaminated water.	Identification of virus in stools using culture-based methods. Identification using PCR, ELISA or latex agglutination. Identification in water using PCR or culture-based techniques.

Etiologic agent	Incubation period	Clinical symptoms	Source of exposure	Confirmation of waterborne disease
Viruses *continued*				
Calicivirus *Norovirus* and *Sapovirus*	10–96 hours (usually 24–48 hours)	Nausea, vomiting and abdominal cramps. Usually about 40% of infected people present with diarrhoea; some have fever, chills, headache and muscular pain. Since some cases present with vomiting only and no diarrhoea, the condition is also known as “winter vomiting disease”.	Contamination caused by ingress of faecal contamination through faults in treatment or distribution of water supplies. Ingestion of faecally contaminated water.	Identification of virus in stools by PCR, ELISA or radioimmunoassay. Positive detection (electron microscopy) of virus in vomit or stool in ill people, or by serology. Identification in water using PCR.
Enteroviruses	12 hours to 35 days, depending on illness	The spectrum of diseases is broad and ranges from a mild febrile illness to myocarditis, meningoencephalitis, poliomyelitis, herpangina, hand-foot-and-mouth disease and neonatal multi-organ failure. The persistence of the viruses in chronic conditions such as polymyositis, dilated cardiomyopathy and chronic fatigue syndrome has been described.	Contamination caused by ingress of faecal contamination through faults in treatment or distribution of water supplies. Ingestion or inhalation of faecally contaminated water.	Identification of virus in stools using culture-based methods or PCR. Identification in water using culture-based methods or PCR.
Hepatitis A virus	15–50 days (median 28–30 days)	Severe damage to liver cells. In general, the severity of illness increases with age. The damage also results in the failure of the liver to remove bilirubin from the bloodstream, causing the typical symptoms of jaundice and dark urine. After a relatively long incubation, there is a characteristic sudden onset of illness, including symptoms such as fever, malaise, nausea, anorexia, abdominal discomfort and eventually jaundice. Although mortality is generally less than 1%, repair of the liver damage is a slow process that may keep patients incapacitated for six weeks or longer.	Contamination caused by ingress of faecal contamination through faults in treatment or distribution of water supplies. Ingestion of faecally contaminated water.	Positive anti-HAV IgM test, or liver function tests compatible with hepatitis in people who drank implicated water. Detection of HAV RNA in blood and stools. Identification in water using PCR.

Etiologic agent	Incubation period	Clinical symptoms	Source of exposure	Confirmation of waterborne disease
Viruses *continued*				
Rotavirus	24–72 hours	Acute infection has an abrupt onset of severe watery diarrhoea with fever, abdominal pain and vomiting; dehydration and metabolic acidosis may develop, and the outcome may be fatal if not appropriately treated.	Contamination caused by ingress of faecal contamination through faults in treatment or distribution of water supplies. Ingestion of faecally contaminated water.	Identification of virus in stools by PCR, ELISA or latex agglutination. Positive detection (electron microscopy) of virus in vomit or stool in ill people, or serology. Identification in water using PCR.
Protozoa				
Cyclospora cayetanensis	1–11 days (median 7 days)	Watery diarrhoea, abdominal cramping, weight loss, anorexia, myalgia and occasionally vomiting or fever. Relapsing illness often occurs.	Contamination caused by ingress of faecal contamination through faults in treatment or distribution of water supplies. Ingestion of faecally contaminated water.	Demonstration of *C. cayetanensus* in stools of two or more ill people.
Cryptosporidium parvum	1–12 days (median 7 days)	*Cryptosporidium* generally causes a self-limiting diarrhoea, sometimes including nausea, vomiting and fever, which usually resolves within a week in normally healthy people, but can last for a month or more.	Contamination caused by ingress of faecal contamination through faults in treatment or distribution of water supplies. Ingestion of faecally contaminated water.	Isolation of *C. parvum* oocysts from implicated water and from stools, or identification in intestinal fluid or small bowel biopsy specimen, or demonstration of *C. parvum* antigen in stools by a specific immunodiagnostic test (e.g. ELISA).

