Monograph

Water Management in Health Care Facilities

Second Edition

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AHA Data & Insights

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ASHE catalog #: P055197

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Editor's Note

This monograph was originally published in 2017 followed by a review and update in 2025. The 2025 update was based on the latest water management standards to bring the document up to date. ASHE thanks the authors of the first edition for their contributions:

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Executive Summary

Health care facilities are increasingly in need of water management planning to reduce and/or eliminate the possibility of waterborne illness. ASHRAE has recently developed and published two water management standards, ANSI/ASHRAE Standard 188, Legionellosis: Risk Management for Building Water Systems (ASHRAE 188) and ANSI/ASHRAE Standard 514, Risk Management for Building Water Systems: Physical, Chemical and Microbial Hazards (ASHRAE 514), that establish minimum risk management requirements for building water systems. Without proper guidance, health care facilities may take steps that are not required, that may be unnecessarily costly, or that are not helpful in reducing the threat from Legionella and other waterborne pathogens. Health care leadership should have a general sense of what is necessary to protect patients, staff and visitors from hazards associated with building water systems.

Because of the numerous waterborne pathogens and water hazards that health care facilities face, a general water management program should be created that is sensitive to the myriad water issues that may be present. A good water management program will give the facility the best plan of action to mitigate as much risk as possible.

This monograph:

1. Provides a summary of the threat of waterborne pathogens.
2. Gives an overview of water management best practices so that health care facilities leaders and facilities professionals can gain an understanding of the risks involved, approaches and general requirements to mitigate these risks.
3. Outlines recommended steps to establish a water management program.
4. Addresses maintenance procedures, monitoring and mitigation strategies, strategies to address control limit breaches, design and construction considerations, and emergency preparation and responses.
5. Provides additional information on potential pathogens and possible response methods within the appendices.

Introduction

According to the 2021 Waterborne Disease and Outbreak Surveillance Report, the Centers for Disease Control and Prevention (CDC) estimates that each year, 17 types of waterborne pathogens are responsible for 7.2 million illnesses, 601,000 emergency department visits, 120,000 hospitalizations, 6,600 deaths and $3.33 billion in direct health care costs for hospitalizations and emergency department visits. Additionally, the CDC estimates that each year, one in 44 people gets sick from waterborne diseases in the United States.

In the Morbidity and Mortality Weekly Report of March 14, 2024, the CDC reported that recent estimates of waterborne infectious illness and health care cost effects in the United States have revealed that two biofilm-associated pathogens, Legionella and nontuberculous mycobacteria (NTM), have emerged as the predominant causes of hospitalizations and deaths from waterborne and drinking water-related disease. While it is important to focus on all waterborne pathogens, an understanding of how specific waterborne pathogens can be managed can help inform the most effective strategy when implementing a water management program.

Legionellosis

Legionellosis is a recognized respiratory disease that can cause death or serious physical harm to building occupants. The term legionellosis refers collectively to two distinct clinical illnesses, Legionnaires' disease and Pontiac fever. Legionnaires' disease is when the bacterium Legionella causes severe pneumonia. Pontiac fever is categorized as a Legionella infection that results in a less severe, nonpneumonic, influenza-like illness. According to the CDC, an outbreak of legionellosis occurs when two or more people become ill in the same place at about the same time, for example, when two or more patients in a hospital become ill.

Legionellosis results predominantly from exposure to Legionella associated with building water systems. Estimates suggest that only 20% of Legionnaires' disease cases are outbreak related, with the majority being isolated cases. Outbreaks have been associated with whirlpool spas, cooling towers, decorative fountains, hotels, water systems of hospitals and nursing homes, and cruise ships. Those at increased risk for legionellosis include but are not limited to the elderly, dialysis patients, people who smoke and people with underlying medical conditions that weaken the immune system. However, a significant percentage of cases are in people who are not part of any identified at-risk population. Building water systems vary substantially in their design and propensity for transmission of Legionella. Conditions that are favorable for the amplification of Legionella growth include the presence of other bacteria, amoebas and other protozoan hosts; water temperatures of 77 to 108 F (25 to 42 C); stagnation; scale; sediment; and biofilms. Legionellosis is not transmitted from person to person. Multiple modes have been identified for transmission of Legionella to humans; there is evidence for aerosolization, aspiration and direct instillation into the lung during invasive procedures. In most instances, transmission to humans occurs when water that contains Legionella is aerosolized in respirable droplets.

The presence of Legionella bacteria in building water systems is not in itself sufficient to cause legionellosis. Other necessary factors include environmental conditions that promote the growth of Legionella, a means of transmitting the bacteria to people in the building (e.g., aerosol generation) and exposure of susceptible populations to colonized water that is inhaled or aspirated into the lungs. Legionella bacteria are not transmitted from person to person or from normal (nonaspirated) ingestion of contaminated water.

To mitigate the risks of acquiring most diseases, including legionellosis, building owners need to understand and develop programs to interrupt the cycle of infection. This can include attacking the organism's reservoir, amplification conditions, transmission and so forth. Effective intervention at any of these points in the cycle can significantly reduce risk. Water management program standards were developed to help building owners understand and assess the risks of waterborne pathogens and to develop water management plans to mitigate these risks. Ensuring that the water management program is part of the utility management program will help align with the Centers for Medicare & Medicaid Services (CMS) Conditions of Participation while providing a sanitary environment that avoids sources and transmission of infections and minimizing pathogenic biological agents in cooling towers, water systems and equipment that generates aerosols.

ASHRAE Standards 188 and 514

The purpose of ASHRAE standards 188 and 514 is to establish minimum risk management requirements for building water systems. In essence, these standards require the creation of a Designated Team that develops a water management program. The plan requires the team to designate control locations to monitor, establish monitoring procedures for those control locations, determine control limits within which the control locations should operate and identify action to take if a control location is outside the control limit parameters. The plan should further outline procedures for building water systems. While plan sections are identified, many of the plan details are at the discretion of the Designated Team.

These standards do not mandate testing for waterborne pathogens. The general approach is one of proper management and risk avoidance as opposed to implementing a testing and disinfection practice. This risk management approach is especially true for hospitals.

Hospital Response

In response to these standards, health care facilities should:

1. Establish a Designated Team.
2. Develop a building water flow diagram.
3. Identify at-risk populations.
4. Identify the areas, equipment and systems at risk.
5. Develop strategies to mitigate the risks.
6. Assign responsibility to implement risk mitigation strategies.
7. Establish a program to monitor the strategy parameters.
8. Develop actions to be taken when monitoring results are outside of established parameters.
9. Document all activities.
10. Periodically review the water management program.

While it is possible that disinfection or testing protocols may be one component of a water management program, hospitals should not begin disinfection or testing regimens until the facility risk assessment has been completed and the water management plan is in place. Additionally, while it is possible that outside consultant help may be required for certain aspects of the program that are beyond the Designated Team's competencies, that determination should be made by the Designated Team while performing the facility risk assessment.

Requirements for Health Care Facilities

ASHRAE standards 188 and 514 recognize the unique nature of health care facilities and provide a unique compliance pathway for these facilities. Health care facilities should comply with either the general requirements or with the health care-specific requirements of the aforementioned standards, depending on their scope. While the general requirements and health care sections of these standards have similar requirements, in some instances the health care sections take a risk management approach, whereas the main document takes more of a prescriptive approach. The health care sections were also developed to allow the required water management program to simultaneously meet the requirements from the CMS Conditions of Participation related to waterborne pathogens and to providing a sanitary environment to avoid sources and transmission of infections and communicable diseases per §482.42. Health care facilities are recommended to use the health care sections since these recognize that most health care facilities have an infection preventionist and existing risk management protocols in place, whereas most other buildings do not have existing system requirements and expert personnel on staff.

This monograph is structured to help hospitals and health care facilities follow the health care sections of these standards.

NOTE: For a detailed comparison of the focus, scope and requirements of these water management standards, see **Appendix D: Health Care Standards Comparison Matrix** on page 55.

The Water Management Program

Instituting an effective water management program will better prepare hospitals to meet the challenges associated with waterborne pathogens and water system hazards in general. This document outlines how to put together an effective water management program. Figure 1 provides a process flow diagram of the components of a health care facility water management program.

Create a Team

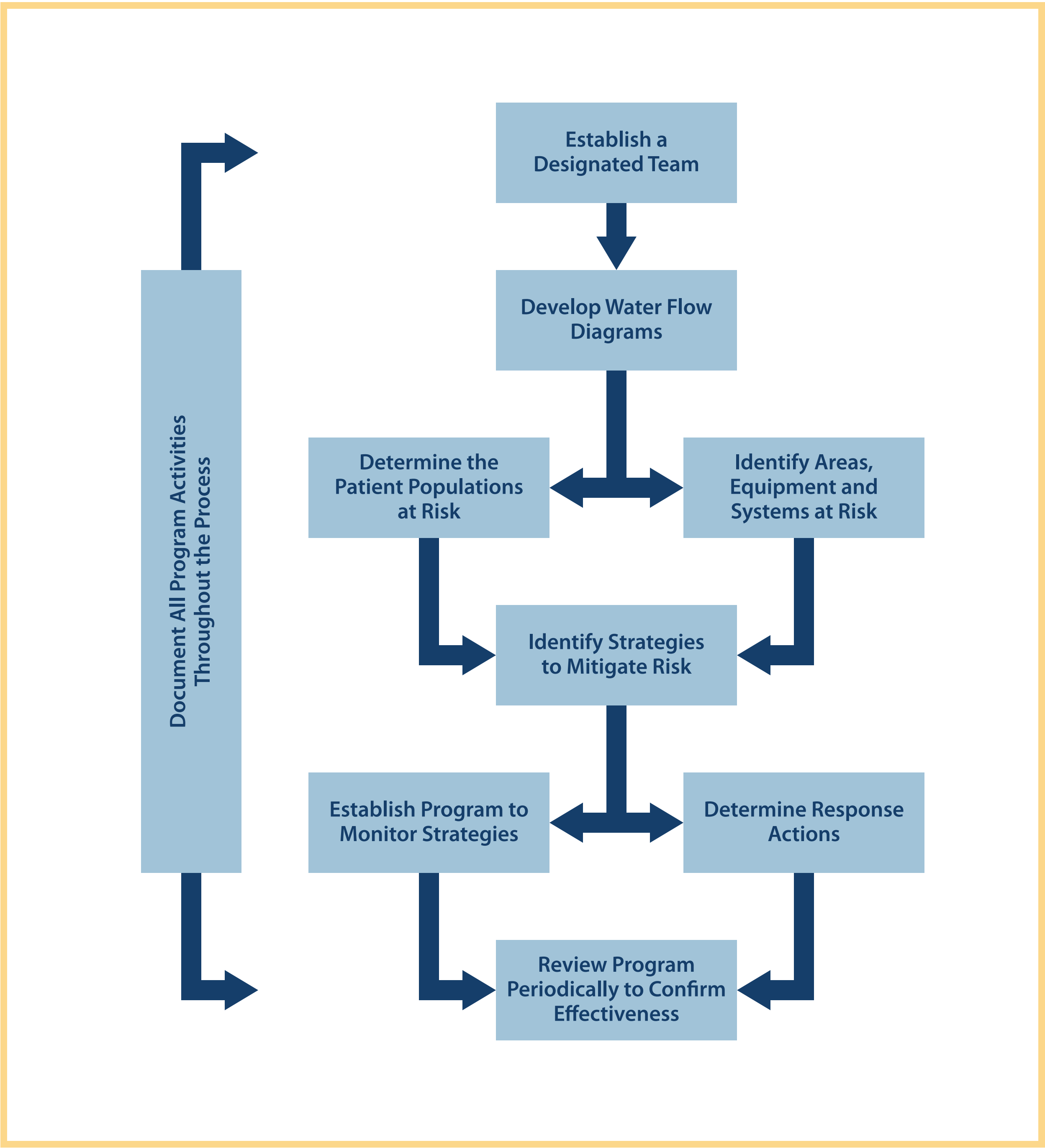
Perhaps the most important aspect of implementing an effective water management program is to create a functioning team that can effectively oversee the program. Health care facilities should establish the team and then have that team oversee writing the water management plan. This team could be a component of the Environment of Care committee or the utility management team within the hospital.

