MINISTRY OF HEALTH
SINGAPORE

Communicable Diseases Agency Singapore

EARLY CHAPTER RELEASE

NATIONAL INFECTION PREVENTION AND CONTROL GUIDELINES ON WATER MANAGEMENT IN ACUTE HEALTHCARE FACILITIES

April 2026

FOREWORD

The National Infection Prevention and Control (NIPC) Committee was established by the Singapore Ministry of Health in 2014 to provide national leadership in infection prevention and control (IPC), including formulation of IPC guidelines and standards for IPC practices across healthcare settings. It is with great pleasure that I present this early release of the newly developed chapter on **Water Management in Acute Healthcare Facilities**. This chapter has been issued ahead of the next revision of the *National IPC Guidelines for Acute Healthcare Facilities* to support timely implementation of critical water safety and IPC measures.

Water safety in healthcare facilities has become increasingly important as healthcare environments grow more complex and new IPC challenges emerge. Singapore's tropical climate, coupled with intricate water systems in modern healthcare infrastructure, presents unique risks for waterborne infections. Given the complexity of modern healthcare water systems, the goal of water management is not absolute elimination of microorganisms, but the effective control of conditions that allow harmful pathogens to proliferate. Emphasis should therefore be placed on prevention, systematic risk assessment, and proactive management. A *risk-based approach* allows healthcare facilities to prioritise monitoring, control measures, and targeted interventions, particularly to protect vulnerable patient populations who may be more susceptible to adverse outcomes.

This chapter has been developed based on current scientific evidence, established international standards, and local operational considerations. It provides practical direction on water system mapping, risk assessment, monitoring strategies, mitigation measures, and water management considerations during construction, renovation, and routine healthcare operations. The recommendations are intended as guidance rather than prescriptive requirements. Facilities should apply the principles in accordance with their local context, infrastructure, and risk profile, and integrate them into their existing Water Management Programmes and IPC governance structures.

As an early release, this chapter will serve as a consultation document during a six-month in-use period prior to its formal incorporation into the revised *National IPC Guidelines for Acute Healthcare Facilities*. During this period, healthcare institutions are encouraged to implement the guidance where appropriate and to provide feedback to inform further refinement. The NIPC Committee and Secretariat welcome constructive feedback, particularly

in areas where clarification or enhancement may be required, we continue to strengthen our national approach to water safety in healthcare facilities.

Finally, I would like to extend my sincere appreciation to the writing committee, PUB, engineering specialists, and clinical partners who contributed their expertise to this work.

Adjunct Asst Prof Kalisvar Marimuthu
Chairperson
National Infection Prevention and Control Committee

ACKNOWLEDGEMENT

This chapter on Water Management, which will be incorporated into the forthcoming revision of the *National Infection Prevention and Control Guidelines Acute Healthcare Facilities,* has been reviewed and endorsed by the NIPC Committee. The composition of the NIPC Committee is provided in Table 1 below.

Table 1: Composition of NIPC Committee

S/N	Name	Role	Designation
NIPC Committee members			
1	Adj Asst Prof Kalisvar Marimuthu	Chairperson	Deputy Clinical Director, Department of Infection Prevention & Control, Tan Tock Seng Hospital (TTSH) Senior Consultant, Department of Infectious Diseases, National Centre for Infectious Diseases (NCID) & TTSH
2	Prof Dale Fisher	Advisor	Group Chief of Medicine, National University Health System (NUHS)
3	A/Prof Ling Moi Lin	Member	Director, Infection Prevention, Singapore Health Services Pte Ltd Lead, Infection Prevention, Regional Health Services, SingHealth Emeritus Consultant, Infection Prevention & Epidemiology, Singapore General Hospital (SGH)
4	Dr Ray Lin	Member	Clinical Lead, Infection Prevention and Control Office, Woodlands Hospital (WH)
5	Adj Asst Prof Surinder Pada	Member	Head of Department of Infection Prevention and Hospital Epidemiology Head of Division Infectious Diseases Senior Consultant, Ng Teng Fong General Hospital (NTFGH)
6	Ms Poh Bee Fong	Member	Deputy Director of Nursing and Infection Control Lead Nurse, TTSH
7	Dr Margaret Soon	Member	Head, Infection Prevention, Control and Outreach Office, NCID
8	Dr Louisa Sun	Member	Consultant, Infectious Diseases, Alexandra Hospital (AH)
9	Dr Tan Si Huei	Member	Head and Senior Consultant, Laboratory Medicine, Changi General Hospital (CGH)
10	Clinical Prof Thoon Koh Cheng	Member	Chairman, Division of Medicine Senior Consultant, Infectious Diseases, KK Women's and Children's Hospital (KKH)

11	Dr Albert Ty	Member	Director, Value, Safety & Performance Division (VSPD), Ministry of Health (MOH)
CDA Representatives and NIPC Secretariats			
12	Dr Adelina Young	CDA Representative	Acting Director, National Infection Control & Healthcare Epidemiology (NICHE) Division, Communicable Diseases Agency (CDA)
13	Ms Ong Xin Yi	CDA Representative	Senior Assistant Director, Infection Control & Strategic Coordination (ICSC), NICHE Division, CDA
14	Ms Nur Dianah Awaludin	Secretariat	Assistant Director, ICSC, NICHE Division, CDA
15	Ms Norine Goh	Secretariat	Senior Manager, ICSC, NICHE Division, CDA
16	Mr Abel Tan	Secretariat	Assistant Manager, ICSC, NICHE Division, CDA
17	Mr Orton Koh	-	Intern, ICSC, NICHE Division, CDA

The MOH and CDA would like to acknowledge A/Prof Ling Moi Lin (Director, Infection Prevention and Control, SGH) & Adj Asst Prof Surinder Pada (Head of Division and Senior Consultant, Division of Infectious Diseases, NTFGH) for leading the guideline development group. The experts who contributed in their individual capacity to the development of the guidance document are listed in Table 2.

Table 2: Experts who contributed to the development of the guidance document (in alphabetical order)

Name	Designation
A/Prof Ling Moi Lin (Chairperson)	Director, Infection Prevention, Singapore Health Services Pte Ltd; Lead, Infection Prevention, Regional Health Services, SingHealth; and Emeritus Consultant, Emeritus Consultant, Infection Prevention and Epidemiology, SGH
Adj Asst Prof Surinder Pada (Co-Chairperson)	Head of Department of Infection Prevention and Hospital Epidemiology; Head of Division Infectious Diseases, and Senior Consultant, NTFGH
Ms Chee Poh Ling	Assistant Nurse Clinician, Infection Control, NTFGH
Dr Deborah Lai Chooi Mun	Consultant, Dept of Microbiology and Dept of Infection Prevention and Epidemiology, SGH
Ms Joanna Tan	Nurse Clinician, Infection Control, TTSH
Ms Toh Hui Xian	Nurse Clinician, Infection Prevention & Epidemiology, SGH
Dr Elaine Quek	Chief Specialist (Treatment & Distribution System), Water Quality Department, PUB Singapore
Dr Sean Wu Jiawei	Deputy Director of Infection Prevention and Control, Division of Infectious Diseases, Department of Medicine, National University Hospital (NUH)

Abbreviations

BWD	Building Water Distribution System
CDC	Centers for Disease Control and Prevention
FSS	Food Safety & Security
GFP	Green Fluorescent Protein
HAI	Healthcare-Associated Infections
HDU	High-Dependency Units
HIV	Human Immunodeficiency Virus
HPC	Heterotrophic Plate Counts
ICRA	Infection Control Risk Assessment
IPC	Infection Prevention and Control
LP	Licensed Plumber
NTM	Non-Tuberculosis Mycobacteria
OPPPs	Opportunistic Premise Plumbing Pathogens
PCRA	Pre-Construction Risk Assessment
pH	potential of Hydrogen (acidity/alkalinity measure)
PUB	Singapore's National Water Agency
POU	Point-of-Use
SFA	Singapore Food Agency
SAC-SINGLAS	Singapore Accreditation Council's Singapore Laboratory Accreditation Scheme
TMV	Thermostatic mixing valves
WMC	Water Management Construction

1.1 Introduction

Hospital water and water-related devices as well as moist environments can serve as reservoirs of waterborne pathogens in healthcare settings (e.g., *Legionella pneumophila*, non-tuberculosis mycobacteria (NTM), *Pseudomonas aeruginosa*). The hospital environment may facilitate colonisation and amplification of these pathogens due to patient care activities, suitable water temperatures for bacterial growth, and the complex structure of hospital water systems, which may lead to stagnation, corrosion, and biofilm formation. Therefore, this chapter aims to provide a framework within which these hazards may be formally monitored and managed as a necessary element of healthcare facilities' Infection Prevention and Control (IPC) Programme, through a dedicated Water Management Programme.

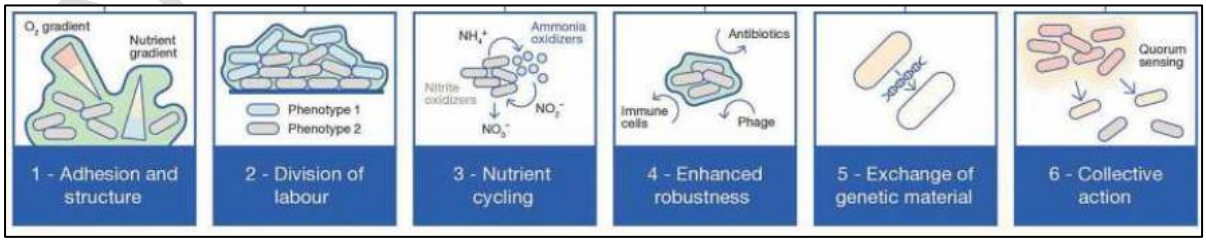
A Water Management Programme should be implemented in all acute healthcare facilities, with relevant sections of this chapter implemented where applicable based on the set up of the facility. This chapter expands on the need for such programmes by examining biofilm formation, associated challenges, and the key component of successful implementation: a dedicated team focused specifically on water management.

1.1.1 Biofilm and the Water System

The hallmark of a biofilm is the embedding of micro-organisms within a matrix of extracellular polymeric substances that is produced by the constituent cells and additionally accumulates material (e.g., metals, salts, bacteria) from the surrounding environment. Problems arise when secondary bacterial colonisers invade this matrix and subsequently pose a problem in the healthcare context.

