BSR/ASHRAE Standard 514P

**Advisory Public Review Draft**

# Risk Management for Building Water Systems: Physical, Chemical and Microbial Hazards

**First Advisory Public Review (March 2021)**
**(Draft Shows Complete Proposed New Standard)**

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**(This foreword is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)**

## FOREWORD

*BSR/ASHRAE Standard 514P,* Risk Management for Building Water Systems: Physical, Chemical and Microbial Hazards*, has been developed as a complement to ANSI/ASHRAE Standard 188,* Legionellosis: Risk Management for Building Water Systems*. Standard 514P is consistent with the structure of ANSI/ASHRAE Standard 188 and its methodology. It is important to note that Standard 514P mandates the use of Standard 188 with regards to legionellosis risk.*

*BSR/ASHRAE Standard 514P provides minimum practices to manage overall risk from microbial hazards other than* Legionella*, as well as from physical and chemical hazards associated with potable and nonpotable building water systems. Consistent with the provisions of ANSI/ASHRAE Standard 188, BSR/ASHRAE Standard 514P provides a framework for the systematic development of water management programs, from design and construction to occupancy, including post-occupancy modifications and renovations.*

*ASHRAE Standard Project Committee (SPC) 514P recognizes that the management of overall risk from hazards associated with building water systems requires careful consideration of potential control measures for any particular hazard in the context of possible unintended adverse consequences with regard to other hazards. Implementation of ANSI/ASHRAE Standard 188 and BSR/ASHRAE Standard 514P is intended to address the need for management of overall risk from physical, chemical, and microbial hazards associated with building water systems.*

*The presence of microbial hazards in a building water system is not in itself sufficient to cause disease. Other necessary factors include transmission of the microbial hazards into an environment where people are exposed to sufficient numbers of the particular microbial hazard to cause infection, taking into account the susceptibility of the exposed person. There also may be other, still unknown factors that contribute to infection.*

*The physical hazard addressed by Standard 514P is the water itself, when the temperature of the water to which building occupants may be exposed is sufficient to cause scalding. Some populations, such as infants, young children and the elderly are especially susceptible to scalding at lower water temperatures and shorter exposure than healthy young and middle age adults.*

*The chemical hazards addressed by Standard 514P include disinfectants, disinfection byproducts, corrosion products, and chemicals that leach from plumbing materials, and include both regulated and unregulated chemicals.*

*Standard 514P is intended for use by owners and managers of human-occupied buildings and those involved in the design, construction, installation, commissioning, operation, maintenance, and service of centralized building water systems and components. Some buildings may not contain all of the components that may be associated with hazardous conditions. It is the responsibility of the water management team to understand the building's water systems, conduct a systematic analysis of the building's water systems for potentially hazardous conditions, and implement controls as appropriate for the building's use and occupancy.*

*Standard 514P consists of numbered normative sections followed by informative appendices. The normative sections contain the requirements that must be met in order to comply with this standard.*

*Building water systems vary substantially in their design, use, and potential for exposure of occupants to hazards. The informative appendices contain additional information that may be helpful for the reader about these different hazards that could be in a given building water system, and the hazardous conditions that can make these hazards dangerous.*

*ASHRAE SPC 514P has devoted a considerable amount of time and thought to writing this standard with the overarching view to protect public health from the overall risk of physical, chemical, and microbial hazards associated with building water systems. The committee thanks everyone who has participated in the development of the standard.*

*Standard 514P is anticipated to be on a continuous maintenance cycle upon publication, which would allow it to be updated through the publication of approved addenda. The ASHRAE standards schedule typically will have Standard 514 published as revised with approved addenda and errata, every three years.*

## 1. PURPOSE

The purpose of this standard is to establish minimum requirements to reduce illness and injury from physical, chemical, and *microbial hazards* from water systems in buildings.

## 2. SCOPE

**2.1** This standard applies to the design, construction, commissioning, operation, maintenance, repair, replacement, and expansion of new and existing *building water systems* (*potable* and *nonpotable*) and components.