Create an effective team with clear objectives, balanced roles, effective communications, defined responsibilities and appropriate leadership. Depending on the organizational structure, this team should have a defining charter and/or management protocol providing clear direction. The team's purpose is to:

1. Write an implementable water management program and operating procedures that effectively reduce the risk of waterborne pathogens; and
2. Oversee effective implementation of the resultant plan.

This team is referred to in some standards as the "Designated Team."

Figure 1: Health Care Facility Water Management Program Process Flow Chart.



Membership

Team membership should include the following roles (depending on the size of the health care facility, more than one of these roles may be represented by the same person):

HOSPITAL EXECUTIVE. The hospital executive should have the ability and authority to provide sufficient resources to the team as required and to report significant issues, findings and risks to hospital senior leadership. They must have the authority to make command decisions about the water management program including water restrictions or other response measures.

FACILITIES MANAGER. Someone very familiar with building water systems must be on the Designated Team. This individual should have the ability and authority to provide maintenance resources, report findings and make command decisions for the facility as it pertains to the water management program.

INFECTION PREVENTIONIST. Someone familiar with the health care facility's infection prevention protocol and with methods of reducing possibilities of infections must be on the team. This individual should be a properly accredited epidemiologist with a master's degree (or equivalent) or be otherwise certified in infection control. This individual should be familiar with the areas where at-risk patient populations are located within the facility, be able to provide recommendations regarding the findings from facilities management and assist with making decisions for appropriate water management.

Additional team members should be considered from the following areas:

NURSING MANAGEMENT. Someone from nursing management with responsibility for nursing policies and procedures could be included. This individual should be able to provide resources to support appropriate actions required for appropriate water management program implementation.

OCCUPATIONAL AND ENVIRONMENTAL SAFETY MANAGEMENT. The team could include someone with an industrial hygienist certification with responsibility for occupational and environmental safety management policies and procedures. This individual should provide appropriate resources to assist with understanding the findings and supporting the decisions of the Designated Team.

REPRESENTATIVES FROM AFFECTED AREAS. As the team determines what areas will be of higher probability of infection throughout the facility based on the intended use of water-based processes and the relative vulnerability of patients to waterborne pathogens, a representative from these areas of the facility should be included on the Designated Team. A team member may represent more than one area within the facility if they have responsibilities for multiple areas. These individuals should have the ability and authority to implement the water management actions determined to be needed within their designated area.

OTHERS. Others, either inside or outside the facility, can be included as directed by senior leadership or Designated Team need or situation.

Purpose

The team should create the water management plan and establish standard building water system procedures. They will then oversee implementation of the plan and be ready to respond to issues.

The team should meet at regular intervals to ensure proper implementation and maintenance of the plan. When the plan is first implemented, the team may need to meet more frequently. They should also meet more frequently when significant issues are discovered.

The team must immediately intervene when epidemiologically indicated. This is one of the reasons to have people on the team with the authority to make command decisions and implement new procedures and changes to the program.

Support

Writing the detailed specifics of the water management plan may be beyond the skill set of the Designated Team. The team should determine if they have the requisite knowledge and, if necessary, seek support to establish a functioning team. This support may include one of the following:

- Engineer with waterborne pathogen experience.
- Infection preventionist.
- Water treatment specialist.
- Industrial hygienist.

Scope

The Designated Team should be able to address and act on water-related issues that arise. Ideally, this should be a proactive approach. In the event that the team is being assembled because of an emergent problem, that problem must be dealt with immediately. The team should solicit qualified assistance, if necessary. After the emergent issue is resolved, the team should evaluate the current water management program and make any necessary corrections or additions to the water management plan.

Map the Water System

The Designated Team should obtain or develop a water system flow diagram of the entire building water system. The purpose of the diagram is to help identify potential hazard conditions as well as to identify high-risk patient care locations. The diagram should include all water supply sources, treatment systems and control measures, processing steps and all end-use points. Additionally, the diagram should include all areas where at-risk patient populations are cared for. These areas include patient care areas housing burn, transplant or critical care; intensive care; surgery; emergency room trauma; neonatal intensive care; sterile processing; and any other locations as determined by the Designated Team. Lastly, the flow diagram should identify equipment where water may be aerosolized; this would include cooling towers, pools, spas and whirlpools, non-steam humidifiers and ice machines.

Everyone on the team must understand how water flows through the building, where it enters, how it is filtered (if applicable), how it is pumped (if applicable) and how it is distributed. Not everyone on the team needs to be a subject matter expert, but all should understand the systems and generally how water flows through the facility. Consideration should be given to having the Designated Team tour the facility to establish a base-level understanding of the building water system.

The hospital should keep updated diagrams illustrating the current state of the facility water distribution system. At any given time, up-to-date diagrams of the system should be easily obtainable. This diagram is necessary during any critical water situations, is helpful when planning construction and can generally help reduce water system-associated risks. In addition, accrediting organizations require that utility systems be properly designed, installed and mapped to meet patient care and operational needs.

Up-to-date plumbing as-built drawings, if available, could be used as the water system flow diagram, but may be too complicated for the team to use to assess risks. A simplified diagram, such as shown in the simplified drawing in Figure 2, may be more useful. The flow diagram should include all the areas and equipment where hazardous conditions may exist as well as locations where high-risk patients are cared for.

Identify Risk and Design a Water Management Plan

The Designated Team next uses the water system flow diagram to help create the water management plan. All aspects of the water management plan must be documented including development, implementation, verification and validation. In addition to the water system flow diagram, the plan should include the following elements.

Contact Information

The plan should include the name, title, role on team and contact information for all Designated Team members.