Biofilms confer many advantages to survival detailed in Figure 1.1 below:

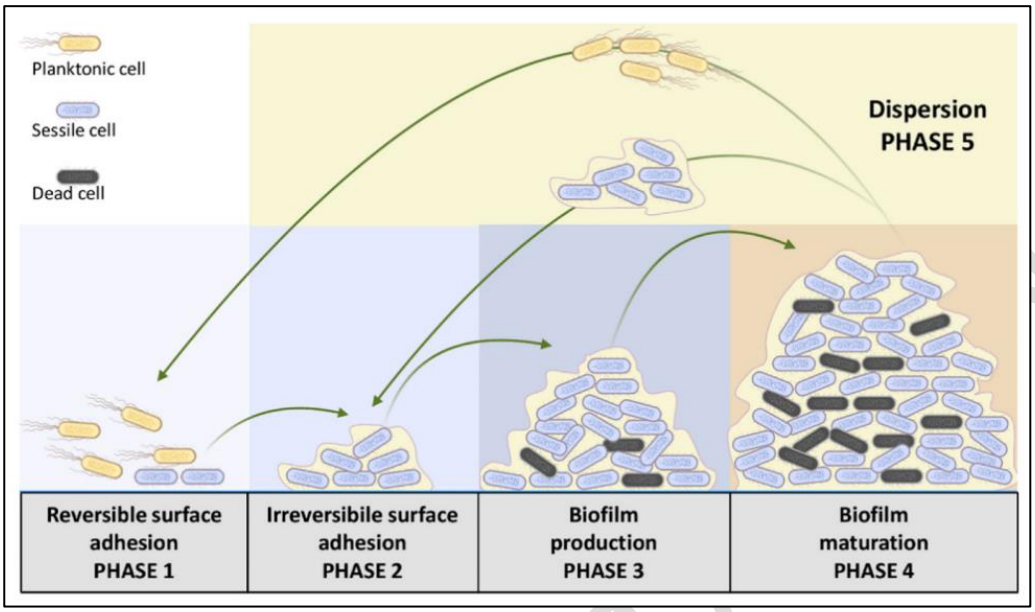
Figure 1.1: Biofilm Life Cycle



Note. From An Introduction to Biofilms – What They Are, Why They Form and Their Impact on Built and Natural Environments, by N. C. Bamford, C. E. MacPhee, & N. R. Stanley-Wall, 2023, *Microbiology*, 169, Article 001338. https://doi.org/10.1099/mic.0.001338.

Biofilm formation occurs very quickly and is in stages as seen from Figure 1.2 below:

Figure 1.2: Phases of Biofilm formation



Note. From Metal-Based Nanoparticles: Antibacterial Mechanisms and Biomedical Application, by D. Franco, G. Calabrese, S. P. P. Guglielmino, & S. Conoci, 2022, *Microorganisms*, *10*(9), Article 1778. https://doi.org/10.3390/microorganisms10091778

Therefore, these well-adapted mechanisms, and the formation of biofilms in our water systems have implications for patient care. In the human environment, they can form, amongst many other scenarios in:

a) Showers since they provide a moist and warm environment for them to thrive;

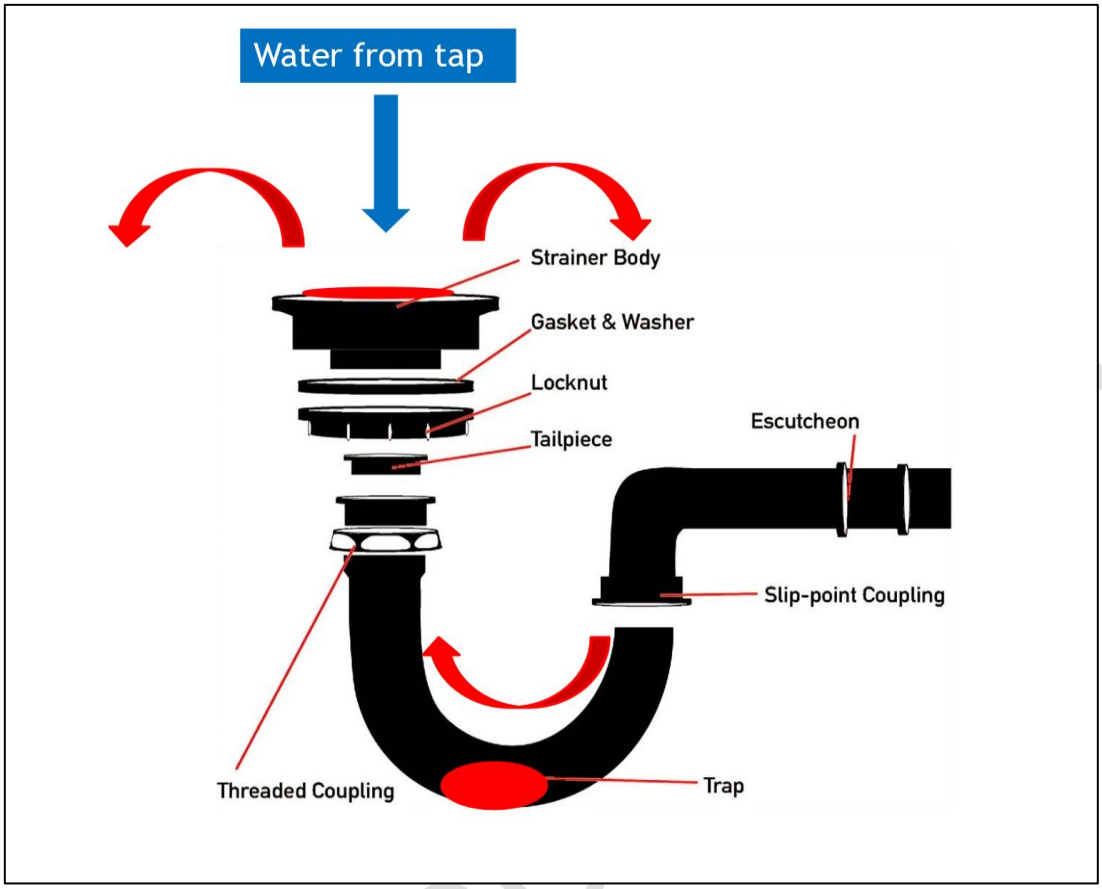
b) Inside water and sewage pipes and cause clogging and corrosion;

c) On floors and counters, where they can make sanitation difficult in food preparation areas;

d) In cooling- or heating-water systems, where they are known to reduce heat transfer and have a potential for dispersal.

The nature of the biofilm itself then makes it difficult for antibiotics and antiseptics to penetrate these surfaces to eradicate pathogens within the matrix and are even capable of evading the host immune system. It is therefore imperative that an understanding of where these biofilms may form and measures/strategies that can mitigate their formation needs to be considered if we are to prevent harm that they pose to our patients and staff. Therefore, it is worthwhile investing the time and expertise to design systems that avoid dead legs – sections of pipework with little or no water flow where water stagnates, which encourage biofilm formation. Type and placement of hardware are also important considerations such as use of aerators and placement of thermostatic mixing valves (TMVs).

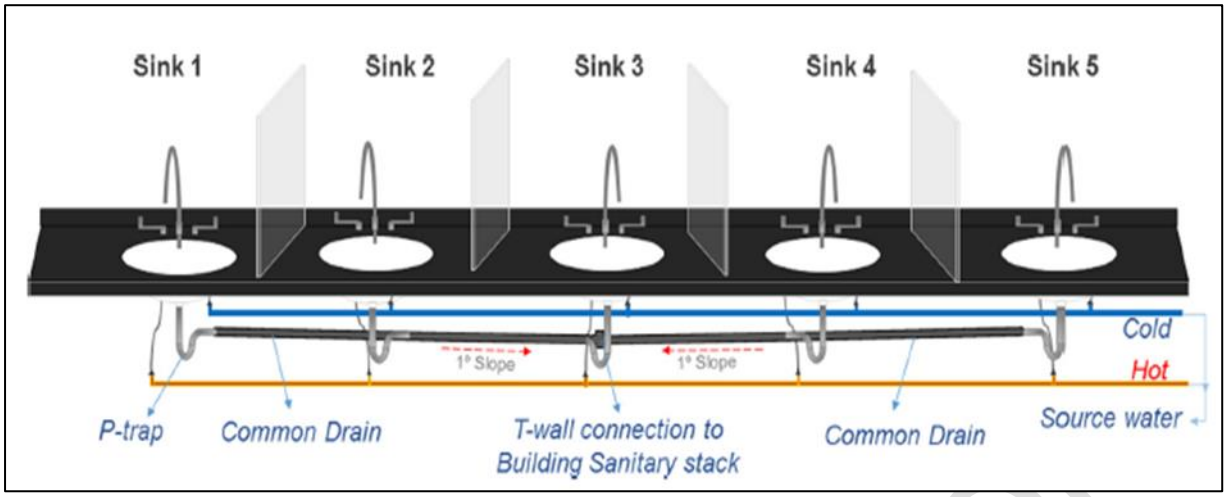
Figure 1.3: Illustration of parts of a sink trap



Note. Adapted from *DIY kitchen sink installation*, by Sinkology (n.d.) https://www.sinkology.com/diy-install/diy-kitchen-sink-installation/

Kotay et al devised a laboratory set up of a gallery of sinks (Figure 1.4) and used dispersion of green fluorescent protein (GFP)-expressing *Escherichia coli* from sink wastewater to the surrounding environment as a model of how transmission may occur. When the GFP-expressing *E. coli* cells were allowed to mature in the P-trap under conditions similar to those in a hospital environment, a GFP-expressing *E. coli*-containing putative biofilm extended upward over seven days to reach the strainer. This subsequently resulted in droplet dispersion to the surrounding areas during faucet operation when water from the faucet hit the contaminated strainer causing the formation of droplets that could readily disperse. The authors also demonstrated that P-trap colonisation could occur by retrograde transmission along a common pipe, suggesting that all parts of a sanitary plumbing system that was connected could become contaminated.

Figure 1.4: Layout of the sink gallery comprising the 5 sink modules and the associated plumbing



Note. From *Spread from the sink to the patient: In situ study using green fluorescent protein (GFP)-expressing Escherichia coli to model bacterial dispersion from hand-washing sink-trap reservoirs*, by S. Kotay, W. Chai, W. Guilford, K. Barry, & A. J. Mathers, 2017, *Applied and Environmental Microbiology*, 83(8), e03327-16

Kanamori et al (2016) published an extensive review of healthcare-associated outbreaks and infections linked to water reservoirs in healthcare settings. Their review highlighted that a wide range of water sources – not linked to sinks – have been associated with nosocomial outbreaks. These include potable water, faucet aerators, showers, tub immersion, toilets, dialysis water, ice and ice machines, water baths, flower vases, eyewash stations, and dental-unit water stations. Pathogens implicated include *Legionella* and other gram-negative bacilli, NTM, fungi, protozoa, and viruses. Transmission may occur through direct or indirect contact, ingestion or aspiration of contaminated water, or inhalation of aerosols.

Yiek et al (2021) similarly reviewed water containing hospital equipment and further elaborated on potential mitigation strategies, reinforcing the importance of proactive water management in healthcare settings.

1.1.2 Local Epidemiology

Within the Singapore context, several outbreaks related to biofilm and waterborne pathogens have been reported. These organisms are characteristic of opportunistic premise plumbing pathogens (OPPPs), a group of microorganisms that colonise and proliferate within building water systems and may cause infection in susceptible individuals. It has become increasingly clear from outbreak investigations that although water coming into hospitals from the PUB (Singapore's National Water Agency) supply is of good quality and well chlorinated, it degrades when stored in water tanks for extended periods of time and when it travels through the extensive network of pipes often found in healthcare facilities.