**2.2** This standard applies to human-occupied commercial, institutional, multiunit residential, assembly, educational, and industrial buildings. This standard does not include single-family residential buildings.

**2.3** This standard is intended for *owners*, *authorities having jurisdiction*, and those involved in the design, construction, management, installation, commissioning, operation, maintenance, and service of *centralized building water systems* and components.

## 3. DEFINITIONS

***Informative Note:*** The users of this document are expected to range from experienced professionals to those with no experience in reducing illness and injury from physical, chemical, and *microbial hazards* from *building water systems*. To effectively communicate with all users, the definitions of terms, abbreviations, and acronyms in this section are intended to be concise and are defined in the context of their use in this document. Terms that are not defined are intended to have their ordinarily accepted meanings, within the context in which they are used, based on American English language usage as found in an unabridged dictionary. Defined terms appear in the text as italicized. Scientific names of *microorganisms* are also italicized, even when they are not defined.

***aerosol:*** microscopic solid particles or microscopic liquid droplets suspended in air.

***analysis of building water systems:*** the systematic evaluation of potentially *hazardous conditions* associated with each step in the *process flow diagrams.*

***aspiration:*** the unintended entry of liquids into the lungs, generally while eating or drinking.

***at-risk individual*:** any person who is more susceptible than the general population to developing disease or injury from water from *building water systems* because of factors such as age, health, medication, occupation, or smoking.

***authority having jurisdiction (AHJ):*** an organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

***backflow:*** unwanted flow of water in the direction opposite from that intended.

***bacteria:*** single-celled microscopic organisms that may cause illness in humans. The plural of *bacterium*.

***beneficial occupancy:*** stage of construction when all or part of a building is to be occupied for the purpose that the building was constructed, whether before or after completion.

***BGR:*** collected or recycled *black water*, *gray water*, and *rainwater*.

***biofilm:*** a group of *microorganisms*, embedded in slime, that adhere to a moist surface.

***black water:*** wastewater containing bodily wastes or other biological wastes, such as from toilets, dishwashers, or kitchen drains.

***blow-down:*** the intentional discharge of system water and replacement with supply water to maintain a desired water quality.

***building water systems:*** *potable* hot- and cold-water systems and *nonpotable water systems*, in the building or on the site.

***building water system risk management plan:*** the documents that contain all information pertaining to the development and implementation of the *building water system risk management* activities of a healthcare facility.

***CDC:*** U.S. Centers for Disease Control and Prevention.

***centralized building water system:*** any system that distributes water to multiple uses or multiple locations within the building or site.

***colonization:*** initial *intrusion* and *growth* of *microorganisms* in a *building water system*

***construction documents:*** drawings and specifications used to construct a building, building systems, or portions thereof.

***contaminant:*** any physical, chemical, biological, or radiological substance or matter in water.

***control:*** to manage the conditions of an operation in order to maintain compliance with established criteria.

***control limit:*** a maximum value, a minimum value, or a range of values to which a chemical or physical parameter associated with a *control measure* must be monitored and maintained in order to reduce the occurrence of a *hazardous condition* to an acceptable level.

***control location:*** a point where a physical, mechanical, operational, or chemical *control measure* is required.

***control measure:*** the *disinfection*, heating, cooling, filtering, flushing or other means to maintain the physical or chemical conditions of water to within *control limits.*

***corrective action:*** action to be taken to return *control* values to within established limits, when *monitoring* or measurement indicates the *control* values are outside the established *control limits.*

***cross-connection:*** a physical connection between *potable* and *nonpotable water systems* or between hot and cold *potable water systems.*

***dead leg:*** a section of pipe, a component, or a vessel that contains water but has no flow or is infrequently used.

***Designated Team:*** see *Program Team.*

***designee:*** the individual designated by the building *owner* to meet the requirements placed on the *owner* by the standard.