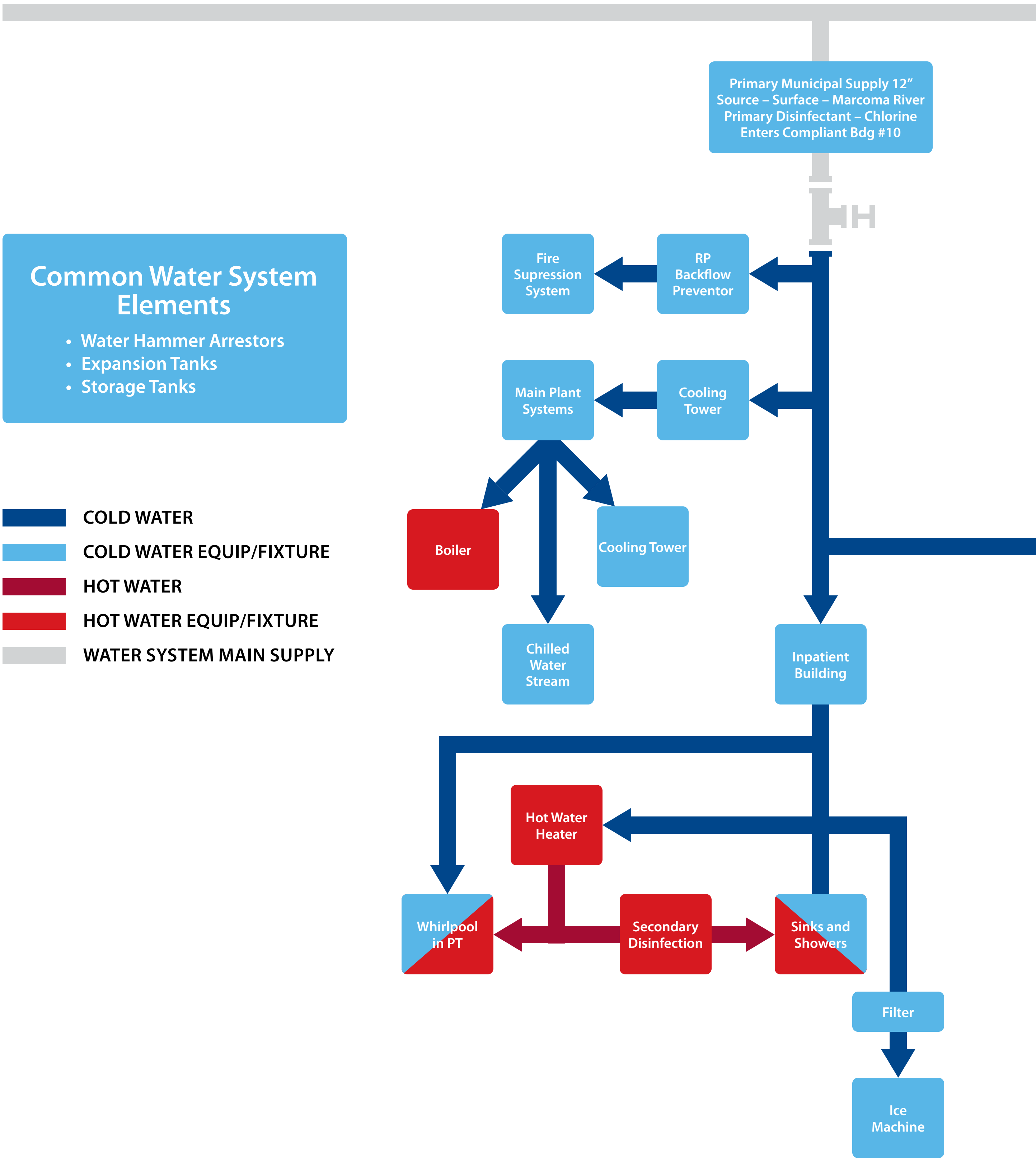
Systematic Evaluation

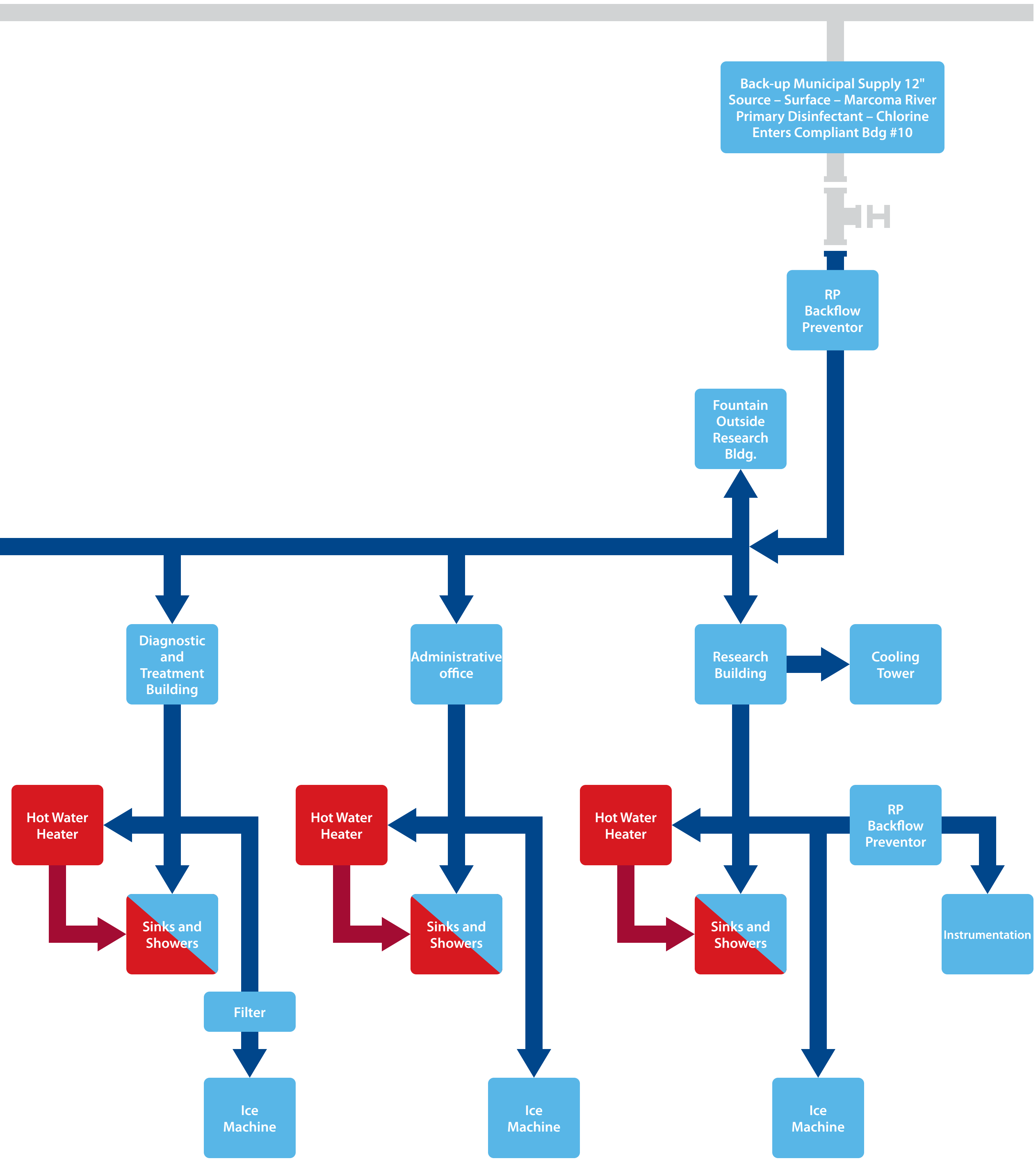
The Designated Team will systematically evaluate the physical and chemical conditions of each step in the water system flow diagram to identify where hazardous conditions may occur. These conditions are most likely in areas with slow or stagnant water. Next, the team should systematically identify areas housing patient populations that have a reduced immunity level and therefore a higher probability of infection. Higher probability of infection results from the intended use of water in those areas combined with relative vulnerability of patients in areas designated for specialized care. Taking these two factors (locations with hazardous conditions and areas with higher probability of infection), the team should estimate the likelihood of waterborne pathogen risk in locations throughout the water system.

Waterborne Pathogen Risk Assessment

While taking the systematic evaluation into account, the waterborne pathogen risk assessment should follow the existing infection prevention and risk management protocols of the facility. The assessment must identify those issues that may compromise water quality (also called hazardous conditions). In assessing risk, the following should be considered:

Figure 2: Building Water Flow Diagram




Back-up Municipal Supply 12"
Source – Surface – Marcoma River
Primary Disinfectant – Chlorine
Enters Compliant Bdg #10
RP Backflow Preventor
Fountain Outside Research Bldg.
Diagnostic and Treatment Building
Administrative office
Research Building
Cooling Tower
Hot Water Heater
Sinks and Showers
Hot Water Heater
Sinks and Showers
Hot Water Heater
Sinks and Showers
RP Backflow Preventor
Instrumentation
Filter
Ice Machine
Ice Machine
Ice Machine

- Determine if the facility has experienced a case of facility-associated or indeterminately caused waterborne infectious disease in the past.
- Consider whether the supply of water to the site poses high risk for waterborne pathogens. The facility should test and document disinfectant levels from the municipality and temperature from the incoming source at change of seasons (for surface water) or annually (for well water).
- Over time, the documentation mentioned above will provide data that could establish baseline information for a "dashboard indicator" for normal operations. Variations from these dashboard indicators may or may not be safe. Variations should be brought to the Designated Team for discussion and risk analysis.

Control Locations and Control Limits

The systematic evaluation is used to identify areas of higher waterborne pathogen risk in the system. These higher-risk areas constitute control locations or points in the system where a control measure may be desirable.

ASHRAE standards 188 and 514 require that the water management plan outline the procedures required for prevention and control of waterborne pathogens associated with the health care facility's building water systems. The approach here is a risk management approach. The systematic evaluation is used to identify control locations and to establish control limits. Control limits are a range of acceptable values associated with a chemical or physical parameter for identified control locations. These control limits could refer to characteristics such as water flow rate, water temperature, disinfectant residual, concentration of pathogen or other identified parameter.

At these control locations, the Designated Team may implement a control measure to help ensure the location stays within control limits. Possible control measures include disinfectant, heating, cooling, filtering, flushing or other means, methods and procedures to maintain the water within the identified control limits.

Monitoring Control Measures

Water management standards require the development of monitoring procedures to monitor control measures. Monitoring is a planned sequence of observations or measurements of the physical and chemical characteristics of control measures. By monitoring the incoming water and water systems within the facility, the team will be able to identify deviations from normal operations and whether the deviation is a fluctuation in the system. Such a fluctuation can be the first indicator that there is a potential for change in risk for waterborne pathogen detection.

If values are ever outside of control limits, the water management plan needs to identify corrective action to be implemented to bring water characteristics back within the established control limits.

The following is an example of corrective actions for waterborne pathogens within a sink:

Handwashing Station

Risk mitigation strategy

- Clean and disinfect surfaces daily near the drain.

Methodology

- Clean and disinfect sink basin.
- Clean and disinfect faucet.
- Clean and disinfect faucet handles.
- Clean and disinfect surrounding countertop.

Remediation actions

- During an outbreak, consider using a biofilm disinfectant for wastewater drains that has been registered with the Environmental Protection Agency.

ASHRAE standards 188 and 514 are not prescriptive in their approach. The framework identified above relies on the Designated Team to construct a system that effectively reduces risk within their facility.

Assignment of Responsibility

Each action required by the water management plan must be assigned to a responsible party.

Maintenance Protocols

The Designated Team should ensure that standardized maintenance protocols are adequate and that they are followed. In addition, maintenance protocol development should be based on best maintenance practices for each piece of equipment. Standard maintenance should be performed at the correct interval by knowledgeable facilities maintenance staff or outside vendors. All work performed should be properly completed and must be documented. The following section on building water system procedures provides guidance on the standard operating procedures. The Designated Team should develop appropriate procedures that address the areas required for a utility management program such as shutting off malfunctioning systems, obtaining emergency repair services and responding to disruptions to the building water systems.

Whenever there is an identified elevated risk (if a control location is outside of control limit parameters, for example), the water management plan must indicate procedures to follow. The procedures here might include notifying infection prevention, facilities management and provider staff of the elevated waterborne pathogen risk.

The water management plan may also indicate under what circumstances testing for Legionella and other waterborne pathogens might be performed.

The water management plan should indicate procedures to follow when infection control identifies a probable or confirmed waterborne pathogen case. The Designated Team should develop contingency response plans that detail procedures to be followed if there are known or suspected cases of diseases associated with waterborne pathogens. These contingency response plans should include criteria for when and where testing should be performed, procedures for emergency disinfection or other remedial actions, procedures for emergency clinical interventions, and recommendations from national, regional and local health department authorities. Procedures should include following established infection control processes and applicable laws, implementing remediation actions and reevaluating the water management plan.

Periodic Review

The team should also develop procedures to confirm that the water management plan is implemented as designed and that the plan effectively controls hazardous water conditions within the building water systems. This confirmation could be as simple as generating a reporting spreadsheet for specific steps within the water management plan and reviewing with the Designated Team when there are anomalies. This should include the review of the maintenance documentation.

Develop Standard Operating Procedures

Developing robust building water system procedures (standard operating procedures) is an effective way to reduce the risk of waterborne pathogens. ASHRAE standards 188 and 514, as well as the Association for the Advancement of Medical Instrumentation's standard ANSI/AAMI ST108, Water for the processing of medical devices (AAMI ST108), require that the water management plan include design and installation of utility systems and system evaluation and building surveys.

For the Design and Installation of Utility Systems

The installation of new utility systems is a valuable opportunity to improve the water system; however, if not done correctly, new installations can create a potentially hazardous situation when changes made ultimately spur pathogen growth. An example of this is how innovative water conservation strategies can increase the age of the water flowing through a building water system due to a decrease in water flow and thus increase the potential for risk of waterborne pathogens. Health care facilities should proactively evaluate and select quality equipment with the best possible low-risk design to ensure safe operation for water systems. Design of the water distribution system should include means and methods for disinfection of the water distribution system before occupancy and/or during outbreak conditions. Extra investment to ensure the system provided minimizes any risk for the development of biofilm or breeding grounds for pathogens should be considered. Caution needs to be practiced while performing any value engineering evaluations on water systems designs to avoid increasing risks for potential hazardous situations. The Designated Team should have final authority to accept or reject any recommended value engineering recommendations.

For System Evaluation

The Designated Team should evaluate the building water management plan on an annual basis. At a minimum, the evaluation would include the following:

- A review or update of the building water flow diagram:
  - Determine if any changes have been made to the water system that would add additional hazard points.
  - Determine if any new equipment systems have been added that have a potential of generating aerosols (cooling towers, spas, fountains, etc.).

- A review of the areas where at-risk patient populations are cared for:
    - Determine if any changes in clinical practices have occurred that either increase or decrease at-risk patient populations.
    - Determine if any additional water-using equipment has been installed.
- A review of monitoring activities:
    - Review the results of the risk mitigation strategy monitoring and make any needed changes in control ranges or maintenance intervals.

The results of this evaluation/survey should be reviewed and summarized to organization leadership. The best way to accomplish this may be to include the summary report in the utilities management program periodic reports through the Environment of Care reporting and as a portion of the annual evaluation report of the utility management program. At a minimum, an evaluation of the building water management plan should be performed annually.

Considerations for Water Safety and Function

The purpose of the water management program is to provide a water system that is safe, functional and reliable. This involves having a plan for preventing and controlling pathogenic agents in building water by ensuring all existing systems are properly maintained and by having a robust water system program in place.