In addition to *Legionella* spp., outbreaks involving other opportunistic Gram-negative organisms have been linked to sinks, tap aerators, ice machines, and heater-cooler units used in cardiac bypass surgery. These events further illustrate the ability of OPPPs to persist in moist environments and water-associated medical devices within healthcare facilities. Singapore's tropical climate, characterised by consistently warm ambient temperatures, may further promote microbial growth within building water systems. Rising environmental temperatures associated with global climate change may exacerbate these risks.

1.2 Water Management Committee

1.2.1 Establishing a Water Management Committee

Each healthcare facility should establish a Water Management Committee responsible for the development, implementation, oversight, and continuous improvement of the facility's Water Management Programme. The Committee provides a dedicated forum for multidisciplinary collaboration, risk assessment, and strategic planning to effectively manage waterborne pathogen risks within building water system in healthcare settings. Suggested composition and structure of the committee are outlined below.

1.2.1.1 Membership and Structure

The membership and structure of the committee should minimally include:

a) Director/Head of Infection Prevention and Control (Chairperson)

b) Facilities management representative (Co-chairperson)

c) Workplace safety representative

d) Microbiologist (or equivalent technical expertise)

e) Infection Prevention Nurse

Depending on the complexity of the facility's water systems, additional engineering, plumbing, or water treatment expertise may be co-opted as needed.

1.2.1.2 Role of the Water Management Committee

The Committee should possess comprehensive knowledge of the building's water system design and operational processes. The Committee should be able to identify hazards and control measures, establish appropriate control limits, implement corrective actions when required, and monitor and document the performance of the Water Management Programme.

Committee members should meet regularly to review findings, monitor programme effectiveness, and address issues identified through routine operations, surveillance, or incident investigations. The Committee is responsible for determining and overseeing necessary actions to manage physical, chemical, and microbiological hazards that may affect water safety within the healthcare facility.

The team should typically meet on a quarterly basis, with additional meetings convened as necessary based on operational needs or emerging risks. The water management programme should be reviewed annually, and whenever changes are made to the water system that may introduce additional risk (e.g., addition of new equipment that could generate aerosols or commissioning of a new ward).

1.2.1.3 Reporting structure

An appropriate governance structure should be established to ensure adequate oversight of water safety management. The Water Management Committee should report regularly on programme performance, identified risks, and mitigation measures to the Infection Prevention Committee. Key findings, identified risks, and recommendations of the Water Management Committee should be communicated to senior management to support timely decision-making and appropriate resource allocation.

1.3 Mapping out Water System

1.3.1 Introduction

An essential step in effective water management is to understand the components and configuration of the facility's water system. This includes the water source, distribution infrastructure such as pipes and fittings, outlets at points of use, and associated systems including water dispensers, ice machines, hot water heaters, etc. Mapping the water system enables the Water Management Committee to identify potential hazards and risks, supporting the development of targeted monitoring, risk mitigation, and management strategies specific to the facility.

1.3.2 Main Water Supply

The bulk of the water supply to healthcare facilities in Singapore is supplied by PUB, Singapore's National Water Agency, through its potable water distribution system. Water supplied by PUB meets the quality standards stipulated under the Food Safety and Security (FSS) (Non-Packaged Drinking Water) Regulations 2025. However, when water enters the healthcare facility's internal distribution system, its quality may change, particularly if water is

stored for prolonged periods prior to use. It is therefore important to map the entire water supply system and understand the specific conditions under which water is stored, distributed, and conveyed to points of use (e.g., taps).

PUB's water supply first enters the facility through a water main (or distribution pipe) connected to a water meter. Beyond the water meter, water is distributed throughout the facility via a network of pipes, pumps, pressure vessels, valves, storage tanks, and other fittings to various outlets, including taps and appliances. This entire water system is generally managed and maintained by the building owner or facility management. An example of water flow within a building is provided in Figure 1.5.

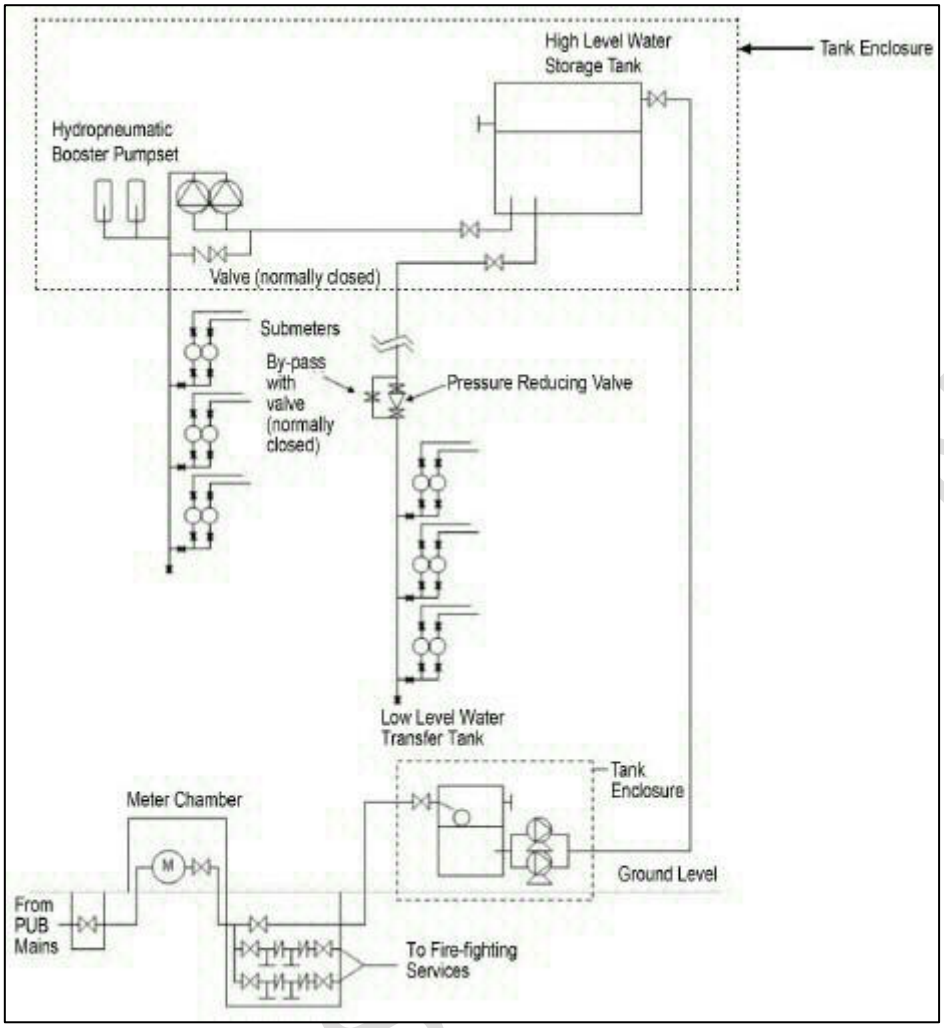
The management and maintenance of the water system should be carried out in accordance with the Singapore Standard (SS) 636: Code of Practice for Water Services, which covers the supply of potable water to all residential, commercial and industrial building/premises. The scope of SS 636 extends from PUB's water supply to the point where the water is drawn off for use, including storage infrastructure. Pipes and water fittings used should comply with PUB standards, and all water service installation work should be undertaken by Licensed Plumbers (LPs).

In addition to compliance with SS 636, there are several operational and environmental factors within healthcare facilities that may affect the quality of water delivered to points of use. These factors should be carefully assessed as part of the facility's water management programme, including considerations beyond those stipulated in existing standards. Key factors are outlined below:

1.3.2.1 Age of water within the water system

Water supplied through PUB's distribution network contains residual chlorine, which gradually degrades over time. As the age of water increases, residual chlorine levels decline, which may increase the risk of microbial growth within the water system.

Figure 1.5: Example of main water supply system within a facility



Note: From PUB, Singapore.

In facilities with multiple buildings, water is commonly stored in rooftop or intermediate storage tanks to ensure continuity of supply, typically providing a buffer of at least 24 hours in the event of supply interruption from PUB. While such storage supports operational resilience, prolonged storage may result in depletion of residual disinfectant levels. Facility managers should therefore balance contingency storage requirements with measures to minimise excessive water age. Water age within storage tanks can be estimated using the following formula:

$$Water\ age\ in\ storage\ tank\ (hr) = \frac{Volume\ of\ water\ in\ tank\ (m^3)}{Water\ demand\ (\ m^3\ /\ day)} x\ 24\ hrs\ /\ day$$

For buildings with low occupancy or low water demand where water age may exceed 24 hours, lowering the tank water levels or increasing turnover may help reduce stagnation. In facilities with multiple storage tanks, water age across different tanks should be considered collectively to estimate the total water age at the point of use.

1.3.2.2 Residual chlorine levels

PUB's water supply contains chlorine, typically in the form of monochloramines, which takes a longer time to decay in the distribution network, preventing microbial growth over a longer distance of the network. However, chlorine levels within building water systems may still decline over time.

Maintaining adequate residual chlorine at points of use is therefore important to minimise the risk of microbial contamination. While the World Health Organisation and FSS regulations indicate that chlorine levels should not exceed 5 mg/L, facility managers should also ensure sufficient residual disinfectant within the internal water distribution system. As a general guide, total residual chlorine levels of at least 0.3 mg/L at tap points may provide a basic level of protection against potential microbial growth.

Further details on measuring, monitoring, and interpreting total residual chlorine levels will be provided in Section 1.4 Water Sampling and Monitoring Guide, which outlines water sampling and interpretation guide for initial building assessment and routine monitoring.

Where measured chlorine levels at the tap points are low, facilities should first assess whether water age within the system can be reduced or whether specific sections of the distribution system are associated with greater chlorine decay. Targeted corrective measures, such as system flushing or optimisation of storage volumes, may then be implemented.

If residual chlorine levels remain low despite these measures, facilities may consider installing a disinfection system (i.e., chlorine/monochloramine dosing system or other equivalent disinfectants). Such systems should be carefully designed and implemented by LPs or experienced contractors to ensure chlorine concentrations remain within PUB regulatory limits and continue to comply with FSS water quality requirements.

1.3.2.3 Temperature of hot water systems

Hot water systems (e.g., instant heaters, storage heaters, etc) may be installed to supply hot water for showers, washing etc. In these systems, the heating process can reduce residual chlorine levels, and if temperatures are not adequately controlled, there is an increased risk of microbial growth within the system. Stagnation of hot water within pipelines may further promote biofilm formation and microbial colonisation of the water distribution system.

While many microorganisms are inhibited at higher temperatures, *Legionella* species are a notable exception and can proliferate in water temperatures of up to 45°C. Appropriate temperature control is therefore an important risk mitigation measure.

To minimise these risks, healthcare facilities should consider the following measures:

a) Maintain hot water tank temperature at >60°C;
b) Ensure that the hot water in circulation does not fall below 49°C;
c) Avoid stagnation within hot water pipework through appropriate system design, maintenance and regular use;
d) Install TMV as close as practicable to the point of use to balance scald prevention with microbial risk control.

1.3.2.4 Unused Pipelines

During renovation or facility upgrades, new water pipelines may be installed while some sections of older pipelines remain connected to the distribution network but are no longer actively used. These old and unused pipelines may retain stagnant water and are often isolated by valves. Over time, valve integrity may deteriorate, potentially allowing stagnant water from unused pipelines to enter and mix with the fresh water supply, thereby affecting water quality and safety.