***disinfectant:*** chemical agent or physical treatment used to kill or inactivate *microorganisms*.

***disinfectant residual (residual):*** the net amount of a chemical *disinfectant* remaining in treated water after chemical demand exerted by the water is satisfied.

***disinfection:*** the process of killing or inactivating *microorganisms*.

***epidemiologically linked:*** a condition in which the chain of *transmission* of the infection from a *building water system* point source to the susceptible individual by the usual modes is plausible.

***FIFRA:*** The Federal Insecticide Fungicide Rodenticide Act is the law that established federal regulation by the U.S. Environmental Protection Agency of pesticide distribution, sale, and use in the United States, including antimicrobial *disinfectants*.

***fill:*** primary cooling tower heat exchange media that cause circulating water to spread out to increase the evaporation rate.

***gray water:*** untreated wastewater that has not come into contact with toilet waste, kitchen sink waste, dishwasher waste, or similarly contaminated sources. *Gray water* includes wastewater from bathtubs, showers, lavatories, clothes washers, and laundry tubs. Natural precipitation that has not been contaminated by use.

***grow:*** to multiply or increase in number of *microorganisms*.

***growth:*** a significant increase in the number of *microorganisms.*

***hazard:*** a physical, chemical, or *microbial* agent associated with a *building water system* that, in the absence of *control*, can cause harm to humans.

***hazardous condition:*** a condition that contributes to the potential for harmful human exposure to *pathogens*, chemicals, or *scalding* temperatures associated with a *building water system.*

***humidifier:*** device to add moisture to air.

***HVAC:*** heating, ventilating, and air conditioning.

***intrusion:*** the physical movement of *bacteria* or other *contaminants* into a *building water system*.

***irrigation system:*** a permanent or temporary means to apply *controlled* amounts of water to hydrate plants or crops located in and around buildings at assigned intervals.

***Legionella:*** the name of the genus of *bacteria* that can cause a pneumonia called *Legionnaires' disease* or a flu-like illness called *Pontiac fever* when inhaled, aspirated, or directly introduced into the lungs of susceptible individuals. *Legionella* are common aquatic *bacteria* found in natural and *building water systems*, as well as in some soils.

***legionellosis:*** the term used to describe *Legionnaires' disease*, *Pontiac fever*, and any illness caused by exposure to *Legionella bacteria*.

***Legionnaires' disease:*** a serious type of pneumonia (lung infection) caused by *Legionella bacteria*.

***main, building water system:*** the principal *potable building water system* pipe artery to which piping branches are connected.

***mains (water utility distribution piping):*** *water utility transmission* pipes that carry water from a water treatment plant to the building water service entrance point.

***microbial:*** having to do with *microorganisms*, especially those harmful to humans.

***microbiological:*** see *microbial*.

***microorganisms:*** very small single celled organisms, including *bacteria*, protozoa, viruses, and some algae and fungi.

***monitoring:*** conducting a planned sequence of observations or measurements of the physical and chemical characteristics of *control measures.*

***multiple housing units*:** a classification of housing where multiple separate housing units for residential and commercial inhabitants are contained within one building or more buildings within one complex.

***NDMA:*** *N-Nitrosodimethylamine* is a semi-volatile organic chemical that is highly toxic and is a suspected human carcinogen and in drinking water has been linked to use of monochloramine.

***nitrification:*** a process that can lead to depletion of the *disinfectant residual* in a *building water system* through the *microbial* oxidation of ammonia in the systems into nitrites, followed by the oxidation of the nitrites into nitrates.

***nonpotable:*** water not intended for human consumption, such as water not intended for drinking, bathing, showering, hand washing, teeth brushing, food preparation, dishwashing, and maintaining oral hygiene.

***opportunistic pathogen*:** *microorganisms* present in *building water systems* that do not typically present a *risk* to healthy individuals but can cause disease in *at-risk individuals* or immunocompromised individuals.