An effective water management program addresses and implements functional controls based on the risk assessment, manufacturers' requirements and ongoing preventive maintenance. These controls should include the following:

- Effective start-up and shutdown procedures.
- Water treatment considerations.
- Monitoring effective water parameters through a monitoring program.
- Preventive maintenance to maintain conditions.
- Removal of dead ends in piping.
- Control of stagnant piping, or dead legs.
- Management of water temperature in systems.
- Control of system components that affect water quality, such as:
    - Cooling towers and evaporative coolers.
    - Water features, pools and spas.
    - Ornamental fountains and other water features.
    - Aerosol-generating misters, atomizers, air washers and humidifiers.
    - Ice machines.
    - Hot- and cold-water storage tanks.
    - Eyewash and emergency shower stations.
    - Water filters.
    - Electronic and manual faucets.

    - Aerators.
    - Faucet flow restrictors.
    - Deionization and reverse osmosis systems.
- Control of medical equipment system components.
- Emergencies and remediation of contamination in system components.
- Control and remediation of water systems during construction and renovation.
- Design considerations for new systems or systems undergoing renovation.
- Additional equipment selection consideration.

Risk reduction strategies include elimination of the identified risk (hazardous conditions), removal of obsolete systems and development of specific industry-recognized controls. Development of controls for these system components and conditions must evaluate known risk factors in building water, and minimally assess the following:

- Accumulation of sediment and debris in systems.
- Disadvantageous water conditions maintained between 77 F (25 C) and 120 F (48.9 C).
- Excessive water age.
- Water with stagnant conditions.
- The absence of a disinfectant residual.

Effective Start-up and Shutdown Procedures

Installation of New Systems

When installing new systems, the manufacturers' requirements for installing, commissioning and preparing for use must be followed. This step is often overlooked and can affect water systems before use. Specific steps often included in new installations include:

1. Inspecting all system functions.
2. Installing and flushing filter systems.
3. Flushing components of the system.
4. Verifying installation of piping, backflow systems and draining components.

5. Checking pressure and flow during operation to ensure consistency with manufacturers' specifications.
6. Verifying system temperature and disinfectant is maintained.

Drain line installation for certain systems must ensure that backflow and contamination of water components will not occur. These and other specific steps are developed by the manufacturer to be completed prior to use. Failure to follow specific start-up procedures can compromise component systems that affect water quality in the entire system.

Figure 3: Improperly installed drain line. Drain line must be at least 3 inches above drain to prevent backflow into systems.

Shutdown Procedures

Pre-planning must be completed when existing systems are shut down for repair or maintenance. Whenever a building water system or portion thereof is in a no-flow condition, the opportunity for pathogen amplification is increased as the disinfection levels are depleted. For these reasons, there should be written procedures that outline the steps to be taken whenever an idled system is placed back in service. Flushing each section of the piping system and connected devices is the most important component of these procedures. Periodic flushing while the system is idle will refresh the disinfectant levels and help mitigate the amplification risk.

Additionally, special care must be taken whenever repairs, renovations, or additions or alterations affect the water system. Health care facilities should maintain stringent standards for how disruptions to the water system are conducted and should include specific instructions for how to shut down, disinfect, test and commission the water system after it has been disturbed prior to putting the system back in use. Furthermore, special care must be taken whenever the water system is not fully utilized. For this reason, the following must be considered:

- How long will the system be out of service?
- Will the no-flow activities present a hazard to other systems and the water quality in the building?
- What are the manufacturer's requirements and procedures for shutdown?
- What are the manufacturer's requirements and procedures for reintroducing the component to the system?
- Will a complete start-up procedure be required to ensure that the component is functioning and in sanitary condition?

Water Treatment Considerations

Treatment is an important component of building water system procedures for potable water systems. The water system treatment procedures should identify monitoring methods and the schedule for temperature measurement in both hot and cold water systems, as well as monitoring methods and the schedule for disinfection and procedures to address treatment should an outbreak occur. Additionally, the water treatment products and procedures for their use in accordance with applicable regulations should be specified for each method.

The utility system, usually provided by a public municipality, is the ultimate source of water provided to the health care facility. Furthermore, some health care facilities provide added treatment methods such as chlorine or chloramines for cases when the utility system water disinfectant cannot be maintained. There are advantages and disadvantages to added disinfectant as well.

The organization should understand the following treatment concepts with evaluation for proper treatment:

- How does the utility treat the water provided to the health care facility?
- What is the concentration of treatment provided?

- What are the advantages and disadvantages of the treatment method provided?
- Is there additional disinfectant added in the facility?
- What are the advantages and disadvantages of the added treatment method?

NOTE: For a more thorough overview of various water treatment methods and their applications, see **Appendix A: Treatment Options** on page 44.

Establishing an Effective Monitoring Program

An effective monitoring program should include routine measurement of select water quality parameters. These parameters should be readily measured and can be easily obtained by direct reading instrumentation. Certain elements of systems must be understood before establishing parameters to measure. In addition, acceptable parameter levels (e.g., temperature, disinfectant, oxidation/reduction levels) must also be listed in the monitoring program. Lastly, the program documentation must include written actions and procedures to follow when parameters are out of acceptable limits.

Establishing a water monitoring program should be discussed and approved by the Designated Team. The team members must understand the purpose of collecting data, what the data interpretation means and what actions are required when parameters are out of range. The following water quality parameters should be considered when establishing a monitoring program:

1. Temperature.
2. pH.
3. Disinfectant.
4. Oxidation/reduction.

Adenosine triphosphate (ATP) testing is a process of rapidly measuring actively growing microorganisms through detection of ATP, a compound found in the presence of living cells. This and other forms of system disinfection verification through rapid reporting should also be considered.

Water hardness, coliforms (i.e., bacteria) or other specific pathogens (such as Legionella and pseudomonas), while useful, are not generally collected during routine sampling due to the complexity and delayed reporting of testing.

Rather, the routine collection and measurement of water parameters established by the program should be designed to give the organization access to instant readings that indicate water sanitation and certain physical properties. Collection of other parameters, such as Legionella, should only be considered for verification of controls in systems and not as a routine measurement.

Once parameters and acceptable levels are established, the measurement frequency and location must be developed. Location considerations for monitoring include:

1. Location of water intake for the facility (e.g., backflow preventor or utility water source).
2. Location of suspected stagnation or limited use, like sinks and showers.
3. Locations furthest from water intake or utility source, like sinks and showers.
4. Locations in high-risk patient population areas (e.g., sinks in rooms, sinks in medication and nourishment rooms).
5. Water features with specific risks, such as cooling towers, decorative fountains, pools or spas.
6. Water ports not routinely used in clinical areas (e.g., dialysis water ports in intensive care units or other areas).

Figure 4: Out of service scrub sink in clinical area. Sinks and other areas of limited use pose a risk for stagnation.

In summary, an effective monitoring program should include the following:

- A selection of water quality parameters to measure.
- Instrumentation used to measure these parameters.
- Actions and procedure to follow when water parameters are not within acceptable limits.
- Locations and frequency of testing.

NOTE: For a detailed overview of various water quality parameters and the acceptable limits dictated by relevant water management standards, see **Appendix E: Water Quality Testing Methods and Parameters** on page 57.

Preventive Maintenance

Adequate maintenance is critical to sustaining properly operating systems. Maintenance and monitoring procedures should include regular inspections for water-containing system components per the manufacturers' recommendations; regular flushing or mixing of known stagnant areas; and cleaning, disinfection, replacement and maintenance of water system components per the manufacturers' recommendations. Equipment that requires maintenance and monitoring includes hot- and cold-water storage tanks, ice machines, water-hammer arrestors, expansion tanks, water filters, shower heads and hoses, electronic faucets, aerators, faucet flow restrictors, non-steam aerosol-generating humidifiers, water heaters and other equipment. Instructions and logs for maintenance must be easily accessible. Manufacturers' recommendations should be used until evidence-based changes are warranted.

Water filters should be changed regularly, as they have a potential to foster pathogen growth. In addition, carbon-based filters will quickly deplete chlorine-based disinfectant levels and their use should be carefully considered and monitored. Growth will be more prevalent in areas where water has the opportunity to stagnate and especially where recirculation is not provided. This includes areas where water flow can stop for an extended period of time because of low usage rates, such as faucets and showers.

Finally, consider evaluation of the components within the water system such as the locations and risk of water-hammer arrestors or expansion tanks, as both of these components can potentially create locations where water can stagnate for an extended period of time. Filters under sinks used for rinsing medical devices in endoscope cleaning areas may require mechanisms to routinely rinse the particulate filters.

The water management program for a health care facility should identify all systems associated with water treatment, water flow and water use. These systems, and components associated with the following systems, should be part of the preventive maintenance program:

- Backflow preventors for fire and domestic water systems.
- Water sanitation and disinfecting system, such as reverse osmosis (RO), deionization (DI), ultraviolet light (UV), additional disinfection injection systems or other methods.
- Storage tanks for cold and hot water.
- Mixing valves used for water distribution.
- Cooling towers.
- Water pumps for water distribution systems.
- Humidifiers and dehumidification systems.
- All systems with in-line filters.
- Ice machines.
- Eyewashes.
- Systems with filters at distribution area (e.g., water fountains, sinks).

Figure 5: Lack of maintenance on a humidifier.

All maintenance performed must follow the manufacturers' requirements or industry guidelines such as an alternate equipment management program. Increased frequency in preventive maintenance activities may be required and determined by the facilities program. Considerations for increased maintenance may include:

1. Observed component or system failure.
2. Increased usage.
3. Age and wear on system components.

Maintenance activities must be documented and list the activities performed. This is important to meet accrediting organization documentation requirements and is required as part of a utility management program. This also allows for verification and validation of the water management program.

Removal of Dead Ends in Piping

Water that does not move eventually loses its disinfectant properties. This is based on the principle of water use and continued introduction of disinfected water from the utility source. Dead ends are lengths of pipe that are closed at one end such that water cannot flow. If these sections of pipe are too long, water does not flow through them as easily, resulting in standing water with no disinfectant. These dead-end pipes present a potential source of bacteria growth that can be introduced into the system.

Unlike dead legs, the dead end has no means to flow water. An evaluation of the water system should identify all locations with dead ends. This task should be completed by individuals knowledgeable of the system design and prior installation. Commonly found dead ends piping sections include:

1. Abandoned piping in walls from removed sinks, mop sinks and water fixtures.
2. Plumbing abandoned, cut off or rerouted in ceiling spaces from hot and cold water system.
3. Abandoned piping in walls from construction or renovation activities.
4. Piping added for future expansion opportunities.

Plumbing staff and utility maintenance personnel are excellent resources for determining areas with dead ends. Newly proposed construction and renovation should be reviewed to ensure that it has not resulted in the creation of dead ends within the system. Every effort should be taken to remove dead ends from the system or, for future expansions, to shorten these as much as possible.

Figure 6: Dead end piping from abandoned system.

Control of Stagnant Water, or Dead Legs

Water that is constantly moving is less likely to develop pathogen contaminants. Water age, or the length of time it takes water to travel through a water system, should be evaluated to verify that it is managed in an efficient manner. The higher the water age within a system, the higher the risk is for development of waterborne pathogens.