Etiologic agent	Incubation period	Clinical symptoms	Source of exposure	Confirmation of waterborne disease
Protozoa *continued*				
Entamoeba hystolytica	A few days to several months or more (commonly 2–4 weeks)	About 10% of infected people present with dysentery or colitis. Symptoms of amoebic dysentery include diarrhoea with cramping, lower abdominal pain, low-grade fever and the presence of blood and mucus in the stool. The ulcers produced by the invasion of the trophozoites may deepen into the classic flask-shaped ulcers of amoebic colitis. *Entamoeba histolytica* may invade other parts of the body, such as the liver, lungs and brain, sometimes with fatal outcome.	Contamination caused by ingress of faecal contamination through faults in treatment or distribution of water supplies. Ingestion of faecally contaminated water.	Isolation of *E. hystolytica* from stools of ill people, or demonstration of *E. hystolytica* trophozoite in tissue biopsy, culture or histopathology.
Giardia lamblia	3 to more than 25 days (median 7–10 days)	Symptoms generally include diarrhoea and abdominal cramps; however, in severe cases, malabsorption deficiencies in the small intestine may be present, mostly among young children. Giardiasis is self-limiting in most cases, but it may be chronic in some patients, lasting more than one year, even in otherwise healthy people.	Contamination caused by ingress of faecal contamination through faults in treatment or distribution of water supplies. Ingestion of faecally contaminated water.	Isolation of *G. lamblia* cysts from implicated water, or isolation of *G. lamblia* from stools of ill people, or demonstration of *G. lamblia* trophozoite in duodenal fluid or small bowel biopsy, or demonstration of *G. lamblia* antigen by specific immunodiagnostic test (e.g. DFA).
Chemicals				
Heavy metals (e.g. copper, lead, nickel and cadmium nickel)	Acute: <1 hour (5 min – 8 hours)	Range of chemical symptoms depending on the metal. Initial acute symptoms may include gastroenteritis (e.g. copper), but broader symptoms range from neurological impacts to kidney damage and cancer.	Ingestion of water containing excessive concentrations due to leaching associated with corrosion or stagnant water.	Demonstration of concentrations of metals in water exceeding guideline values.
Nitrite (e.g. in boiler treatment fluid)	1–2 hours	Methaemoglobinemia, nausea, vomiting, cyanosis, headache, dizziness, dyspnoea, trembling, weakness, loss of consciousness.	Ingestion of water contaminated by backflow or cross-connection of devices such as boilers to drinking-water supplies.	Demonstration of concentrations of nitrites in water exceeding guideline values.

Etiologic agent	Incubation period	Clinical symptoms	Source of exposure	Confirmation of waterborne disease
Chemicals *continued*				
Organic chemicals (e.g. benzo(a)pyrene, styrene, vinyl chloride)	Chronic, many years	Most likely symptom is cancer from long-term exposure.	Ingestion of water contaminated by inappropriate materials used in plumbing.	Demonstration of concentrations in water exceeding guideline values.
Water treatment chemicals (e.g. chlorine)	Acute (chlorine)	Substantial tastes and odours.	Ingestion of water containing excessive concentrations of chlorine.	Demonstration of concentrations in water exceeding guideline values.

DFA, direct fluorescent antigen; ELISA, enzyme-linked immunosorbent assay; HAV, hepatitis A virus; HIV, human immunodeficiency virus; IgM, immunoglobulin M; PCR, polymerase chain reaction; RNA, ribonucleic acid.

Source: Information adapted from Percival et al. (2004), Heymann (2008) and WHO (2008).

Glossary

Accreditation	An official authorization or certification to a person, organization or laboratory that has the credential to deliver certain tasks; certification to a laboratory, institution or someone who has met the standard required by an official authority (WHO, 2009). Accreditation provides an independent assessment of competency that provides confidence to users of services.
Actor	Individuals, groups or organizations that influence the overall safe management of building water supplies, including those who design, construct, manage, operate, maintain and regulate building water systems.
Aerosol	A suspension of fine solid or liquid particles in a gas, such as air.
Backflow	The unintended reverse flow of water or other substances into distribution pipes of drinking-water from an unintended source that is capable of polluting the drinking-water (American Society of Sanitary Engineering, 2007).
Backflow protection	Devices that prevent backflow (e.g. one-way valves, air gaps).
Back-siphonage	The reverse flow of water within a water-supply system due to negative pressures in the pipe system, enabling atmospheric pressure to force the flow of water backwards through a siphon action (World Plumbing Council, 2008). The reversing of normal flow resulting from negative or subatmospheric pressures in the distribution piping of a drinking-water supply system (WHO and WPC, 2006).
Biocide	A diverse group of poisonous substances, including preservatives, insecticides, disinfectants and pesticides, used to control organisms that are harmful to human or animal health, or that cause damage to natural or manufactured products.
Biofilm	A slimy matrix produced and inhabited by bacteria, which enables the bacteria to adhere to a surface and carry out certain essential biochemical processes.
Certification (personnel)	A programme to substantiate the capabilities of personnel by documenting their experience and learning in a defined area of endeavour (Symons et al., 2000).
Community acquired	Cases of illness that are not acquired in a health-care, travel or domestic (i.e. the patient's home) setting (Bartram et al., 2007). Community-acquired cases of legionellosis can almost always be attributed to inhalation of aerosols from devices such as cooling towers, hot tubs, industrial equipment and indoor fountains.