***outbreak:*** an increase in the number of illnesses caused by *microbial hazards* from *building water systems* above what is normally expected and linked to the same site.

***OSHA:*** the U.S. Occupational Safety and Health Administration.

***owner:*** an individual, individuals, or entity possessing title to the building, or an agent, manager, board, or entity authorized to act on behalf of the individual, individuals, or entity possessing title to the building.

***pathogen:*** *microorganisms* that cause disease in human beings.

***Pontiac fever:*** a flu-like illness caused by *Legionella bacteria* that usually resolves without the need for treatment.

***potable water:*** water intended for human consumption, such as water intended for drinking, bathing, showering, hand washing, teeth brushing, food preparation, dishwashing, and maintaining oral hygiene.

***potable water system:*** a building water distribution system that provides hot or cold *potable water*.

***process flow diagram:*** a step-by-step drawing of a *building water system* that includes the location of all water processing steps, including, but not limited to, conditioning, storing, heating, cooling, recirculation, and distribution that are part of the *building water systems.*

***Program:*** the *water management program* or *risk management plan.*

***Program documents:*** procedures, work instructions, specifications, and records for all activities of the *Program*, established or collected by the *Program Team* and residing in one or more locations and formats.

***Program Team:*** the group or individual designated by the building *owner*, senior organizational leadership, or their *designee* to be responsible for developing, implementing, and maintaining the *Program.*

***rainwater:*** natural precipitation that has not been contaminated by use.

***remedial treatment:*** short term application of chemical, physical, or biological measures beyond those regularly applied in order to return water conditions within *control limits*.

***residual:*** see *disinfectant residual.*

***risk:*** the potential for harm to humans that can be caused by a *microbial*, chemical, or physical agent that is a function of the probability of harm times the severity of harm.

***risk assessment:*** a quantitative, analytic process to estimate the nature and *risk* of adverse human health effects associated with exposure to specific physical, chemical or *microbial hazards* from *building water systems*, now or in the future.

***risk management:*** systematic activities to reduce *risk*.

***risk management plan:*** see *water management program.*

***sampling point:*** the location in the *building water system* from which a quantity of water is collected for evaluation or *testing*.

***scalding:*** burning by a hot liquid, such as water.

***secondary disinfection:*** application of a *disinfectant* to water leaving a drinking water treatment plan and intended to prove continuing *disinfection* as water moves through the *water utility* water distribution system.

***shall:*** is/are required to and must.

***siphoning:*** water flow from one location to another due to gravity, atmospheric pressure, and/or molecular cohesion.

***supplemental disinfection:*** on-site application of a means of *disinfection* to water in the *building water system*.

***taps:*** *water use end points* such as faucets, spigots, and shower heads.

***testing:*** conducting a planned sequence of observations or measurements of physical, chemical, or *microbial* characteristics of water to assess whether conditions throughout *building water systems* meet the goals set by the *Program Team.*

***transmission:*** the physical transport of chemicals or *microorganisms* that can cause injury or illness from a *building water system* to humans.

***trihalomethanes:*** *disinfection* byproducts that are the result of a reaction between chlorine used for disinfecting *tap* water and natural organic matter in the water.

***turbidity:*** cloudy condition of water due to the presence of fine particulate materials in suspension.

***validation:*** initial and ongoing confirmation that the *Program*, when implemented as designed, *controls hazardous conditions* throughout the *building water systems.*

***VBNC:*** see *viable but nonculturable*.

***verification:*** initial and ongoing confirmation that the *Program* is being implemented as designed.

***viable but nonculturable (VBNC):*** a state where *microorganisms* have very low metabolic activity and cannot be detected by culture *testing* but are alive and can *grow* when conditions are favorable.

***water age:*** the residence time of the water in one or more locations in the *building water system*.

***water management program* (*Program*) (*risk management plan*):** the plan for the prevention and *control* of illness or injury caused by physical, chemical, and *microbial hazards* associated with *building water systems*, including documentation of the plan's implementation and operation.