Facilities should therefore identify the locations of unused or redundant pipelines and, where appropriate, physically disconnect or permanently isolate these pipelines from the active distribution network to minimise potential water quality risks.

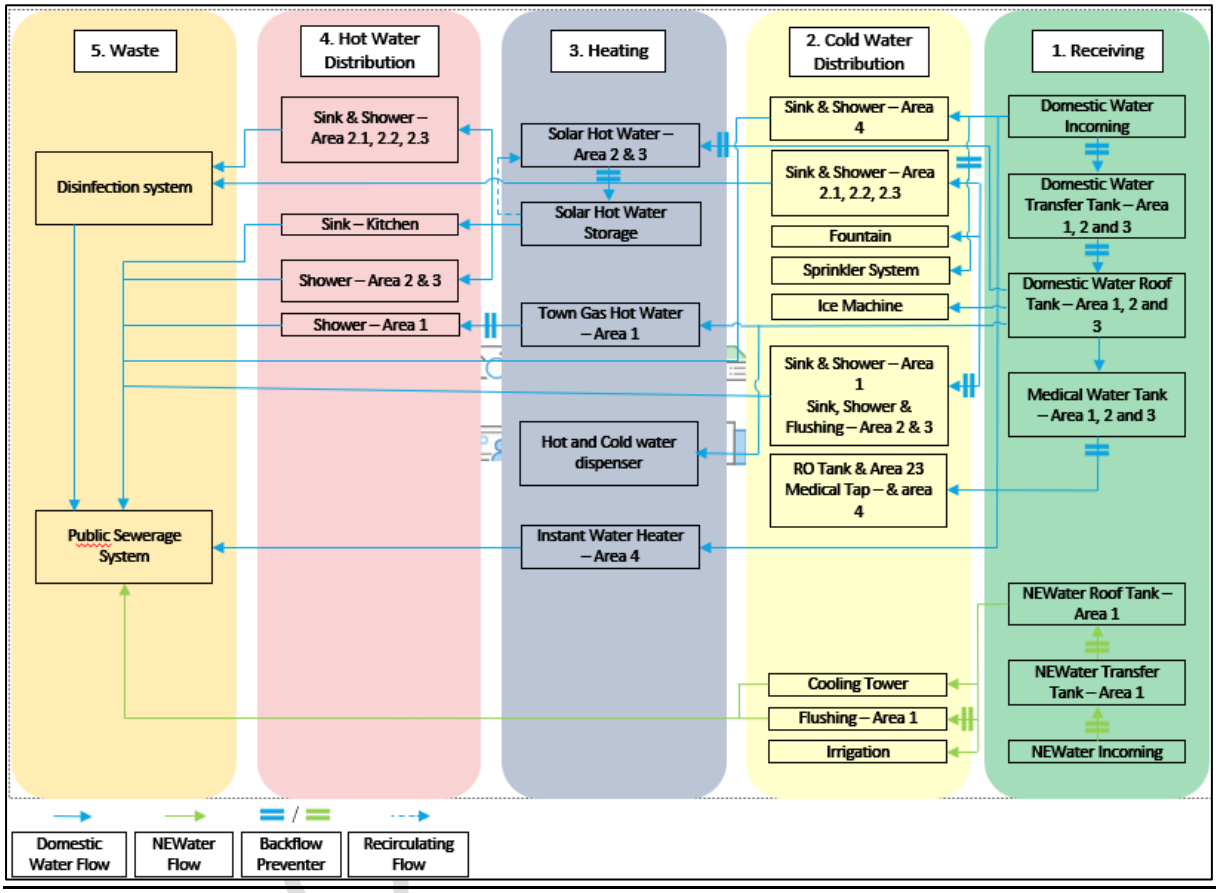
In addition, facilities are encouraged to maintain up-to-date schematic or flow diagram of the building water system specific to the facility, ensuring that all components are clearly identified and labelled. An example of such a flow diagram is provided in Figure 1.6. The water system flow diagram should be reviewed and updated whenever major modifications occur, such as after renovation works, new construction, installation or replacement of equipment (e.g., pumps, valves), or reconfiguration of the water supply system.

1.3.3 Other Water Supply Systems / Equipment with Water Reservoirs

Water serves multiple functions in healthcare environments, and the presence of moisture or wet biofilms has been associated with a proportion of healthcare-associated infections (HAIs). In addition to the primary water supply from PUB, healthcare facilities may have supplementary water systems or equipment such as water filters, water dispensers, ice machines and similar appliances, some of which may contain internal water reservoirs.

These systems are often installed at the point of use, and water/ice from such equipment may be used directly by patients, workers and visitors. Appropriate maintenance, monitoring and risk assessment of these systems are therefore important to minimise potential waterborne infection risks within healthcare settings.

Figure 1.6: Flow diagram for water system



Note. From NTFGH, Singapore.

For water filters and water dispensers, there are common touch points such as taps, valves and tubing that may be exposed to environmental microorganisms and could potentially contribute to the transmission of microorganisms through contact or contaminated water. Healthcare facilities should therefore maintain an inventory of such water supply equipment and ensure that cleaning and maintenance are carried out regularly in accordance with manufacturer's instructions and facility risk management plans.

With regard to water dispensers, whether tabletop or wall-mounted, even where biofilm control measures are applied at point of entry (e.g., filtration), the internal pipework of the device may still allow biofilm formation over time due to its complex structure. Facilities should establish clear protocols for routine maintenance, replacement of parts and tubing where

applicable, and ensure that these devices are included in investigations should waterborne outbreaks or contamination events be suspected.

Where filters are used in these systems, they should be replaced according to the manufacturer's recommendations and at intervals that minimise the risk of biofilm formation. The filter grade and pore size are important considerations. For point-of-use (POU) filtration intended as a physical barrier against bacterial transmission in potable water, a size of ≤0.22µm is generally recommended. Point-of-entry devices that are meant to remove contaminants in water that may promote growth of bacteria, but not the bacteria themselves, may be considered where applicable and may be of larger pore size. However, regular maintenance for both types of filters is essential in order to avoid these filters themselves forming biofilm and being conduits for bacterial transmission.

In addition to these recognised water sources, healthcare facilities are advised to maintain an inventory of all other equipment and fixtures that may support biofilm formation. Hot- and cold-water mixer taps, for example, are often overlooked. In tropical climates where hot water may not be essential outside of specific applications such as bathing or showers, facilities may consider reviewing the necessity of such mixer taps. Maintaining an inventory may allow facilities to progressively replace them with simpler cold-water taps during routine maintenance, which may reduce biofilm risk and potentially offer cost efficiencies.

Devices utilise water reservoirs or generate water as a by-product should also be systematically identified and monitored. Examples include direct evaporative air coolers, misters, and portable humidifiers, which are generally not recommended for routine use in healthcare settings due to potential infection risks. Other equipment requiring careful oversight may include heater-cooler units, fluid warmers, blanket warmers, reverse osmosis or haemodialysis systems, scalp coolers, incubators, dental unit chairs, thermal stimulators and water baths. Even when water systems operate within closed or semi-closed circuits, aerosol generation or splashing may still pose exposure risks.

Overall, maintaining a comprehensive inventory of water supply systems, associated equipment and fixtures is an important component of a facility water management programme. Such documentation supports risk assessment, facilities outbreak investigations and informs routine maintenance, replacement planning and risk mitigation strategies.

1.3.4 Non-Potable Water

In addition to potable water supplied by PUB, some facilities utilise alternative water sources for non-potable purposes. These include recycled greywater generated within the building and NEWater supplied by PUB.

Recycled greywater is the product of recycling wastewater taken from wash basins, sinks and showers in the buildings. PUB has published technical guidelines for recycling greywater for non-potable use and requires strict monitoring of performance of the treatment processes. NEWater is recycled wastewater supplied by PUB for non-potable use by industries. The most common use of NEWater is for washing of floors, cooling tower water, and toilet flushing.

Although both recycled greywater and NEWater are suitable for non-potable uses, both do not contain any disinfectant for the prevention of microbial growth, especially within storage facilities prior to use. Storage and downstream distribution without residual disinfectant may permit microbial regrowth of OPPPs such as *Legionella* spp., *Pseudomonas aeruginosa*, and NTM. The use of such water sources for activities including toilet flushing may generate aerosols which may increase the risk of exposure to waterborne pathogens.

Recycled greywater or NEWater that does not contain a residual disinfectant is not recommended for use in clinical areas. Where operational needs necessitate the use of non-potable water in patient care areas, facilities should implement appropriate risk mitigation measures. These include the provision of onsite chlorination or equivalent disinfection to maintain a residual disinfectant, with total residual chlorine levels maintained at 0.5–2.0 mg/L at the outlet of storage tanks (or as determined by site-specific risk assessment). Facilities should ensure routine monitoring and documentation of disinfectant levels.

Such systems should be incorporated into the facility's water management programme and *Legionella* risk assessment, with appropriate engineering controls to prevent cross-connection with potable water systems. Prior to implementation, especially at the building design stage, facilities should conduct and document a risk assessment to ensure that the use of recycled greywater or NEWater does not compromise patient safety.

1.4 Water Sampling and Monitoring Guide

1.4.1 Introduction to Risk Assessment

Having mapped the water system and identified potential hazards within the system, it is important to ensure that routine water quality testing is conducted across the water supply network to monitor quality and safeguard water safety.

The facility water risk management plan should be informed by system schematic and should include an evaluation of water system components and patient populations in each area to determine risk levels. Areas where potentially hazardous conditions may occur include:

a) Areas with slow or stagnant water (e.g., excess storage capacity, dead legs, excessive heat loss, cross-flow from the water system);
b) Areas that are unoccupied or temporarily closed;
c) Areas where aerosol generation may occur (e.g., showers, shower chairs, spray taps, toilet flushing);
d) Areas where nutrient sources are present (e.g., rust, sludge, scale, organic matter);
e) Areas where water is stored or recirculated as part of the system;
f) Areas of untreated water sources;
g) Areas with outlets where POU filters are deployed for prolonged periods.

Within acute healthcare facilities, areas housing *high-risk* patient populations require enhanced monitoring and control of waterborne pathogens, particularly *Legionella*. High-risk areas include, but are not limited to, the following:

a) Units caring for susceptible patients, including Intensive Care Units (ICU) (adult, paediatric, and neonatal), High-Dependency Units (HDU) (adult, paediatric, and neonatal), haematology-oncology, transplant, burns, and dedicated renal services, dedicated respiratory services, as well as areas managing other immunocompromised patients (e.g., Human Immunodeficiency Virus (HIV) infection, rheumatologic conditions);
b) Units Handling of sterile items (e.g., sterile supplies units, pharmacy compounding facilities);
c) Operating theatres.

1.4.2 Initial Building Assessment

Environmental sampling for waterborne pathogens, including *Legionella* spp. and OPPPs, forms part of the facility's Water Management Programme and may be conducted for baseline characterisation, validation of control measures, or investigation of suspected transmission events. Sampling may be undertaken under the following circumstances:

a) In response to a confirmed or suspected case or outbreaks of legionellosis or other healthcare-associated OPPPs;

b) Following significant water service disruptions, system modifications, or exceedance of established control limits; and

c) As part of routine surveillance to establish baseline status of *Legionella* colonisation and monitor trends within the building water system.