These lengths of pipe where water passes through infrequently, leading to a localized increased water age, are called dead legs. An evaluation of the water system should identify all locations with potential stagnant water use in an effort to control for reduced disinfectant in the system. Areas of particular concern for dead legs include:

- Showers with limited or no patient use.
- Closed units, such as sinks and showers.
- Sinks and water fixtures with low flow.
- Eyewash and emergency shower stations.

- Hot- and cold-water storage tanks.
- Areas undergoing new construction or renovation activities.

There are several methods used to control for stagnant use. These practices include increase water flow, decrease water age and maintain conditions to prevent bacteria growth. The following methods should be considered to prevent stagnant conditions.

Controlled Drainage of Systems and Components

Health care facilities have dozens of shower heads. If the shower heads are not self-draining, they could present a location for pathogen growth. The Designated Team should consider enacting a policy requiring all shower heads to be self-draining or, for those shower heads that do not meet this requirement, a policy that they be evaluated and potentially replaced as soon as possible. More stringent requirements may be necessary for protective environment units, and the Designated Team should develop the appropriate requirements for these areas. In areas with high-risk patient populations, consider removing hooks for handheld showerheads, as these prevent the flexible shower hoses from draining.

Management of Water Temperature

Hot water systems are particularly important to monitor because they can operate at temperatures that encourage pathogen growth. Pathogens can multiply in water between the temperatures of 68 F and 122 F (20 to 50 C) with temperatures between 77 F and 108 F (25 to 42 C) providing ideal growth conditions. Temperatures fluctuate within hot water systems. Even hot water systems with initial settings above 122 F (50 C) may have sections where water is in the temperature range that encourages pathogen multiplication.

Hot water must never be introduced to the use area above scalding temperature, 120 F (48.8 C). For that reason, systems designed to recirculate water back into hot water systems and storage tanks can be used to maintain temperature above 122 F (50 C) before distribution. The hot water system maintains temperature via loop systems that redistribute water to the user at a lower temperature by means of mixing valves. The mixing valve is generally located in the mechanical spaces and coordinates water temperature by mixing cold and hot water sources. Some facilities have installed these mixing valve devices at sinks prior to use. This allows for maintained hot water temperature in the system just prior to distribution.

Figure 7: Mixing valve in a mechanical space.

Figure 8: Mixing valve under sink.

Similarly, cold water systems should be kept cold enough to discourage pathogen growth. Care must be taken since cold water systems with initial setting below 60 F (20 C) may have sections where the water rises to the temperature range ideal for pathogen multiplication. Temperature should be checked regularly and at different system locations to ensure it is kept low. Selecting piping with minimal adhesiveness wherever possible will reduce biofilm growth. The use of automatic flushing devices can decrease the risk of biofilm and pathogen growth and should be considered.

Control of System Components Affecting Water Quality

Cooling Towers

Cooling towers represent a particular risk for Legionella and other waterborne pathogens and specific care needs to be taken in properly maintaining them. Issues arising from cooling tower water mists and aerosolization are well known and have been historically defined. Cooling tower standards include separation of towers from air intakes and entrances to building. Additionally, water treatment considerations include addition of biocide, chemical treatment and other measures to prevent development of conditions enhancing bacteria growth.

The water management plan documents should identify this as a specific hazardous condition and develop specific protocols for maintenance and treatment of water in cooling towers.

Specific industry guidelines for pathogen prevention of cooling tower water are detailed in ASHRAE Guideline 12, Managing the Risk of Legionellosis Associated with Building Water Systems, and in ASHRAE standards 188 and 514.

Water Features, Spas and Pools

Special care must be taken for water-using features that are particularly susceptible to pathogenic agents, and Facility Guidelines Institute documents do not allow water features in certain areas. This includes fountains, water features, therapy pools and therapy spas. Proper maintenance and chemical treatment will reduce and potentially mitigate the risk of waterborne pathogen aerosolizing. The patient population should be taken into account when considering the location of such features. The water management program should include specific testing requirements and acceptable chemical levels and clearly identify chemicals used. If a chemical treatment is changed, pay close attention to update the water management program to reflect this.

Policies and procedures for maintaining water features that follow the manufacturers' recommendations should be developed and followed. These procedures would typically include draining, cleaning all components, and disinfecting and refilling the water feature. Recirculating pumps should be provided and confirmed to be running.

In general, it is recommended that most health care facilities eliminate water fountains and water features. Those facilities that continue to maintain such features should follow the guidance of ASHRAE standards 188 or 514, which explicitly state that pools and spas shall be operated and maintained in accordance with the original equipment manufacturers' requirements.

Eyewash and Emergency Shower Stations

Manufacturers of eyewashes and emergency showers recommend specific time frames for testing and flowing of devices. These time frames are generally designed to ensure operation, as well as to ensure that water quality to the device is maintained. ANSI standards for eyewashes and emergency showers also require flowing. Organizations must follow time frames (e.g., weekly) and flow time (e.g., one minute or until water is clear) based on manufacturers' requirement and industry guidelines.

Water Filters

Organizations must inventory and maintain filter systems. Like air filters, water filters have end-of-life time frames based on the manufacturers' safety testing and approvals. For that reason, organizations must change filters based on manufacturers' requirements and more frequently if identified in the risk assessment process. Water filters can be found in the following systems:

1. Ice machines (carbon filters for taste and manufacturers' filters for purity).
2. Water fountains.
3. RO systems.
4. DI systems.

Control of Medical Equipment System Components

The risks associated with water and medical equipment is often overlooked. Several pieces of biomedical equipment (e.g., dialysis or heart-lung machines) use water for specific processes and procedures. This equipment may also rely on regular, DI or even RO water. The need to routinely flush, clean or change water in these systems should be detailed in medical equipment policies, user manuals or procedures.

Examples of medical equipment that affect water or have potential risk of aerosolization include:

1. Endoscopy cleaning systems.
2. Dialysis systems.
3. Continuous positive airway pressure machines.
4. Hydrotherapy equipment, water cooling/warming system.
5. Bronchoscope cleaning processes.
6. DI or RO systems used for dialysis and instrumentation processing.
7. Medical instrumentation washers and cleaning systems.

Consideration for management of these system must be thoroughly discussed and understood. An excellent resource is the biomedical engineering department personnel. Medical equipment use of water, biofilm issues and stagnant water issues must be examined. The Designated Team must routinely assess risk of such equipment and develop control strategies based on the manufacturers' requirements.

Figure 9: Water circulating (hydrotherapy) system used at the bedside. Manufacturer requirements include routine changing of water in reservoir.

Emergencies and Remediation of Contamination in System Components

Every health care facility must have emergency management protocols. Water systems must be included within the emergency plan. Loss of water can shut down a health care facility and create the need for patient evacuations. The loss of potable water for any reason is a critical situation. The emergency plan should include potential reasons for the loss of water, alternate means of acquiring water, the length of time the health care facility can be sustained through those alternate means and when to consider evacuation. A small fraction of water is used for drinking water compared to total water usage in a health care facility. Operational issues related to toilet flushing, sanitation, bathing, hand washing and cooking need to be addressed as part of emergency planning.

Loss of service as a result of external circumstances outside the control of the health care facility must be considered within the emergency management program. Consideration should include alternate means for providing functionality for operations usually delivered through the primary water source. Alternate means could be as simple as having a second water feed into the facility from a different water main within the municipality. It could also be the potential of on-site water storage for nonpotable water, patient drinking water converted to bottled water and bathing with wipes. Additionally, contracts can be in place for water to be trucked in on emergency call. All staff should be proficient and have documented procedures for the alternate means deemed appropriate for the facility. All of these potential alternate means will only be sustainable for a determined period of time. Evacuation procedures should be considered if the outage lasts longer than the sustainable alternate.

If water loss is a result of an internal failure, applicable alternative water means should be determined. Evaluation of the failure, estimated time down and repairs should be clearly communicated to the emergency command center. All repairs should be treated with the same considerations for cleaning and disinfection as renovations and new construction.

Design Considerations for New Systems or Systems Undergoing Renovation

The effective design of new or renovated systems must not only consider compliance with code requirements, but how systems will be accessed and managed. This includes staff ability to routinely inspect and maintain key components. More frequently than most, water system design features are not understood. Water flow direction, maintenance and accessibility are sometimes overlooked.

Design documents that should be reviewed and accessed should include:

- System overview.
- Construction documents (schematic diagrams).
- Process flow diagrams (monitoring and control diagrams).
- Compliance with codes/standards.
- Procedures for start-up.
- Location of:
    - Makeup.
    - Flushing areas.
    - Sampling.
    - Temperature monitoring.
    - Drain.

- Outdoor intakes.
- Building water equipment manuals.
- Commissioning documents.

Design documents that should routinely be reviewed and understood include:

- Operating instructions and procedures.
- Maintenance schedules, frequencies and procedures.
- Location of sampling points.
- Incoming water quality report used for the Basis of Design.
- Design provisions that address hazardous conditions.
- No-flow and low-flow portions of piping.
- Impact of heat loss or gain.
- Cross connections.
- Access to expansion tanks, water hammer arrestors, water storage tanks, water heaters, and other equipment and components that contain water.
- Pipe size, length and flow.

Additional Equipment Selection Consideration

Equipment selection is an important factor in reducing waterborne pathogen risk. For example, some plumbing fixtures that reduce flow rates may also trap water within the fixture or create flows so low that pathogen risk increases. Oversizing water pipes can lead to low flow situations throughout the building. Therefore, when selecting system components, system efficiency and patient risk must be part of the decision process.

Aerators and flow restrictors in faucets have also been a contentious debate. There has been much discussion over the years regarding suspect aerosolization risk and potential pathogen spread from aerators on sinks. The decision to remove aerators should be directed by the Designated Team based upon review of evidence. Many organizations have chosen to remove these devices in high infection risk areas (e.g., cancer hospitals, bone marrow units, transplant units). Others have removed them altogether.

Some evidence suggests that splashing at hand water stations could transmit bacteria to the water system through the faucets, and that aerators enhance this potential risk. Flow restrictors should not be allowed that restrict the flow to less than 1.5 gallons per minute since this can increase water age to an unacceptable length of time.

Lastly, the Designated Team should continue to examine and review the most recent evidence regarding effective water treatment and system controls. Changes in processes, addition of systems affecting water quality and review of existing systems must be discussed routinely. The use of such systems must be assessed and discussed before installing.

Document and Communicate

It is important to maintain documentation associated with the water management program. ASHRAE Standard 188, ANSI/ASHRAE Standard 514 and ANSI/AAMI ST108:2023, among others, include some form of documentation requirement. Documentation maintenance can involve several different departments within the facility. These include but are not limited to: facilities, biomedical/clinical engineering, sterile processing, steam plant, dialysis, operating rooms, neonatal intensive care units and infection prevention departments. Designated Team members may be responsible for documentation within their department. Documentation received and stored in several departments and efforts to consolidate the documentation into one operation program manual will be beneficial to provide instant access to documentation when needed for regulatory review or diagnosis of water system problems. Documentation should conform to the regulatory authority requirements and may involve some or all of the following parts of the water system related to:

- Facilities waterborne pathogen prevention, including of cooling towers and potable water.
- Facilities utility water and critical water for sterile processing departments.
- Facilities steam quality in reference to clean steam, process steam, and plant or house steam for use as humidification and sterilization in operating rooms and sterile processing departments.
- Potable water used in ice machines, drinking water stations and sensor faucets.
- Dialysis equipment and treatment areas.