***water service disruption:*** planned or unplanned events that reduce water delivery pressure below 20 psi (140 kPa) and that are caused by, but not limited to, new construction tie-ins; replacement of valves, hydrants, or meters; pumping failures; pipeline breaks; and other system repairs or emergency conditions.

***water use end point:*** the points at which water exits from all *potable* and *nonpotable building water systems*, fixtures and equipment.

***water utility:*** entity that provides *potable water* to buildings for use in *building water systems*.

***water utility distribution piping:*** see *mains*.

## 4. COMPLIANCE

The results of each Section 4 compliance determination and the associated building review in Section 4.1 and survey in Section 4.2 *shall* be documented and *shall* be physically or electronically on-site for review by the *authority having jurisdiction* (*AHJ*).

a. Compliance with this standard also requires compliance with the requirements in ANSI/ASHRAE Standard 188, *Legionellosis: Risk Management for Building Water Systems*. Where it is not possible to comply with the requirements of both Standard 514 and Standard 188 because a requirement in Standard 188 is in conflict with a requirement in this standard, comply with the more stringent requirement, or, if compliance with the more stringent requirement does not resolve the conflict, comply with the requirement in Standard 514.
b. Except for the required compliance with ANSI/ASHRAE Standard 188, Standard 514 does not use or require compliance, training, or certification in any additional *hazard* analysis, *risk assessment*, or *risk management* methodologies.

**4.1 Building Designer Requirements.** The building designer *shall* review the design of each new building, renovation, addition, or modification and the associated *building water systems*. If the design contains any of the following systems, devices, or factors, the design of the new building, renovation, addition, or modification *shall* comply with the applicable requirements of Section 7, "Requirements for Designing and Documenting Building Water Systems":

a. public pools or spas, either in the building or on the site
b. ornamental fountains or other water features, misters, atomizers, air washers, *humidifiers*, or other *nonpotable* water systems or devices that release water *aerosols* in the building or on the site
c. the building includes *multiple housing units* with one or more centralized *potable water*-heater systems that are serving two or more housing units
d. the building includes equipment for on-site *supplemental disinfection* of *building water system potable water*
e. the building is more than six stories above grade
f. the building is larger than 50,000 $ft^2$ (5,000 $m^2$) and contains one or more *potable water* booster pumps
g. the building is identified by the *owner* or *designee* as being for the purpose of housing occupants under the age of 2 years or over the age of 65 years
h. the building is a healthcare facility where patient stays exceed 24 hours
i. the building is a facility that provides all of the following:
    1. lodging,
    2. board, and

3. nursing care, or physical care, or both nursing and physical care

j. the building contains one or more areas for the purpose of surgery, or for the purpose of treating occupants receiving treatment for burns, chemotherapy for cancer, solid organ transplantation, or bone marrow transplantation

k. the building contains one or more areas for the purpose of treating occupants that are immunocompromised, are taking drugs that weaken the immune system, have renal disease, have diabetes, have chronic lung disease, or for the purpose of treating dental conditions

**4.2 Building Owner Requirements.** Before occupancy of a new building, and before construction begins on renovations, additions, or modifications to an existing building, and at least annually, the *owner shall* survey to determine whether the requirements of Section 4.2.1, Section 4.2.2, or Section 4.2.3 apply.

**4.2.1** If the building has any of the systems or devices in Section 4.1(a) or (b), and does not have any of the factors in Section 4.1(c), (d), (e), (f), (g), (h), (i), (j), or (k), then all of the systems and devices in Section 4.1(a) and (b) *shall* comply with the requirements of Section 5, "General Requirements" and all of the applicable requirements of Section 6, "Requirements for Building Water Systems."

**4.2.2** If the building has any of the factors in Section 4.1(c), (d), (e), (f), or (g), and does not contain any of the factors in Section 4.1(h), (i), (j), or (k), then all *building water systems* and associated devices *shall* comply with the requirements of Section 5, "General Requirements," and all of the applicable requirements of Section 6, "Requirements for Building Water Systems."