Routine surveillance may be considered to understand the prevailing microbiological status ("state of affairs") of the building water system, particularly in acute healthcare facilities where patient risk is dynamic. Vulnerable or immunocompromised patients may not always be confined to designated high-risk wards and may be admitted or transferred to other clinical areas based on operational demands. Environmental monitoring should therefore not be limited solely to traditionally defined high-risk areas but should take into account potential exposure pathways across the broader water distribution network.

The extent and frequency of environmental sampling should be determined based on facility-specific risk assessment, system complexity, patient population characteristics, historical findings, and prevailing national guidance. Sampling intervals should be defined within the Water Management Programme and reviewed periodically.

1.4.2.1 Cooling Towers

Water quality in cooling towers is regulated under the Environmental Public Health (Registrable Aerosol-generating Systems) Regulations 2021 which requires cooling towers to be registered with the National Environment Agency (NEA).

Cooling tower owner/occupier may refer to the Guidelines on Cleaning and Disinfection of Cooling Towers for the Control of *Legionella* Bacteria for guidance on cleaning and disinfection of cooling towers. Refer to NEA Website (https://www.nea.gov.sg/our-services/pollution-control/water-quality/aerosol-generating-systems) for more information on management of cooling towers.

1.4.2.2 Water Storage Tank

In accordance with Regulation 14 of the Public Utilities (Water Supply) Regulations, all consumers responsible for potable water storage tanks, including those installed in healthcare facilities, shall engage an LP at least once every 12 months to inspect the storage tank, and where necessary, carry out cleaning and disinfection. The LP shall certify that the storage tank is fit and safe for the storage of drinking water. The inspection and certification shall include water sampling for the appropriate chemical and bacteriological examinations. For more

information on mandatory annual inspection and certification requirements, please refer to the PUB website (https://www.pub.gov.sg/Professionals/Requirements/Water-Supply-Services/Water-Storage-Tanks).

1.4.2.3 Hot and Cold Water Distribution Systems (System-Level Sampling)

Initial sampling should include water entering the building, storage tanks (where present), and distal hot and cold-water sites at multiple representative points throughout the building. Where hot and cold water systems are separate, independent sampling sets should be obtained for each system to ensure representative assessment of the entire distribution network.

Based on risk assessment, the Water Management Committee will need to identify the potential locations where *Legionella* may be present and propagate, based on the number of potable water systems and distribution components. The recommended sampling sites may include, but are not limited to:

a) Potable water sources: If there are multiple water mains, samples should be taken from each source;

b) Potable water storage tanks: Separate hot and cold storage tanks should be sampled, where present;

c) Potable water zones: Larger facilities may have multiple building zones due to height, pressure differentials, or system design. Representative samples should be taken from each zone;

d) Separate hot or cold water systems: For each system, sampling should include:

    i. The inlet cold water supply at the first available tap;

    ii. The return piping of the circulated heating system(s);

    iii. The outlet of the heating system(s);

e) Samples from floors that house patients: Sampling from patient care areas should represent the horizontal distribution run on each floor. Where appropriate, this may include:

    i. An outlet closest to the first delivery of hot water from the riser;

    ii. An outlet located in the middle of the system;

    iii. The last outlet before the water returns to heaters;

    iv. Additional representative random sample when floors have extensive lengths of piping and complex paths;

f) Distribution risers: Samples should be drawn from enough risers to provide a good evaluation of all risers. If sampling is done at regular intervals, a random or rotational selection of risers may be considered. Selection should always include risers where water use is minimal. Where multiple risers supply hot water to a limited number of rooms from a circulation loop, several locations corresponding to the loop should be sampled;

g) Potable hot water heat exchangers: Where used, they should be evaluated and sampled;

h) Potable hot water return piping: Where used, it should be sampled, as conditions are often suitable for *Legionella* growth;

1.4.2.4 Distal sites for monitoring

Environmental sampling of distal sites for *Legionella* should be incorporated into the facility's Water Management Programme as a validation tool and should be risk-based, taking into account building size, plumbing complexity, patient vulnerability, and historical findings (e.g., previous cases of legionellosis or other OPPP outbreaks).

As a pragmatic starting point for programme implementation, facilities may consider scaling the number of representative distal sampling sites according to bed capacity, in conjunction with site-specific risk assessment. However, the final determination of sampling locations and numbers should be guided by system design, hydraulic configuration, zoning, and risk stratification. More extensive sampling may be appropriate during the initial programme development phase, following system modifications, after water service disruptions, after implementation of mitigation measures or in response to clinical or environmental findings.

Water outlets selected for monitoring should include locations where patients may be exposed to water or water aerosols. Suggested sampling sites include, but are not limited to:

a) Taps, aerators, and flow restrictors;

b) Showerheads and bidets;

c) Drinking water dispensers;

d) Infrequently used outlets (e.g., eyewash stations, sit-and-shower chairs);

e) Dental chairs;

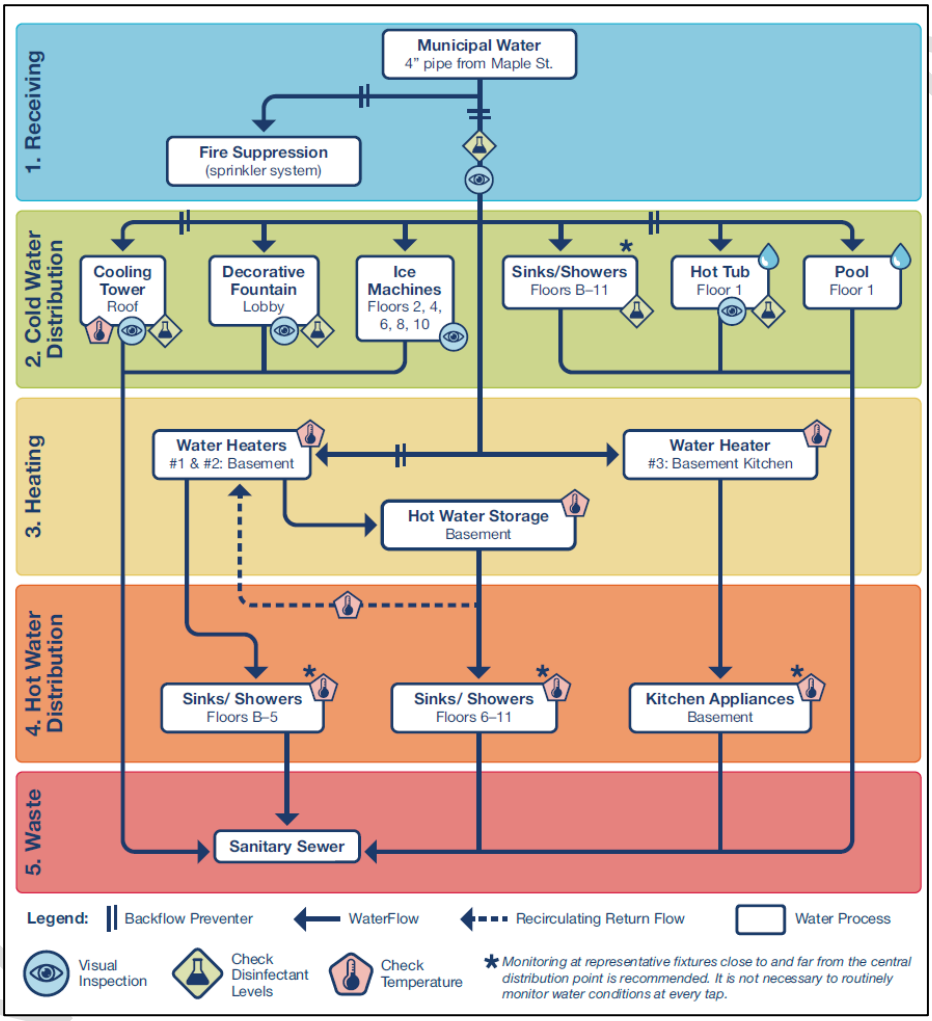
f) Equipment that alters water temperature (e.g., ice-making machines, water chillers, heater-cooler units);

g) Patient care equipment (e.g., dialysis machines, hydrotherapy devices, respiratory therapy equipment);

h) Centrally installed misters/atomisers/air washers/humidifiers.

The diagram (Figure 1.7) below shows which types of monitoring could occur at different locations within a building's water system to reduce the risk of growth and spread of *Legionella*. Distal outlet sampling complements system-level sampling (e.g., storage tanks and return loops) and should not be interpreted in isolation.

Figure 1.7: Example of a water system design showing water outlets at different locations within a building's water system



***** *Example content is provided for illustrative purposes only and is not intended to be relevant to all buildings.*

Note. From *ANSI/ASHRAE Standard 188-2018*, Legionellosis: Risk Management for Building Water Systems, by ASHRAE, 2018

1.4.3 Parameters to monitor

1.4.3.1 Temperature

Hot water systems (e.g., instant heaters, storage heaters, etc) are installed to supply hot water for showers, washing etc. Monitoring of temperature at these locations is to ensure the following:

a) Hot water in storage tank is maintained above 60°C;
b) Hot water in circulation does not fall below 49°C;
c) Hot water is not stagnant in the pipelines.

Temperature monitoring may be conducted using installed thermometers or thermostats integrated within hot water systems. Monthly checks on the temperature of the water in the water tanks, hot water systems and at routine sampling points can be done by: (a) confirming that the thermometer readings in the hot water systems are within the optimal temperature range of above 60°C, (b) thermostats are set at temperatures above 60°C and (c) temperature of the hot water in circulation (before TMV) should be at least 49°C. A checklist may be considered to record the thermostat/thermometer readings, and the temperature readings taken from samples from hot water inlet of the TMV.

1.4.3.2 Chlorine Levels

Potable water supplied by PUB typically contains chloramines rather than free chlorine. Monitoring should therefore focus on total residual chlorine levels. Chloramines provide longer-lasting disinfection protection but can decline over time within distribution systems, particularly where water stagnates or temperatures are elevated. To minimise microbial proliferation:

a) Total residual chlorine at tap points should generally be maintained at ≥0.3 mg/L;
b) Higher temperatures may accelerate chloramine decay, underscoring the importance of maintaining recommended hot water temperature ranges.

Measurement of chlorine can be carried out with portable meters using a colorimetric method. Briefly, a sample of water is taken from the tap point into a vial, a reagent is added and mixed into the sample, before the vial is inserted into the meter for direct measurement of total chlorine levels. These can be done within a few minutes. As such, the monitoring can be carried out easily by facility managers and on a routine basis at different locations within the healthcare facility.

1.4.3.3 pH Levels

Drinking water usually has a neutral to alkaline pH, and water supplied by PUB is usually in the range of pH 7.5 – 9, in order to ensure the stability of monochloramine. Measurement of pH levels in water can be done by inserting the pH probe of the portable meter into a sample of water and waiting for the reading to stabilise or using pH strips available commercially.