It is important to create a strategic water plan that becomes a living document and remains current. One way to ensure the validity of the plan's documentation is to review the plan in established time intervals with the organization's environment of care or infection prevention committees. CMS Conditions of

Participation require the water management program to be an active program, meaning the program is adequately communicated to those affected by the program. With this in mind, a Designated Team should include individuals from several of the departments described above. These team participants in high-risk areas will be the liaisons for their respective departments in providing communication, ensuring the water program elements are compliant.

Conclusion

Risk management for building water systems is particularly important for health care facilities because of the vulnerable patient populations they serve, the large size of their water systems and the organizational difficulties associated with governing multiple critical complex systems. Therefore, health care facilities must carefully institute effective plans and procedures to reduce the risks associated with waterborne pathogens in building water systems. Fortunately, health care facilities have resources other organizations do not have, such as infection preventionists, existing management systems that may prove useful for building water system purposes and experience with risk management. Health care organizations should take advantage of these resources in developing a risk management approach. Health care facilities that establish effective building water system procedures with active risk management protocols and that empower their teams can ensure that their performance will meet the requirements of current health care standards and guidance and greatly reduce risks arising from their building water systems.

As a facilities leader, the task of ensuring that a water management plan meets all requirements throughout the facility may at first seem like a daunting task. ANSI/ASHRAE Standard 188-2021, ANSI/ASHRAE Standard 514-2023 and ANSI/AAMI ST108:2023 collectively outline step-by-step guidance on how to incorporate several elements of the water management program. A comprehensive water management program should account for the recommendations of all three standards.

The 2021 edition of ANSI/ASHRAE Standard 188, Legionellosis: Risk Management for Building Water Systems, provides baseline practices to manage overall legionellosis risk for building water systems. The standard provides minimum legionellosis risk management requirements for the design, construction, commissioning, operation, maintenance, repair, replacement and expansion of new and existing buildings and their associated (potable and nonpotable) water system components.

The 2023 edition ANSI/ASHRAE Standard 514, Risk Management for Building Water Systems: Physical, Chemical, and Microbial Hazards addresses possible unintended adverse consequences with regard to other hazards and is intended to address the need of overall risk from physical, chemical and microbial risks associated with building water systems. This standard provides minimal practices to manage overall risk from microbial hazards other than Legionella, as well as risk from physical and chemical hazards associated with potable and nonpotable building water systems. Section 8, "Requirements for Healthcare Facilities," pertains to hospitals and long-term residential care, skilled nursing and physical rehab care. The standard applies to buildings that include areas for surgery, chemotherapy, burns units, solid organ transplants or treatment of immunocompromised patients. The standard also includes several informative appendices used as guidance to help build and maintain water management plans.

ANSI/AAMI ST108:2023, Water for the processing of medical devices, provides guidelines for selecting the water quality necessary for the processing of categories of medical devices and addresses water treatment equipment, water distribution and storage, quality control procedures for monitoring water quality, strategies for bacterial control, and environmental and personnel considerations. The objective of the standard is to set the quality requirements for different categories of water used in the processing of medical devices. The standard defines the characteristics of tap water, utility water, critical water and steam water category requirements, as well as performance qualification levels of water quality used in the processing of medical devices.

Establishing Control Points and Water Testing

Testing is sometimes recommended when establishing some types of control points for physical, chemical and microbial hazards and water quality. Some authorities having jurisdiction require Legionella testing of cooling towers and potable water systems at certain time intervals. If testing is to be completed, the facility should use a qualified, accredited testing laboratory. Testing for physical and chemical hazards will help determine the water quality. After a baseline is established, certain equipment or chemicals to increase the quality of the water within recommended standards for water use may be applied. Take note that when testing water, certain manufacturers' instructions for sample collection and transport should be adhered to. Guidance for physical and chemical standards and testing frequency can be found in the above-mentioned standards.

It is important to understand water sources and their uses throughout the facility. Water purity and quality can vary depending upon its intended use. Other control points to be determined may include, but are not limited to, temperature logging points, water filtration locations (e.g., ice machines) and water used to create steam for sterilization and humidification.

Utilizing all three standards to complete a thorough risk-based water program analysis will help validate and confirm that the program, when implemented as designed, controls hazardous conditions throughout the building water systems.

Many health care facilities managers have campuses that include building types other than health care facilities. To assist with the proper application of water management standards for these types of structures, the Centers for Disease Control and Prevention has developed a tool kit, "Developing a Water Management Program to Reduce Legionella Growth and Spread in Buildings: A Practical Guide to Implementing Industry Standards." This tool kit, which will help develop and implement a water management program for these other building types, can be accessed at cdc.gov/control-legionella/php/toolkit/wmp-toolkit.html.

Appendix A: Treatment Options

Several treatment options exist for water pathogen disinfection. This section is an overview of various treatment options for consideration. Due to the complexity of some of the available treatment options, health care facilities should consider consulting a waterborne pathogen expert prior to implementing treatment options who can provide specific guidance on which treatment options are best to use for the specific needs of the facility.

When addressing water systems for waterborne pathogens, several factors should be considered. The primary concern is the efficacy of the chosen treatment method in eliminating a broad range of pathogens. Equally important is the treatment's ability to disrupt and remove biofilms, which can harbor pathogens and protect them from disinfection efforts. Biofilms play a significant role in the persistence of waterborne pathogens; therefore, treatment strategies must effectively target both the pathogens and the biofilms they inhabit. Additionally, some treatment methods leave behind residual chemical agents that can inhibit pathogen regrowth after the initial disinfection process. This residual effect can be crucial in maintaining long-term safety in water systems, especially in health care environments where vulnerable populations may be at risk.

Alternatively, possible consequences of chemical treatment include disinfection byproducts, such as ammonia, nitrite and nitrate. These byproducts feed some microbial hazards in the health care environment and should be monitored on a regular basis as part of a health care facility's water management program.

The following chart provides a brief overview of various treatment options, outlining their procedures, advantages, and disadvantages.

	Treatment Type	Description	Procedure	Advantages	Disadvantages
Primary Disinfection	Chlorination	Chlorine dioxide is an oxidizing biocide that kills microorganisms by disrupting nutrient transport across cell walls. It is less reactive than other oxidizers, making it ideal for baseline disinfection.	Chlorine dioxide gas is dosed into water, activated by adding an acid, allowing it to maintain effectiveness even in low concentrations. Chlorine dioxide systems often require precise dosing equipment to control residual levels.	• Effective in a wide pH range (4–10). • Highly effective against biofilms and Legionella. • Offers a preventive effect at low, continuous dosing levels.	• Chlorine dioxide decomposes quickly and requires continuous monitoring of residuals to maintain efficacy. • Heating can remove chlorine dioxide from the water, so extra equipment may be needed on the heating side to ensure its effectiveness.
	Ozone Disinfection	Ozone (O3) is a potent oxidizing agent that effectively removes organic contaminants and inactivates a wide range of microorganisms. It is highly useful for initial high-level disinfection where residuals are undesirable.	Ozone is generated by an ozone generator, which uses electrical energy to convert oxygen (O2) into ozone (O3). The ozone is then injected into the water at concentrations between 0.2 and 0.5 milligrams per liter (mg/L) with a contact time of around 10 minutes for effective microbial inactivation.	• Highly effective against bacteria, viruses and protozoa. • Eliminates organic contaminants, improving water quality. • Ozone reverts to oxygen, leaving no harmful residuals.	• Requires specialized equipment and frequent monitoring to ensure ozone concentration. • Ozone can be toxic at high concentrations, so facilities must implement safety measures to protect staff. • Does not remove heavy metals and other nonorganic contaminants.
	Copper-Silver Ionization	Releases copper and silver ions that disrupt microbial cell walls and inhibit biofilm formation. Highly effective for Legionella control and biofilm prevention in hot water systems.	The ionization process involves releasing electrically charged copper and silver ions into the water system. These ions are effective at disrupting cellular walls of microorganisms, leading to cell death and providing a long-lasting residual effect that inhibits biofilm formation.	• Long-lasting residual effect against Legionella and other biofilm-associated pathogens. • Low maintenance requirements once installed.	• Precise ion concentration control is necessary to avoid buildup in pipes, which can lead to toxicity issues. • Monitoring is essential to maintain appropriate ion levels, and initial setup can be costly due to equipment and installation.

	Treatment Type	Description	Procedure	Advantages	Disadvantages
Primary Disinfection	Thermal Eradication	Thermal eradication, also known as superheat and flush, involves raising water temperatures to kill pathogens, especially Legionella, in the distribution system. It is a nonchemical method for routine microbial control.	Heat water in the hot water tank to at least 158 F (70 C) and then flush all outlets, faucets and showerheads with this heated water for a minimum of 45 minutes. During this time, ensure the temperature at each outlet reaches at least 140 F (60 C) to achieve microbial kill rates.	• No special equipment is required, making it an accessible method for routine microbial control. • Can be quickly implemented in response to contamination.	• Thermal eradication is a temporary solution, as recolonization can occur after treatment. • High risk of scalding if proper precautions are not taken, making it unsuitable for some patient care areas.
	Reverse Osmosis (RO)	Reverse osmosis is a highly effective filtration process that removes dissolved solids, ions and microorganisms, producing high-purity water for critical health care applications.	Water is forced through a semipermeable membrane under high pressure, which removes ions, bacteria, endotoxins and other impurities. RO is commonly used in facilities with high-purity requirements, such as dialysis or sterile processing departments.	• Produces high-purity water ideal for sensitive medical applications. • Effective at removing a broad spectrum of contaminants.	• High initial setup cost and requires prefiltration to prevent membrane fouling. • RO systems also need regular maintenance and have limited capacity, making them costly for high-volume applications.
Secondary Disinfection	Ultrafiltration	A membrane-based filtration process that removes particles, bacteria and endotoxins. Often used as a pretreatment for RO or as a stand-alone method for producing high-purity water.	Ultrafiltration membranes are available in two modes: cross-flow (where part of the water flows across the membrane surface to reduce fouling) and dead-end (where all water passes through, requiring more frequent cleaning). It is typically used downstream of other treatment methods like ultraviolet or deionization.	• Highly effective at removing large molecules, bacteria and endotoxins. • Supports continuous operation when maintained. • Reduces the load on subsequent purification processes, improving overall system efficiency.	• Membrane fouling can occur, requiring regular maintenance and cleaning. • Initial capital and operational costs can be high. • Not effective for removing dissolved salts or low-molecular-weight contaminants without additional processes.