Component	Appliance, equipment. A device in which potable water is used and/or modified (e. g. water heater, chemical dosing unit, coffee-machine, toilet).
Contamination	Presence of an infectious or toxic agent or matter on a human or animal body surface, in or on a product prepared for consumption, or on other inanimate objects, including conveyances, that may constitute a public health risk (WHO, 2005). Presence of a disease agent on or in food, or any object that may come into contact with food (WHO, 2007).
Control	In a case–control study, the control group is the group of people who do not have the disease or condition of interest, and who are used to compare with those people who do.
Control measure	Any action and activity that can be used to prevent or eliminate a water safety hazard or reduce it to an acceptable level.
Cooling tower	Heat-transfer device in which warm water is cooled by evaporation in atmospheric air. Cooling towers usually incorporate an air fan for forced air movement, a circulating water pump, a water spray system and a cooling coil (World Plumbing Council, 2008).
Corrective action	Any action to be taken when the results of monitoring at the control point indicate a loss of control.
Corrosion	A surface reaction causing a gradual erosion of the material affected (WHO & WPC, 2006). The gradual deterioration or destruction of a substance (usually a metal) or its properties as a result of a reaction with the substance's surroundings (Symons et al., 2000).
Cross-connection	Any connection, physical or otherwise, between a drinking-water system and non-drinking-water, where contamination can enter the drinking-water supply lines by back pressure, back-siphonage, and backflow occurring in the water-supply system (American Society of Sanitary Engineering, 2007). Any physical connection or arrangement between two otherwise separate piping systems or containment means, one of which contains potable water, and the other water or fluid of unknown or questionable safety (WHO & WPC, 2006).
Dead leg	A length of water-filled pipe where there is little or no flow.
Disinfectant	An agent that destroys or inactivates harmful microorganisms (Symons et al., 2000).

Disinfection	The supply of safe drinking-water through the destruction of microbial pathogens (bacteria, viruses and protozoa), involving reactive chemical agents. It is used for surface waters and for groundwater subject to faecal contamination (WHO, 2008).
	The procedure whereby health measures are taken to control or kill the insect vectors of human diseases present in baggage, cargo, containers, conveyances, goods and postal parcels (WHO, 2005).
	The process of destroying or inactivating pathogenic organisms (bacteria, viruses, fungi and protozoa) by either chemical or physical means (Symons et al., 2000).
Disinfection by-product	The formation of chemical by-products (inorganic or organic) that results from the use of chemical disinfectants in water treatment (WHO, 2008).
Domestic water	Water used for all usual domestic purposes, including consumption, bathing and food preparation (WHO, 2008).
	Pertaining to municipal (household) water services as opposed to commercial and industrial water. The term is sometimes used to include the commercial component (Symons et al., 2000).
	Water that is delivered for normal personal use within a household, school or commercial premises (World Plumbing Council, 2008).
Enforcement	Administrative or legal procedures and actions to require compliance with legislation or associated rules, regulations or limitations (Symons et al., 2000).
Exposure	Concentration or amount of a particular agent that reaches a target organism, system or (sub)population in a specific frequency for a defined duration (WHO, 2004a).
	Contact between an agent and a target (WHO, 2004b).
Greywater	Water from the kitchen, bath or laundry, which generally does not contain significant concentrations of excreta (WHO, 2006b).
	Untreated household-used water, such as wash or rinse water from a sink, bathtub, or other household plumbing fixture, except a toilet (Symons et al., 2000).
Guidelines	Minimum requirements of safe practice to protect health or derive numerical guideline values.