According to the FSS regulations, potable water pH should generally remain between 6.5 – 9.5. Deviations may indicate contamination and/or deterioration in water quality within the network. Abnormalities in pH levels should be investigated by doing a spatial analysis across the water system so that corrective measures can be taken promptly.

1.4.3.4 Microbiological Parameters

Water sampling in healthcare settings is crucial for detecting *Legionella* and other OPPPs and monitoring overall water quality, particularly in areas serving vulnerable and patient populations.

There are specific requirements for microbial sampling and testing to ensure integrity of the samples and accuracy of results. Proper documentation of sampling objectives, methodology (e.g., pre-flush vs post-flush), outlet preparation, and any deviations from established protocols is essential, particularly during outbreak investigations.

a) Sampling

Sampling methodology should be selected based on the objective of testing. Distal outlet sampling may include immediate (first-draw) samples, post-flush samples, paired sampling, and/or biofilm swabs, depending on whether the intent is to assess point-of-use exposure risk, upstream system colonisation, or source localisation.

Where the objective is to assess point-of-use exposure risk or distal outlet colonisation, an immediate (first-draw) sample may be collected upon opening the outlet, without prior flushing. Deliberate cleaning or disinfection of the outlet immediately prior to sampling is avoided in this context to reflect “as-used” conditions.

Where the objective is to assess upstream distribution system water, a post-flush sample may be collected after flushing for a defined duration or functional endpoint to obtain water representative of the system feeding the outlet. Where outlet disinfection is incorporated into the protocol, any residual disinfectant should be flushed prior to sample collection.

The volume of water collected should be sufficient to perform all required tests, with 100 mL being the minimum recommended.

Biofilm swab sampling of aerators, showerheads, and other distal fittings may be performed as a complementary method, particularly during case or cluster investigations where identification of localised colonisation is required. Swabbing may help detect organisms embedded within biofilm reservoirs that are not consistently recovered in bulk water samples. However, biofilm swabbing is generally not required for routine surveillance unless there are specific concerns or epidemiological indications.

b) Transportation

Samples must be transported at cold temperatures (around 4°C) to prevent changes in microbial populations that may occur at ambient temperatures. Chemical additives, such as sodium thiosulfate, are used to neutralise chlorine or other halogens.

c) Testing

Testing should be conducted as soon as possible, preferably within 24 hours. Water testing in healthcare settings can be complicated by the fact that disinfected water often contains stressed organisms that may not grow well under standard testing conditions, leading to false-negative results. As such, recovery media should be carefully selected—reduced nutrient media like R2A is preferred over high-nutrient media to allow stressed microorganisms to recover. Specialised assays may be required for clinically significant pathogens, and these are more complex and costly compared to standard water quality tests like coliform testing.

Healthcare facilities may not have the necessary infrastructure or set-up to conduct in-house testing of these water quality parameters. As such, these tests may be outsourced to external laboratories. To ensure that results are accurate and that testing is carried out in accordance with international standards, laboratories carrying out these tests are required to be accredited by the Singapore Accreditation Council's Singapore Laboratory Accreditation Scheme (SAC-SINGLAS). Non-accredited laboratories may not use standard protocols in their testing, and results may not be representative.

Different appointed laboratories may adopt varying sample collection methodologies (e.g., default post-flush sampling, outlet disinfection protocols, prescribed flush durations, or specified sample volumes). The IPC team, Water Management Committee, and Facilities Management team should therefore work collaboratively with the appointed laboratory or testing vendor to define and document the sampling strategy prior to testing. Alignment of

sampling objectives and collection methodology (as described in Section 1.4.3.4.a) is essential to ensure that results are meaningful, comparable over time, and actionable.

1.4.4 Interpretation of results and recommended corrective actions

A summary of the requirements for temperature, pH and chlorine monitoring is provided below.

Table 4: Temperature, chlorine and pH monitoring requirements

Monitored Parameter	Requirements
Temperature at - Hot water systems - Hot water in circulation	 >60°C ≥49°C
Total residual chlorine (or monochloramine) (for cold taps)	≥0.3 mg/L
Free chlorine (for points downstream of chlorine dosing systems, wherever installed) (for cold taps)	≥0.3 mg/L
pH	6.5 - 9.5

1.4.4.1 Temperature

Steps can generally be taken to adjust temperature promptly if checks confirm that recommended temperatures guidelines are not met. This may include adjusting thermostats to ensure that the temperature set point is at least 60°C. For taps where the recirculated temperature is lower than 49°C, the hot water flow may be adjusted to achieve the target recirculation temperature, and the tap flushed regularly to bring higher-temperature water into the pipeline and prevent stagnation.

If temperatures remain consistently below the target, a LP may be engaged to review the system and identify measures to achieve higher temperatures. Recirculation of hot water may also be included into the design of the hot water system to prevent the development of temperature gradients within the pipeline.

1.4.4.2 Chlorine Levels

It is recommended that chlorine levels be maintained at or above 0.3 mg/L at all tap points. Chlorine levels below 0.3 mg/L may indicate insufficient disinfectant residual to protect

the water supply against microbial contamination. While this does not necessarily indicate contamination of the water supply, maintaining an adequate chlorine residual helps to ensure the safety of the water. For tap points where chlorine levels are lower than 0.3 mg/L, regular flushing of the tap points could be carried out to reduce stagnation, if the chlorine levels recover to above 0.3 mg/L after flushing. Otherwise, an evaluation of the water age and water demand within the system could be undertaken to ensure that there is no prolonged stagnation in the pipes.

1.4.4.3 pH Levels

For pH levels beyond the target range, a spatial analysis of the nearby water system could help identify whether the issue is localised or confined to a specific part of the water network. In particular, in areas with newly laid cement-lined pipes, the pH of the water within the pipes may be higher than normal due to leaching from the cement lining. Flushing of the water system would usually help resolve any pH issues within the network.

1.4.4.4 Microbiological Parameters

While monitoring temperature, pH and chlorine levels in the water system helps reduce the risk of infection transmission through the water supply, low chlorine levels or temperatures outside the recommended ranges do not in themselves indicate health risk and are not predictive of disease. Where there are concerns regarding temperature or chlorine levels, microbiological analyses should be carried out to confirm whether the water supply is a potential source of infection.

For microbial testing, heterotrophic plate counts (HPC) should be performed. This serves as an indicator of general microbial water quality and the potential for biofilm formation. According to Singapore Food Agency's (SFA's) Guidelines on Drinking Water Quality Management Plan for Non-Packaged Drinking Water, HPC counts should be ≤500 CFU/ml. This is also consistent with CDC recommendations in their infection prevention guidelines for healthcare facilities. Occasionally, HPC counts may exceed 500 CFU/ml but should not be persistent, as sustained elevations may indicate a higher rate and extent of biofilm formation within the water system.

Where microbiological testing is performed, results may be interpreted according to Table 5 below (adapted from Health Technical Memorandum 04-01 Part B fig. 4). Some recommended actions are listed and are intended as a guide for mitigating measures that can be taken to improve the water quality in the facility.

1.4.5 Routine monitoring

This section outlines suggested intervals and considerations for ongoing *Legionella* monitoring following the initial building assessment described in Section 1.4.2 and the parameter-specific guidance in Section 1.4.3.

All high-risk areas (refer to Section 1.4.1) should be routinely monitored at intervals determined through environmental risk assessment and the facility's Water Management Plan. As a pragmatic starting point, facilities may consider six-monthly monitoring in higher-risk patient care areas. For non-high-risk areas, sampling sites and monitoring intervals should likewise be determined through environmental risk assessment. However, the final monitoring frequency for both high- and lower-risk areas should be tailored to the institution's specific risk profile, taking into account initial test results, historical trends, system characteristics, patient vulnerability, and the effectiveness of implemented control measures.

While monitoring of water temperature, disinfectant residuals, and distal-point flushing programmes can help identify conditions conducive to *Legionella* growth risks, culture results should ultimately be used to validate the effectiveness of the water management plan, regardless of building size, configuration, or patient population characteristics. Table 6 provides an example of a plan for routine monitoring plan, including proposed sampling points and testing frequency.

Sampling intervals for routine monitoring should remain dynamic and be re-evaluated by the Water Management Committee following significant system modifications, changes in patient mix, exceedance of action thresholds, or implementation of corrective interventions. Following corrective measures, at least two sequential satisfactory test results, spaced appropriately, are required to confirm that the issue has been resolved.

The figure (Figure 1.8) below, adapted from the US Centres for Disease Control & Prevention, provides guidance on interpretation of *Legionella* data.

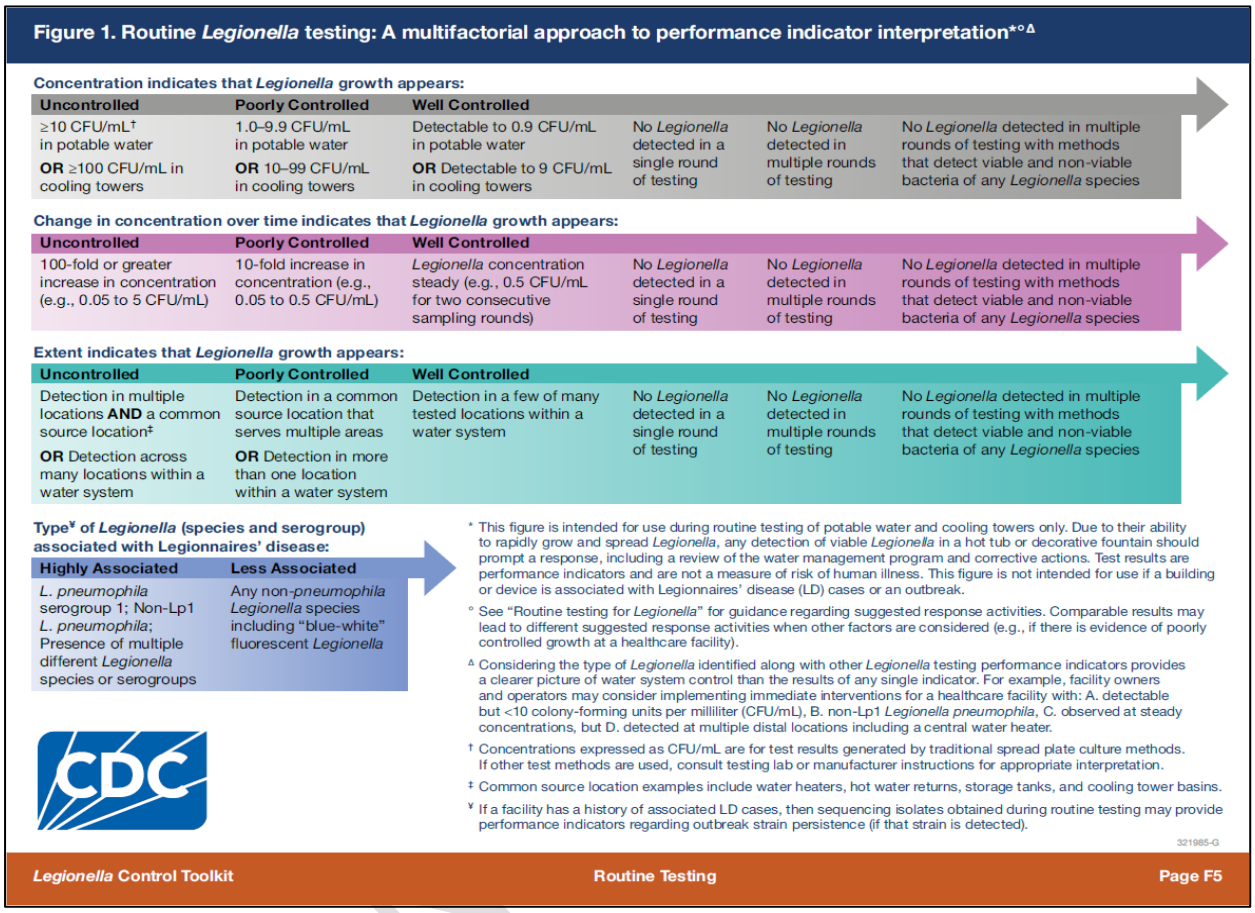
Table 5: Actions that may be considered following *Legionella* testing in water systems