	Treatment Type	Description	Procedure	Advantages	Disadvantages
Secondary Disinfection	Chlorine Dioxide	A disinfectant with a strong residual effect; effective against biofilms and bacteria. Secondary disinfection with good residual and biofilm control.	Chlorine dioxide is added to the water to maintain a residual that prevents microbial growth and biofilm formation. Continuous dosing is used to ensure consistent residual levels throughout the system.	• Provides strong residual protection; particularly effective against biofilms and Legionella. • Generates fewer harmful byproducts compared to traditional chlorine disinfection.	• Requires careful dosing and monitoring to avoid toxicity. • Chlorine dioxide is potentially harmful at high concentrations and requires special handling and dosing equipment.
	Activated Carbon Filtration	Used to remove chlorine, organic compounds and odor/taste compounds, commonly as a pretreatment step for systems sensitive to disinfectants.	Water flows through activated carbon, which absorbs contaminants like chlorine and organics, improving taste and reducing residual disinfectant levels. Often used before reverse osmosis or deionization to protect equipment.	• Reduces chlorine and organic compounds effectively, improving water aesthetics and safety for processes sensitive to chlorine. • Low operational cost.	• Does not remove microbial contaminants, and if not replaced regularly, the filter media can become a source of microbial growth. • Requires frequent filter replacement and maintenance.
	Monochlorination	Provides extended residual protection with a slow-release chlorine compound. Ideal for large systems requiring long-term residual disinfection.	Chlorine gas or sodium hypochlorite is introduced to the water supply, mixed thoroughly and allowed to maintain contact time for effective disinfection. The residual is maintained throughout the system with regular monitoring.	• Long-lasting residual effect; stable in distribution systems; fewer harmful byproducts than free chlorine. • Suitable for long-duration disinfection needs.	• Less effective as a rapid disinfectant due to slower action. • May cause taste and odor issues if not properly managed. • Requires careful dosing and monitoring to avoid overdosing.
	Sodium Bisulfite Injection	Used to neutralize chlorine in water, especially for equipment sensitive to residual chlorine, such as reverse osmosis units.	Sodium bisulfite is injected into the water to chemically neutralize chlorine. This process is often used after activated carbon filtration for applications where chlorine-free water is required.	• Effectively removes chlorine, protecting equipment from chlorine damage and preventing biofilm growth in chlorine-sensitive systems. • Simple dosing process.	• Overdosing can contribute to biofilm growth. • Requires precise dosing control and additional equipment for monitoring and distribution.

	Treatment Type	Description	Procedure	Advantages	Disadvantages
Supplemental Methods	Peracetic Acid	A highly effective oxidizing disinfectant used for targeted applications in critical equipment areas, often in high-level sterilization processes.	Peracetic acid is injected directly into water lines or used as a batch treatment for high-touch areas. It provides fast microbial kill without residual byproducts, making it suitable for specialized sterilization needs.	• Broad-spectrum efficacy against a variety of pathogens. • Does not produce harmful byproducts, making it environmentally friendly.	• Corrosive and requires careful handling, especially in confined spaces. • Lacks a residual effect, so continuous protection is not provided.
	Ultraviolet (UV) Disinfection	UV light inactivates microorganisms by damaging their DNA; commonly used for point-of-use applications in sensitive health care areas.	Water is exposed to UV light as it passes through a UV chamber, deactivating pathogens without adding chemical residuals. Ideal for areas where chemical additives are undesirable.	• Effective against a wide range of pathogens with no chemical byproducts. • Easy to install. • Suitable for point-of-use disinfection.	• Does not prevent biofilm formation. • Offers no residual protection. • Requires high maintenance for UV lamps to ensure effectiveness.
	Deionization (DI)	An ion exchange process that removes both cations and anions from water, resulting in highly purified water suitable for sensitive applications like lab work.	Water passes through a DI system with ion-exchange resins that replace contaminants with hydrogen and hydroxide ions. DI is often combined with carbon filtration and ultrafiltration to enhance purity.	• Highly effective in removing ionized contaminants. • Produces high-quality water suitable for sensitive applications. • Can be integrated with other purification processes for enhanced effectiveness.	• Ineffective at removing non-ionized substances, such as bacteria and endotoxins, without additional treatment. • Requires regular monitoring and maintenance, including resin regeneration. • Not recommended as a primary purification method due to limitations in removing low-molecular weight toxins.
	Nanofiltration (NF)	Membrane filtration that removes select ions and small molecules; especially useful for removing nitrates and organics in specific applications.	Water passes through NF membranes, which selectively filter molecules, including nitrates, at low energy cost compared to RO. Suitable for partial softening and selective ion removal.	• Selectively removes ions and organics, reducing the need for complete demineralization. • Lower energy requirements compared to reverse osmosis.	• Limited microbial removal, so it often requires additional downstream treatment for comprehensive pathogen control. • Regular maintenance is necessary to prevent fouling.

Appendix B: Pathogens

Legionellosis

Legionnaires' disease and Pontiac fever are caused by a type of bacteria called Legionella (cdc.gov/legionella/index.html). Legionella bacteria are found naturally in the environment, usually in water. The bacteria grow best in warm water, like that found in hot tubs, cooling towers, hot water tanks, large plumbing systems, decorative fountains and within the tubing of ice machines.

People get Legionnaires' disease when they breathe in a mist or vapor (small droplets of water in the air) containing the bacteria. One example might be from breathing in droplets sprayed from a hot tub that has not been properly cleaned and disinfected. The bacteria are not spread from one person to another person.

Escherichia coli (E. coli)

CONTAMINATED FOOD: The most common way to acquire an E. coli infection (cdc.gov/ecoli/about/) is by eating contaminated food, such as:

- *Ground beef*. When cattle are slaughtered and processed, E. coli bacteria in their intestines can get on the meat. Ground beef combines meat from many different animals, increasing the risk of contamination.
- *Unpasteurized milk*. E. coli bacteria on a cow's udder or on milking equipment can get into raw milk.
- *Fresh produce*. Runoff from cattle farms can contaminate fields where fresh produce is grown. Certain vegetables, such as spinach and lettuce, are particularly vulnerable to this type of contamination.

CONTAMINATED WATER: Human and animal feces may pollute ground and surface water, including streams, rivers, lakes and water used to irrigate crops. Although public water systems use chlorine, ultraviolet light or ozone to kill E. coli, some outbreaks have been linked to contaminated municipal water supplies. Private wells are a greater cause for concern because they do not often have any disinfecting system. Rural water supplies are the most likely to be contaminated. Some people also have been infected after swimming in pools or lakes contaminated with feces.

PERSONAL CONTACT: E. coli bacteria can easily travel from person to person, especially when infected adults and children do not wash their hands properly. Family members of young children with E. coli infection are especially likely to acquire it themselves. Outbreaks have also occurred among children visiting petting zoos and in animal barns at county fairs.

Pseudomonas aeruginosa

In hospitals, where the most serious infections occur, Pseudomonas can be spread on the hands of health care workers or by equipment that gets contaminated and is not properly cleaned (cdc.gov/pseudomonas-aeruginosa/about/).

Serious Pseudomonas infections usually occur in people in the hospital and/or with weakened immune systems.

Patients in hospitals, especially those on breathing machines, those with devices such as catheters and patients with wounds from surgery or from burns are potentially at risk for serious, life-threatening infections.

Klebsiella pneumoniae

To get a Klebsiella infection, a person must be exposed to the bacteria (cdc.gov/klebsiella/about/). For example, Klebsiella must enter the respiratory tract to cause pneumoniae, or the blood to cause a bloodstream infection.

In health care settings, Klebsiella bacteria can be spread through person-to-person contact (for example, from patient to patient via the contaminated hands of health care personnel or other persons) or, less commonly, by contamination of the environment. The bacteria are not spread through the air.

Patients in health care settings also may be exposed to Klebsiella when they are on ventilators (breathing machines) or have intravenous (vein) catheters or wounds (caused by injury or surgery). Unfortunately, these medical tools and conditions may allow Klebsiella to enter the body and cause infection.

Cronobacter

Cronobacter (formerly called Enterobacter sakazakii, cdc.gov/cronobacter/about/) is a germ found naturally in the environment that can survive in very dry conditions. Cronobacter has been found in dry foods, such as powdered infant formula, powdered milk, herbal teas and starches. It has also been found in sewer water and may be found in other places, too.

Multiple reports have incriminated the hands of personnel, endoscopes, blood products, stethoscopes and devices for monitoring intra-arterial pressure as sources of infection. Outbreaks have been traced to various common sources: total parenteral nutrition solutions, isotonic saline solutions, albumin, digital thermometers and dialysis equipment.

Acinetobacter baumannii

Acinetobacter is a group of bacteria commonly found in soil and water (cdc.gov/acinetobacter/about/). There are many species of Acinetobacter and all can cause human disease. Acinetobacter baumannii accounts for about 80% of reported infections. Outbreaks of Acinetobacter infections typically occur in intensive care units and health care settings housing very ill patients. Acinetobacter infections rarely occur outside of health care settings. The ability of A. baumannii to grow as biofilm on abiotic surfaces plays an important role in causing health care-associated infections because of the surface colonization of hospital equipment and indwelling medical devices, such as urinary catheters, central venous catheters, endotracheal tubes and the like. In general, biofilms in the distribution system are much more resistant to disinfection than planktonic cells, and Acinetobacter have been found in drinking water distribution system biofilms. An A. calcoaceticus strain isolated from drinking water was shown to form biofilms on stainless steel, copper, polypropylene, polyethylene and silicone.

Acanthamoeba

Acanthamoeba is a free-living protozoan that poses significant health risks, particularly in hospital environments (cdc.gov/acanthamoeba/about/). This microorganism is best known for causing Acanthamoeba keratitis, an eye infection commonly associated with contact lens use. Individuals who follow poor hygiene practices, such as using tap water to rinse contact lenses or exposing them to water while swimming or showering, are most susceptible. However, individuals who do not wear contact lenses can also be infected.

In health care settings, Acanthamoeba can enter the environment through contaminated water sources, which may be present in sinks, showers or hot tubs. Vulnerable patients, including those with compromised immune systems, those with open wounds or individuals undergoing invasive procedures, are at heightened risk. Acanthamoeba can invade the body through breaks in the skin or mucous membranes, subsequently spreading via the bloodstream to vital organs, including the lungs, brain and bones. Notably, Acanthamoeba infections are not transmitted from person to person, but its presence in hospitals can also facilitate the survival of other pathogens, further complicating patient care.

Naegleria fowleri

Naegleria fowleri (N. fowleri) is a pathogenic amoeba that can cause a severe brain infection known as primary amoebic meningoencephalitis (PAM) when water containing the organism enters the body through the nose (cdc.gov/naegleria/about/). Once inside, the amoeba travels to the brain, leading to rapid and destructive tissue damage. Unfortunately, there is no standardized treatment for N. fowleri infections, and they are nearly always fatal.

Infections are most commonly associated with activities such as swimming in warm freshwater bodies like lakes and hot springs, where the amoeba thrives. While N. fowleri has been found in some potable water systems, actual cases linked to drinking water are extremely rare. One potential route of infection in a hospital setting could occur through the irrigation of sinuses with contaminated tap water. Importantly, N. fowleri is not transmitted through drinking contaminated water, water vapor or aerosols, such as those from a shower or humidifier, and it cannot spread from person to person. Given its high fatality rate, awareness and preventive measures in environments where exposure could occur are crucial for patient safety.

Klebsiella oxytoca

Klebsiella oxytoca is a type of bacterium that is frequently spread in intensive care units or nursing homes (cdc.gov/klebsiella/about/). It is closely related to Klebsiella pneumonia.