Hardness	Hardness in water is caused by dissolved calcium and, to a lesser extent, magnesium. It is expressed as the equivalent quantity of calcium carbonate. Hardness above about 200 mg/litre can result in scale deposition, particularly on heating. No health-based guideline value is proposed for hardness (WHO, 2008). Hardness is caused mainly by the presence of calcium and magnesium in the water. Scale formation and excessive soap consumption are the main concerns. When heated, hard waters have a tendency to form scale deposits, which shorten the life of water heaters and other appliances (Health Canada, 2009).
Hazard	In the context of this document, a hazard is a biological, chemical or physical agent in water, or a condition of water, with the potential to cause an adverse health effect.
Hazard identification	The identification of the type and nature of adverse effects that an agent has an inherent capacity to cause in an organism, system, or (sub)population.
Hazardous event	An event that introduces hazards to, or fails to remove them from, the water supply (Bartram et al., 2009).
Health-based target	Target based on critical evaluation of health concerns.
Hot tub	Facilities that are designed for sitting in (rather than swimming); contain water usually above 32 °C; are generally aerated; contain treated water; and are not drained, cleaned or refilled for each user. Hot tubs are also called spa pools, whirlpools, whirlpool spas and heated spas.
Infection	The entry and development or multiplication of an infectious agent in a host. Infection may or may not lead to disease symptoms (e.g. diarrhoea) (WHO, 2006b). The entry and development or multiplication of an infectious agent in the body of humans and animals that may constitute a public health risk (WHO, 2005). The presence in the body of viruses or organisms, such as bacteria, protozoa, fungi or helminths, which multiply or develop, completing all or part of their lifecycle within the tissues of an animal or human host (infection may or may not lead to a disease state) (WHO et al., 1996).
Legislation (primary and secondary)	Law enacted by a legislative body or the act of making or enacting laws (WHO, 2006b). Primary legislation is the law-making legislation, which is also known as enabling legislation, and can be found in the form of an Act, a statute or a bill. Subordinate legislation is legislation that is subordinate to the primary law-making legislation. It cannot make laws or change Acts, statutes or bills (World Plumbing Council, 2008).

Maintenance	Activities aimed at keeping existing capital assets in serviceable condition (e.g. by repairing water-distribution pipes, pumps and public taps) (WHO, 2000).
Material	The substance from which a product is made.
Monitoring	The act of conducting a planned sequence of observations or measurements of control parameters, to assess whether a control point is operating within design specifications.
Multiple barrier approach	The multiple barrier approach in drinking-water is the concept of using more than one type of protection or treatment in series in a water-treatment process to control contamination (Symons et al., 2000).
Operational monitoring	The act of conducting a planned sequence of observations or measurements of control parameters to assess whether a control measure is operating within design specifications (e.g. for wastewater turbidity treatment) (WHO, 2008).
Outbreak	An epidemic limited to localized increase in the incidence of a disease (e.g. in a village, town or closed institution) (McMichael et al., 2003). A waterborne outbreak is a situation in which at least two people experience a similar illness after exposure to water (and possibly food) and the evidence suggests a probable water source (WHO, 2007).
Pathogens	Any microorganisms that cause disease in an organism, through direct interaction (infection) (Schmoll et al, 2006).
pH	The pH of a solution is the negative common logarithm of the hydrogen ion activity (WHO, 2008): $\mathrm{pH} = -\log(\mathrm{H}+)$ An expression of the intensity of the basic or acid condition of a liquid (WHO, 2006b).
Plumbing	The piping, fixtures and appliances within a property; and all the work associated with the design, installation, removal, alteration or repair of piping, fixtures and appliances in connection with drinking-water supply, non-drinking-water supply and drainage systems that flow in and out of buildings and between given connection points to points of use or disposal (World Plumbing Council Working Group, 2008).
Point of consumption	Draw-off point. Those points in the potable water installation from which water can be drawn.
Point-of-entry (PoE) treatment	A treatment device applied to the drinking-water entering a house or building for reducing contaminants in the drinking-water distributed throughout that house or building (Symons et al., 2000).
Policy	The set of procedures, rules and allocation mechanisms that provide the basis for programmes and services (WHO, 2006b).