***Legionella* bacteria**	**Results from Pre-flush samples**	**Systemic results (Post-flush samples)**
	Pre-flush samples tends to be indicative of local conditions and if detected, post-flush samples may be required to determine whether contamination is localised or systemic.	Post-flush samples (or multiple positive samples) may indicate broader systems contamination and potential failure of control measures.
Not detected	Continue with current control measures and routine monitoring.	
<1000 CFU/L (<1 CFU/mL)	Actions to consider i. Review local conditions and investigate: a. Usage frequency; b. Outlet for corrosion and scale; c. Local heat gain; d. Local dead ends; e. Cross flow between hot and cold systems, and vice versa; f. Localised failure of hot water system return. ii. Resampling between two and seven days may be undertaken to assess the effectiveness of initial corrective measures. iii. Follow-up resampling at three to six months may be considered to confirm sustained control before reverting to routine surveillance intervals. iv. If the outlet is served by a TMV: a. Review the necessity of the TMV weighing scalding and infection risks.	Actions to consider i. Review system control measures and risk assessment. ii. Investigate potential system-wide factors: a. Hot water backflow via the calorifier cold feed pipes; b. Calorifier discharge via open vents to the cold tank; c. Failure of hot water system to operate at target temperatures; and d. Overcapacity or underuse. iii. System-wide cleaning and disinfection. iv. Resampling between two and seven days may be undertaken to assess the effectiveness of initial corrective measures. v. Follow-up resampling at three to six months may be considered to confirm sustained control before reverting to routine surveillance intervals.

	b. If retained, clean and disinfect the TMV, outlet, and associated strainers. c. Identify flexible hoses (particularly downstream of TMV) and consider replacement, avoiding flexible hoses where practicable.	
1000-10,000 CFU/L (1 - 10 CFU/mL)	<u>Actions to consider</u> In addition to the above: i. Urgent review of local control measures and risk assessment. ii. Cleaning and disinfection of affected outlets (particularly showers and spray taps) may be undertaken. iii. Where outlets cannot be removed from service, consider installing point-of-use microbiological filters temporarily. iv. Resampling between two and seven days may be undertaken to assess the effectiveness of initial corrective measures. v. Follow-up resampling at three to six months may be considered to confirm sustained control before reverting to routine surveillance intervals.	<u>Actions to consider</u> In addition to the above: i. System-wide cleaning and disinfection may be required. ii. Resampling between two and seven days may be undertaken to assess the effectiveness of initial corrective measures. iii. Follow-up resampling at three to six months may be considered to confirm sustained control before reverting to routine surveillance intervals.
>10,000 CFU/L (>10 CFU/ml)	<u>Actions to consider</u> In addition to the above: i. Implement immediate measures to prevent exposure from the affected outlet until remediation is confirmed effective.	<u>Actions to consider</u> In addition to the above: i. Implement immediate measures to prevent exposure from the affected outlet until remediation is confirmed effective.

	ii. Resampling between two and seven days may be undertaken to assess the effectiveness of initial corrective measures. iii. Follow-up resampling at one to two months may be considered to confirm sustained control before reverting to routine surveillance intervals.	ii. Resampling between two and seven days may be undertaken to assess the effectiveness of initial corrective measures. iii. Follow-up resampling at one to two months may be considered to confirm sustained control before reverting to routine surveillance intervals.

Figure 1.8: Routine *Legionella* testing: A Multifactorial approach to performance indicator interpretation



Note. From *Developing a water management programme to reduce Legionella growth & spread in buildings: A practical guide to implementing industry standards (Version 1.1*), by Centers for Disease Control and Prevention, 2021, Centers for Disease Control and Prevention. https://www.cdc.gov/control-legionella/media/pdfs/toolkit.pdf

Table 6: Recommended routine sampling points and frequency of testing

Testing Parameter	Sampling Locations	Recommended Frequency[1]	Remarks / Target Ranges
Physical / Chemical Parameters			
Temperature	• Hot water tanks / systems • Hot water recirculation system • Taps with hot/cold mixers, especially at the tail end of water system or in high-risk wards / clinics	Monthly for all areas	Temperature at hot water tanks to be >60°C; Temperature of hot water in circulation

[1]The frequency is recommended for routine testing, although the water management team can vary the frequency based on risk assessment. A higher frequency of testing would be suitable at the start of the implementation of the water management plan, and this can then be stepped down to a lower frequency for specific tap points where there are no issues with the monitoring results.

Testing Parameter	Sampling Locations	Recommended Frequency[1]	Remarks / Target Ranges
			(before TMV) to be ≥49°C
Total chlorine (or monochloramine) or free chlorine*	• Storage tank inlets & outlets • Tap points, especially at the tail end of water system • Newly renovated areas or areas with low occupancy	Monthly	Total residual chlorine ≥0.3 mg/L at outlets; Free chlorine* ≥0.3 mg/L at outlets
pH	• Representative points across the water distribution systems	Periodic monitoring aligned with water management plan	6.5 < pH < 9.5
*Microbiological Parameters***			
Heterotrophic plate count (HPC)	• Storage tanks inlets & outlets • Tap points, especially at the tail end of water system or in high-risk wards / clinics • Newly renovated areas or areas with low occupancy	Annual	<500 CFU/ml
Legionella spp.	• Tap points, especially at the tail end of water system • Showerheads • Newly renovated areas or areas with low occupancy	As indicated by risk assessment	Refer to Figure 1.8

**Free chlorine to be tested for facilities with chlorine dosing systems, and free chlorine requirement is to be measured at the taps downstream of the chlorine dosing systems*

*** In high-risk areas or suspected OPPPs outbreaks, facilities may consider testing for involved OPPPs as appropriate, based on risk assessment.*

1.4.6 Documentation

Significant findings from the risk assessment should be documented. All monitoring activities should also be recorded, including:

a) The operational status of the water system (i.e., in use or not in use);

b) Records and results of monitoring, inspections, testing and maintenance activities conducted;

c) Details of any corrective actions taken when test results fall outside acceptable limits or when control limits are not maintained, including any follow-up testing results;

d) Records of cleaning and disinfection procedures, together with associated reports and certificates where applicable;
e) Training records of relevant personnel;
f) Records of the work carried out by external service providers (e.g., water treatment specialists), including safety data sheets for chemicals or biocides used;
g) Documentation of personnel responsible for the work (with sign-off), date completed, and location details to facilitate repeat sampling or follow-up actions where necessary.

1.5 Managing Water Systems During Construction and Renovation

Note: *This section is included in this chapter release to support immediate implementation of water management during construction and renovation activities. It will subsequently be relocated to the Chapter on Renovation and Infrastructure in the updated National IPC Guidelines for Acute Healthcare Facilities.*

1.5.1 Construction of New Buildings and Renovation of Existing Facilities

Water-related risks arising from construction, renovation, prolonged shutdown, or commissioning activities should be assessed and managed as part of the Infection Control Risk Assessment (ICRA) process described in the National IPC Guidelines for Acute Healthcare Facilities. This section outlines additional water management considerations that should be incorporated into construction planning and recommissioning activities where potable or non-potable water systems are affected.

An operational framework to assist with categorising water-related construction activities and identifying corresponding mitigation measures is provided in Annex A. This framework supplements, and does not replace, the Construction ICRA process described in the Construction and Renovation chapter.

The project officer in-charge is required to perform an ICRA prior to commencement of any construction, renovation or facility maintenance project to ensure appropriate controls are in place prior to operational use. Where plumbing systems are affected, risks related to water age, stagnation, loss of residual disinfectant, and potential amplification of OPPPs should be assessed. The project officer in-charge of each project is responsible for notifying IPC personnel of the projected dates, location, and scope of renovation works. Notification should occur as soon as a project is planned, and at minimum before the scheduled start date.

Water-related risks should be evaluated in conjunction with the multidisciplinary construction team. The anticipated duration of water interruption, extent of plumbing

disruption, and proximity to high-risk patient care areas should be considered in determining mitigation measures.

1.5.2 Water Age and Stagnation Risk

Water age (duration of stagnation) is a key determinant of microbial proliferation risk during construction and renovation activities. Interruptions to water flow, reduced occupancy, or delayed commissioning may result in depletion of residual disinfectant, temperature drift into ranges favourable for microbial growth, increased biofilm formation, and amplification of waterborne pathogens.

As a general guide, short-term interruptions (<24 hours) are unlikely to significantly affect microbial control in well-maintained systems. Intermediate dormancy (several days to weeks) may result in measurable disinfectant decay and may require flushing prior to reuse. Prolonged stagnation (>30 days) significantly increases risk and may necessitate enhanced recommissioning and verification measures. The anticipated duration of stagnation should therefore be considered when determining flushing frequency, monitoring requirements, and recommissioning protocols.

1.5.3 Pre-Construction Planning and Control

Prior to commencement of works affecting the water system, the project team should notify the IPC team and the Water Management Committee; review system schematics to identify affected areas; assess proximity to high-risk patient care areas; identify isolation valves and backflow prevention measures; and plan mitigation strategies to minimise stagnation and maintain water quality. Water-related mitigation measures should be documented within the project plan and incorporated into the facility's Water Management Programme.

1.5.4 Flushing and Recommissioning

Before newly constructed or renovated areas are placed into service, hot and cold water should be flushed through all points of use (e.g., showers, sink faucets, dispensers) to replace stagnant water with fresh supply. Flushing may need to be conducted in segments depending on plumbing configuration and facility size. Where systems have remained stagnant for extended periods, longer flushing durations may be required. Care should be taken to minimise splashing and aerosol generation during flushing.

From the time fixtures are wetted, a regular flushing schedule should be maintained until occupancy. Guidance for managing infrequently used outlets should be followed (refer to

Annex A), which may include flushing each outlet for at least four minutes every other day to significantly reduce the risk of *Legionella* proliferation within the system. Water-using devices (e.g., ice machines, heater-cooler units, dialysis systems, or other equipment with internal reservoirs) should be cleaned, disinfected, or recommissioned in accordance with manufacturer instructions and risk assessment.

Where indicated by risk assessment, verification prior to occupancy may include temperature measurements, residual disinfectant measurements, targeted microbiological testing (including *Legionella* spp.), and review of results by the Water Management Committee.