Such organisms are known as opportunistic pathogens. Many of these infections occur in patients who are hospitalized for some other reason, and the bacteria can be easily spread on the hands of hospital workers.

Patients whose care requires devices, like ventilators or intravenous catheters, and patients who are taking long courses of certain antibiotics are most at risk for Klebsiella infections.

Additional risk factors include the use of a catheter or feeding tube, which can allow the bacteria to enter the body and bypass its defense mechanisms.

Elizabethkingia anopheles

Elizabethkingia is a genus of bacterium that is found in soil, river water and reservoirs (cdc.gov/elizabethkingia/about/). It rarely makes people sick; however, since Elizabethkingia are opportunistic pathogens, people with weakened immune systems are more at risk of infection. Outbreaks that occur are typically in health care settings. A recent study of an outbreak in London showed acquisition was water source-associated in critical care. In a recent outbreak in Wisconsin, Michigan and Illinois, most infections were bloodstream infections but some patients had Elizabethkingia isolated from the respiratory system or joints.

Appendix C: A Risk Management Process

Much like the infection control risk assessment (ICRA) that is used for construction, renovation and maintenance activities, the risk assessment process for waterborne pathogens is a process that first identifies areas where there may be risks of either bacterial amplification or water aerosolization. The risk mitigation strategy that is then employed is somewhat dependent on the location or proximity to a high-risk patient population. Some risk mitigation strategies are independent of their location. Cooling towers, ornamental fountains or pools provide good examples. Maintenance and disinfectant programs for items like these are a core component of the water management program. Other items, such as faucet aerators or ice machines, are very dependent on where they are located. Using the ICRA process as an example, the infection control risk mitigation recommendations for a renovation of a suite in an administration building would be significantly different than a renovation within the intensive care unit. Likewise, the program for maintaining ice machines in a non-patient area may be quite different from the one in a clinical setting. In general, systems and equipment supporting patient care areas will have more stringent program elements with the highest-risk patient populations having the most focus. Non-patient care areas will still need to be considered but will cause less concern.

Appendix D: Health Care Standards Comparison Matrix

	ASHRAE Standard 188	AAMI ST108	ASHRAE Standard 514
Primary Focus	Establishes minimum Legionella risk management practices for building water systems to prevent outbreaks in diverse facilities.	Focuses on defining and maintaining water quality standards necessary for cleaning, disinfecting and sterilizing medical devices.	Outlines comprehensive risk management for building water systems covering physical (e.g., scalding), chemical and microbial hazards beyond Legionella.
Target Environment	Primarily applies to all buildings with specific guidance for health care facilities, ensuring safety for at-risk occupants.	Targeted at health care facilities, specifically addressing water needs in environments where medical devices are processed.	Broad application across commercial, institutional and multiresidential buildings with detailed focus on health care facilities' unique risks.
Scope	Identifies and mitigates Legionella-related risks through systematic planning, monitoring and management practices.	Provides guidelines on selecting and maintaining water quality based on device categories, covering treatment, storage and use.	Focuses on the systematic assessment of physical, chemical and microbial hazards in building water systems, from design to ongoing maintenance.
Risk Management Program	Requires a multidisciplinary water management team to assess risks, set control points and implement response protocols.	Emphasizes the role of health care personnel in managing water quality, with specific guidance for various device processing stages.	Establishes a multihazard risk management approach involving a Designated Team for managing all potential water system hazards across the building life cycle.
Control Measures	Specifies routine assessments and monitoring of control points (e.g., water temperature, disinfectant levels) with corrective actions for out-of-limit readings.	Details water quality control measures such as filtration, disinfection and storage standards tailored to device categories, minimizing microbial contamination risks.	Controls for diverse hazard types including temperature control to prevent scalding, disinfectants to manage pathogens and mitigation of chemical exposures.

	ASHRAE Standard 188	AAMI ST108	ASHRAE Standard 514
Monitoring Requirements	Focuses on proactive management rather than routine Legionella testing, requiring documentation of inspections and adjustments based on risk.	Prescribes frequent monitoring for water quality consistency, including testing for specific contaminants depending on the device type.	Detailed monitoring plans are required for each identified hazard, ensuring ongoing verification of system integrity and control limits.
Documentation and Compliance	Mandates thorough documentation for each aspect of the water management program, including water flow diagrams, risk assessments and actions taken.	Requires comprehensive documentation of water treatment processes, personnel roles and adherence to quality assurance protocols.	Extensive documentation of hazard assessments, control measures and corrective actions are necessary, alongside validation and verification records.
Health Care Specificity	Annex A addresses health care needs, requiring infection prevention protocols and system mapping specifically for hospitals and health care facilities.	Highly specific to health care facilities, addressing water quality concerns critical to the safety of device processing and patient outcomes.	Includes health care-specific guidance with special requirements for health care buildings, supporting infection control, patient safety and facility-specific risks.
Frequency of Review	Requires periodic reviews of the water management program, particularly after system changes or if Legionella risk levels increase.	Recommends regular assessments and updates of water quality and treatment processes to adapt to new risks or device requirements.	Requires ongoing system reviews and adjustments based on any building modifications, usage changes or hazard control challenges.
Additional Hazard Types	Addresses Legionella specifically, aiming to control exposure through management of water temperature, flow and disinfection.	Limited to microbial risks specific to medical device processing, focusing on preventing contamination and preserving sterility.	Broadly addresses waterborne pathogens alongside physical hazards like scalding and chemical hazards from water treatment processes.

Appendix E: Water Quality Testing Methods and Parameters

The following table details water testing methods and acceptable parameters. Notation is provided if direct reading testing is available in lieu of laboratory analysis. Each testing method has specific applications, advantages and limitations, making it essential to choose the right approach based on the intended outcome and environmental conditions.

Water Quality Testing Methods Table

Testing Method	Advantages	Disadvantages	Direct Reading / Analytical Lab	Acceptable Parameters	References
Adenosine triphosphate (ATP) Testing (Cooling Towers)	Quick results, sensitive to microbial contamination.	May not differentiate between live and dead cells.	Direct reading	< 250 relative light units (RLU) for cooling wate	ASHRAE 188
				< 500 RLU for cooling towers	ASHRAE 12
ATP Testing	Rapid assessment of microbial load.	• Limited to ATP presence; does not specify organism types. • Can be influenced by organic matter.	Direct reading	< 100 RLU for drinking water	AAMI ST108
Biocide Testing	• Monitors effectiveness of biocides. • Ensures effective control of biofilms. • Can target specific pathogens.	• May require specific reagents. • Cost of testing can be high.	Analytical lab	Varies by biocide; e.g., > 10 milligrams per liter (mg/L) for chlorine	As per manufacturers' recommendations (varies by product)

Testing Method	Advantages	Disadvantages	Direct Reading / Analytical Lab	Acceptable Parameters	References
Free Chlorine	Effective for disinfection monitoring.	• Influenced by pH and temperature. • Does not account for combined chlorine.	Direct reading	0.2-4.0 mg/L	EPA Safe Drinking Water Standards
				0.2-4.0 mg/L	AAMI ST108
Total Chlorine	Comprehensive measure of chlorinated compounds.	Can overestimate if other oxidants present.	Direct reading	0.5-4.0 mg/L	EPA Safe Drinking Water Standards
				< 4.0 mg/L	ASHRAE 188
Water Hardness	Indicates scaling potential and corrosion risk.	Requires additional testing for comprehensive analysis.	Analytical lab	60-120 mg/L as calcium carbonate (soft to moderately hard)	ASHRAE 12
Oxidation/ Reduction Potential	Provides information on water's ability to reduce contaminants.	Can be complex to interpret.	Analytical lab	> 0 millivolts (mV) preferred for potable water	EPA Safe Drinking Water Standards
Microbial Testing (Coliforms)	Essential for safety monitoring.	Time-consuming; false positives possible.	Analytical lab	Absence in 100 mL for drinking water	EPA Safe Drinking Water Standards
pH Testing	Simple and rapid; affects many chemical reactions.	Not indicative of contamination alone.	Direct reading	6.5-8.5 for drinking water	EPA Safe Drinking Water Standards
Turbidity Testing	Indicates water clarity and potential contaminant levels.	Does not provide specifics on types of contaminants.	Direct reading	< 1 Nephelometric Turbidity units (NTU) for drinking water	EPA Safe Drinking Water Standards
Conductivity	Quick assessment of ion concentration.	Not specific to types of ions.	Direct reading	< 500 microsiemens per centimeter (μS/cm) for drinking water	EPA Safe Drinking Water Standards

Additional Notes:

- **Guidelines for Hospitals:** Hospitals often follow stricter protocols due to risk to immunocompromised patients, emphasizing the need for lower levels of microbial contamination, especially in water used for medical procedures.
- **Testing Frequency:** Routine monitoring is essential, particularly in cooling towers and hospital settings, to mitigate risks associated with waterborne pathogens.

References:

- **EPA Safe Drinking Water Standards:** U.S. Environmental Protection Agency regulations that ensure safe drinking water.
- **ANSI/AAMI ST 108: Water for the Processing of Medical Devices:** Guidelines for water quality in health care facilities.
- **ASHRAE Standard 188, Legionellosis: Risk Management for Building Water Systems:** Outlines standards for the prevention of legionellosis associated with building water systems.
- **ASHRAE Guideline 12, Managing the Risk of Legionellosis Associated with Building Water Systems:** Addresses the evaluation of the water quality for various applications.

Other methods to consider are listed in the table below. This table summarizes various water quality testing methods, including their advantages, disadvantages and acceptable parameters for testing:

Testing Method	Advantages	Disadvantages	Acceptable Parameters
Chemical Oxygen Demand (COD)	Indicates organic pollution levels.	Requires chemical reagents; can be expensive.	COD values vary; generally < 250 mg/L for clean water.
Dissolved Oxygen (DO)	Essential for aquatic life; quick results.	Sensitive to temperature and pressure variations.	5-10 mg/L is often acceptable for aquatic life.
Fecal Coliform Test	Indicates fecal contamination; easy to perform.	Only indicates the presence of coliforms, not pathogens.	< 200 colony-forming units (CFU) per100 mL is often considered safe for swimming.
pH Measurement	Simple and quick; indicates acidity or alkalinity.	May not reflect overall water quality alone.	Typically between 6.5 and 8.5 for drinking water.
Total Dissolved Solids (TDS)	Indicates overall water quality; easy to measure.	Does not specify types of dissolved solids present.	< 500 mg/L is generally acceptable for drinking water.
Turbidity Measurement	Indicates clarity and presence of suspended particles.	May not reflect microbial contamination.	< 1 NTU is desirable for drinking water.
Nitrate Testing	Indicates potential contamination from fertilizers.	May require specialized equipment.	< 10 mg/L for drinking water.
Phosphate Testing	Indicates nutrient levels; important for eutrophication assessment.	Can be affected by natural variations.	< 0.1 mg/L is often recommended for prevention of algal blooms.
Heavy Metals Testing	Detects harmful metals; important for safety.	Can be expensive; requires complex procedures.	Varies by metal (e.g., lead < 0.015 mg/L; mercury < 0.002 mg/L).

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