Recycled water	Water that has been treated so that its quality is suitable for particular specified purposes, such as irrigation, toilet flushing or possibly drinking (WHO, 2006b). Sources of recycled water include sewage and greywater.
Risk	The probability of an adverse effect in an organism, system, or (sub)population caused under specified circumstances by exposure to an agent (WHO, 2008). The likelihood of a hazard causing harm in exposed populations in a specified time frame, including the magnitude of that harm (WHO, 2008).
Risk assessment	A process intended to calculate or estimate the risk to a given target organism, system, or (sub)population, including the identification of attendant uncertainties, following exposure to a particular agent, taking into account the inherent characteristics of the agent of concern, as well as the characteristics of the specific target system. The overall process of using available information to predict how often hazards or specified events may occur (likelihood) and the magnitude of their consequences (adapted from AS/NZS 4360:1999).
Risk management	Decision-making process involving considerations of political, social, economic and technical factors with relevant risk-assessment information relating to a hazard so as to develop, analyse, and compare regulatory and non-regulatory options, and to select and implement appropriate regulatory response to that hazard. Risk management comprises three elements: risk evaluation, emission and exposure control, and risk monitoring (WHO, 2004a). The systemic evaluation of the water-supply system, the identification of hazards and hazardous events, the assessment of risks, and the development and implementation of preventive strategies to manage risks (WHO, 2006b).
Sensitive or vulnerable population	Vulnerable groups or populations are people who might be vulnerable to the effects of exposure because of their development stage (e.g. children) or because of pre-existing health conditions (e.g. asthmatics and air pollution).
Spa pool	A facility that is designed for sitting in (rather than swimming); contains treated water usually above 32 °C; is usually aerated; and is not drained, cleaned or refilled for each user. Also known as a hot tub, whirlpool, whirlpool spa, heated spa, bubble bath or jacuzzi.
Stakeholder	Person or entity with an interest or 'stake' in the outcome of a particular action or policy (McMichael et al., 2003).
Storage (cistern)	Tank or storage container in which water is stored (American Society of Sanitary Engineering, 2007).

Surveillance	The systematic ongoing collection, collation and analysis of data for public health purposes and the timely dissemination of public health information, for assessment and public health response as necessary (WHO, 2005).
Thermostatic mixing valves	Tempering valves that are typically temperature-activated. Used to mix hot and cold water to achieve a predetermined outlet temperature, and that are fitted between the water heater and the point of use to control the distribution temperature. Slightly different temperature ranges are used in some countries.
Turbidity	Cloudiness caused by the presence of suspended matter in water (WHO, 2008).
Validation	The process of obtaining accurate and reliable evidence that a water safety plan is effective.
Verification	The application of methods, procedures, tests and other evaluations, in addition to monitoring, to determine compliance with a water safety plan.
Water safety plan	A comprehensive risk-assessment and risk-management approach that encompasses all steps in water supply, from catchment to consumer.
Water system (external or building-specific)	An external system is one that provides multiple users and can be either publicly or privately owned. A building-specific supply is defined as an individual and isolated drinking-water system that is distinct from any external water system.

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Extensive experience shows that poor design and management of water systems in buildings can cause outbreaks of disease. The types of building, water uses, disease outcomes and individuals affected are diverse. The health risks are preventable and can be readily controlled. However, evidence from outbreak detection suggests that the overall trend is increasing. With increasing global urbanization, the overall exposure of the human population to poorly designed or managed water systems in buildings is increasing rapidly. Consequently, the risk of disease outbreaks is also increasing. Actions to reduce the risk of disease should be considered a public health priority.

This document provides guidance for managing water supplies in buildings where people may drink water; use water for food preparation; wash, shower, swim or use water for other recreational activities; or be exposed to aerosols produced by water-using devices, such as cooling towers. These uses occur in a variety of buildings, such as hospitals, schools, child and aged care facilities, medical and dental facilities, hotels, apartment blocks, sport centres, commercial buildings and transport terminals.

This text is one of a series of supporting documents that provide guidance on implementing the World Health Organization's *Guidelines for drinking-water quality* (WHO, 2008). It is intended to support the improvement of water safety within buildings.

The target audience for this document includes the full range of "actors" who influence the overall safe management of building water supplies. In particular, it is directed at those who design, construct, manage, operate, maintain and regulate building water systems. This document is intended to be a useful resource for the development of training and information material.

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