1.5.5 Delayed Occupancy and Dormancy Management

Where there is a delay between water system activation and occupancy, routine flushing of infrequently used outlets should be implemented and documented. Flushing schedules should be risk-based and overseen by the Water Management Committee. Particular attention should be given to high-risk patient care areas, newly installed pipework, distal outlets at the tail ends of systems, and areas with low anticipated occupancy. Routine monitoring of temperature and residual disinfectant should continue during dormancy periods.

1.5.6 Commissioning and Governance

Water quality parameters should be reviewed prior to occupancy of renovated or newly constructed areas. Where corrective measures are implemented, sequential satisfactory results may be required before patient care operations commence. Water-related mitigation measures and verification activities should be documented and incorporated into the facility's ongoing Water Management Programme.

1.6 References

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ANNEX A: Water Management Construction

Infection Prevention and Control Risk Assessment Checklist

This Water Management Construction (WMC) framework supplements the Construction ICRA process described in the Construction and Renovation chapter. It is intended to address water-specific risks, including water age and stagnation, that may not be explicitly covered in the general construction ICRA matrix.

Step 1.

Using Table 1 below, evaluate the Building Water Distribution System (BWDS) construction activities and scope of work to be performed, duration and level of water age for the project, and determine WMC Project Category:

Table 1: WMC Project Category

Category	BWDS Construction Activities and Scope of Work	Water Age Category
A	• Minimally invasive BWDS • Brief duration	Low (≤24 hours)
B	• Small scale BWDS • Short duration	Modest (≤7 days)
C	• Moderate to high levels of BWDS construction	Medium (≤30 days)
D	• Major BWDS demolition, renovation, infrastructure, and/or new construction	High (>30 days)

Refer Appendix 1-1 for examples of each category.

Step 2.

Using Table 2 below, identify the Occupant Risk Groups (i.e., patients, visitors, volunteers, staff, etc.) and affected departmental areas. If more than one building occupant risk groups will be affected, select the higher risk group.

Table 2: Building Occupant Risk Groups

Low Risk	Medium Risk	High Risk	Highest Risk
• Office areas • Non-patient areas	• Cardiology • Physiotherapy / Occupational Therapy / Speech Therapy Department • Radiology/ Magnetic Resonance Imaging (MRI) • Patient care areas not covered under high or highest risk groups • Public corridors • Laboratories not specified as high or highest risk groups • Cafeteria / Kitchen • Material management department • Endoscopy Centre	• Coronary Care Unit • Emergency Medicine • Labour & Delivery • Newborn Nursery • Paediatrics • Pharmacy laboratory • Medical and Surgical wards • Rehabilitation ward	• Any areas caring for immuno-compromised patients (incl. HSCT, SOT, haematology) • Oncology ward • Neonatal ward • Burn Unit • Cardiac Cath Lab / angiograph procedure areas • Central Sterile Supply • Intensive Care Units • Operating theatres including Ambulatory Surgery • Dialysis Centre • Vascular and interventional radiology

NOTE: Highest risk group for WMC will include HDU, dedicated inpatient renal services, dedicated respiratory services, and areas managing other immunocompromised patients (e.g., HIV infection, rheumatologic conditions)

Step 3.

Match the Building Occupant Risk Group (Low, Medium, High, Highest) with the planned WMC Project Category (A, B, C, D) on the WMC Infection Control Risk Assessment Matrix (Table 3) to determine the WMC Risk Mitigation Level (WMC - 1, 2, 3, or 4) for hazard control strategies to be implemented over the entire duration of the construction project scope (Table 4).

Larger scale projects (WMC - 4 with > 30 days of dormancy or new start-up) as indicated in WMC-ICRA Category D should conduct a pre-construction risk assessment (PCRA). The PCRA checklist should be reviewed by Infection Prevention and Project Officer.

Table 3: WMC Infection Control Risk Assessment Matrix

Occupant Risk Group	WMC Project Category			
	A	**B**	**C**	**D**
	Minimally invasive BWDS, brief duration, and low water age (≤24 hours)	Small scale BWDS, short duration, and modest water age (≤ 7 days)	Moderate to high levels of BWDS construction, and medium water age (≤30 days)	Major BWDS demolition, renovation, infrastructure, and/or new construction with high water age (>30 days)
Low Risk	**WMC - 1**	**WMC - 2**	**WMC - 3**	**WMC - 3 / 4**
Medium Risk	**WMC - 1**	**WMC - 2**	**WMC - 3**	**WMC - 4**
High Risk	**WMC - 2**	**WMC - 3**	**WMC- 3 / 4**	**WMC - 4**
Highest Risk	**WMC - 2**	**WMC - 3 / 4**	**WMC - 3 / 4**	**WMC - 4**

Step 4.

Review, finalise, and implement the selected WMC Risk Mitigation Levels determined as risk group (Table 4). All mitigation measures (hazard controls) and associated numeric values (i.e. temperature and residual free chlorine levels) need to be reviewed, coordinated and implemented in context with the organization's on-going Water Management Programme.

Table 4: WMC Risk Mitigation Level and Hazard Control Strategies

WMC - 1	1) Works not requiring plumbing or repair of water system a) No measurements are required 2) Works requiring plumbing or repair of water system a) No measurements required b) Flushing of fixtures is not required

WMC - 2	1) Baseline measurements are required for highest risk areas prior to commencement of construction activities. 2) Establish the following for all risk groups: a) Enclose the area securely to prevent aerosolized water (and potential pathogens) from dispersing into the environment. b) Close doors within the area (i.e., patient room door, toilet/shower room door, etc.) c) Install non-flammable visqueen/clear plastic sheeting/other approved vapor barrier for protection d) Install isolation valve, backflow prevention device, or other piping isolation method, when needed. e) Perform flushing protocol. Minimum requirements are as follows: i. Flush all water fixtures and water dispensers within the construction zone and in unoccupied areas adjacent to the construction zone ii. Flushing may be performed at defined intervals (e.g., every other day for several minutes) based on risk assessment and anticipated water age. iii. Follow on with flushing for 4 minutes with hot water if applicable iv. Record on flushing form or project information record system. f) Barriers should be left in place until all plumbing work is complete, including flushing activities g) When construction activities are completed, and area is ready to return to service: i. Flush all fixtures and water dispenser for 4 minutes with cold water ii. Follow on with flushing for 4 minutes with hot water if applicable iii. Take corresponding temperature and residual free chlorine levels measurements iv. Repeat steps i-iii until measurements are within safe limits (1) Outlet temperature: hot water range (≥49°C at outlets) (2) Residual free chlorine levels: minimum ≥0.3 mg/L at outlets v. The area should be thoroughly cleaned and dried, and barriers or seals removed 3) For highest risk areas, the following parameters should be measured at water outlets of renovated cubicle OR the 3 designated sites for sampling along a floor, whenever the water system is affected: a) Analytical laboratory sampling for water quality, to comply with PUB drinking water standards b) Residual free chlorine level c) *Legionella* sp. culture
WMC - 3	**Perform ALL of WMC– 2 risk mitigation levels adjusting for scale of project, PLUS the following:** 1) Baseline measurements will be required for medium, high and highest risk areas prior to commencement of construction activities. 2) Establish the following for all risk groups: a) Flushing protocol as per WMC-2 requirement. In addition, obtain residual free chlorine levels and temperature readings post-flushing 1 day per week in unoccupied and occupied areas, sampling 10 % of

	designated fixture locations to be considered as representative. Record readings in the project information record system. b) Review any disinfection (i.e. hyperchlorination) procedures to be performed with the Owner's Project Representative including location(s), method, schedule, and timing to return water system for potable usage, where applicable. Provide any reports of activities for building water main (i.e., point-of-entry), building distribution systems (hot and / or cold). c) Where necessary (where there is no valve to isolate the water system from renovated area), provide any temporary inline or POU filtration during construction for designated sinks, showers, or other fixtures or piping lines to reduce risk of exposure. d) Review installation for patient and medical equipment with water reservoirs (i.e. ice machines or other) on the project and preventive maintenance prior to occupant start up. e) The following parameters should be measured at water outlets of renovated cubicle OR the 3 designated sites for sampling along a floor, whenever the water system is affected: i) Analytical laboratory sampling for water quality, to comply with PUB drinking water standards ii) Residual free chlorine level iii) *Legionella* sp. cultures
WMC - 4	**Perform ALL of WMC– 3 risk mitigation levels adjusting for scale of project, PLUS the following:** 1) Contact the Building Owner's Project Representative for preparing a WMC Project Analysis. 2) Conduct a project-specific pre-construction risk assessment for potential growth and spread of waterborne pathogens 3) Review site / construction activity risk factors 4) Review building design and construction risk activity risk factors 5) Based upon the risk assessment prepare a project specific WMC plan for commissioning the building water system(s) per recommendations by the hospital Water Management Committee. 6) Establish a WMC plan with scheduled milestones starting from the date of water activation through first day of patient care operations 7) Implement / operationalize project specific controls (i.e., protocols for flushing, temperature, and residual free chlorine levels) 8) Water sampling will be required 2 weeks before the operation of the newly renovated area or building. 9) Confirm WMC plan & operations with verification and validation. 10) Obtain Building Owner's Project Representative approval of the WMC plan, process, and documentation. 11) Implement the agreed upon WMC Plan for achieving water quality and safety. 12) Obtain approval from the hospital Water Management Committee for new start-up before initiating patient care operations.

APPENDIX 1-1: WMC Project Categories

Category	Examples:
A	**BWDS inspection, maintenance/repair and non-invasive activities of brief duration, and low water age.** Includes but not limited to: • replacing fixture trim(s) • replacing fixture "in-kin" (i.e., meaning 1:1 or like for like) • impact and risk are only to building users in the immediate area of construction • water by fixture or area is shut down for ≤24 hours (minimal water age/stagnation)
B	**Small scale BWDS, short duration activities which create minimal water disruption, and modest water age.** Includes but not limited to: • replacing or installing fixtures and trim • working within wall cavities and/or ceiling areas • water by fixture or area is shut down for ≤7 calendar days (1 work week for water age)
C	**Work generates moderate to high BWDS disruption or removal of any fixed BWDS components or assemblies with medium water age.** Includes but not limited to: • plumbing work requiring multiple fixtures (existing, replacement or new) • major water system component replacement (boilers, heaters, water main, etc.) • work in wall cavities or ceilings with major disruption to local and downstream occupied areas • change of functional building space programme (i.e., moving / changing room or dept. functions) in existing building • water by fixture, component, or area is shut down ≤30 days
D	**Major BWDS demolition, renovation, infrastructure, and/or new construction projects with high water age.** Includes but not limited to: • change in functional building space programme (i.e., series of rooms and departments) • tenant improvements (i.e., existing buildings, or tenant space within unoccupied buildings) • new shell and core buildings, additions, or expansions on campus (i.e., near existing patient environments) • acquisition of building with unknown water quality / safety conditions

	• infrastructure projects connecting to building water systems (i.e., underground piping, utility tunnels, etc.) • water by fixture or area is not active (new start-up) or was shut down (>30 days).

---- End of Guidelines -----