**4.2.3** If the building has any of the factors in Section 4.1(h), (i), (j), or (k), then all *building water systems* and associated devices *shall* comply with the requirements in Section 4.3, "Healthcare Facility Requirements."

**4.2.4** The building *owner shall* require the designer of a new building, or any renovation, addition, or modification to an existing building, to follow the requirements of Section 4.1, "Building Designer Requirements" for the provided design.

**4.2.5** The building *owner* of exhibition space *shall* require users of the exhibition space, including space used for temporary public display, that operate whirlpools, spas, ornamental fountains, misters, atomizers, air washers, *humidifiers*, or other *nonpotable* water systems or devices that release water *aerosols* in the space or on the site, to comply with the equipment manufacturer's operating instructions.

**4.3 Healthcare Facility Requirements**

**4.3.1** Buildings containing healthcare facilities that do not contain any of the factors listed in Section 4.3.2(a), (b), (c), or (d) *shall* comply with the requirements in Section 4.2, "Building Owner Requirements."

**4.3.2** Buildings containing one or more of the factors described in Section 4.3.2(a), (b), (c), or (d) *shall* comply with the requirements in Section 8, "Requirements for Healthcare Facilities," and all of the applicable requirements in Section 6, "Requirements for Building Water Systems."

a. the building is a healthcare facility where patient stays exceed 24 hours

b. the building is a facility that provides all of the following:

1. lodging,
2. board, and
3. nursing care, or physical care, or both nursing and physical care

c. the building contains one or more areas for the purpose of surgery, or for the purpose of treating occupants receiving treatment for burns, chemotherapy for cancer, solid organ transplantation, or bone marrow transplantation

d. the building contains one or more areas for the purpose of treating occupants that are immunocompromised, are taking drugs that weaken the immune system, have renal disease, have diabetes, have chronic lung disease, or for the purpose of treating dental conditions.

## 5. GENERAL REQUIREMENTS

Required compliance with this section *shall* be determined by Section 4.2.

***Informative Note:*** Recommendations and guidance on the design, maintenance, and operation of *building water systems* can be obtained Informative Appendices B through J, from ASHRAE Guideline 12, *Managing the*

*Risk of Legionellosis Associated With Building Water Systems*, and through informative documents, such as those listed in Informative Appendix A, "Bibliography."

**5.1 Elements of a Water Management Program.** A *Program* utilizing the following subsections *shall* be written and implemented to reduce the overall *risk* of illness or injury from *hazards* associated with *building water systems*.

**5.2 Program Development**

**5.2.1** A *Program shall* be implemented to manage the *risk* from physical, chemical, and *microbial hazards* associated with all the *building water systems* and devices listed in Section 4.1(a) and (b).

**5.2.2** If the building has any of the factors listed in Section 4.1(c), (d), (e), (f), and (g), then a *Program shall* be implemented to manage the *risk* from physical, chemical, and *microbial hazards* associated with all *building water systems* and all associated devices.

**5.2.3** A summary of *Program* development steps is represented in Figure 5.1, "Elements of a Water Management Program." The *Program shall* be detailed in a plan that embodies all of the elements described in Figure 5.1 and *shall* include the elements Sections 5.2.4 through 5.2.12.

**5.2.4** ***Program Team*.** The building *owner*, senior organizational leadership, or their *designee shall* select the members of the *Program Team* and *shall* delegate the responsibility to the *Program Team* for developing and implementing the *Program* and its tasks and any other activities assigned by the *owner*, senior organizational leadership, or their *designee*. The *Program Team shall* be permitted to delegate *Program* tasks to subgroups. The *Program Team shall* have knowledge of the *building water system* design and water management as related to physical, chemical, and *microbial hazards*, and associated *hazardous conditions.* A member of the *Program Team shall* have building *owner* or senior organizational leadership authority and responsibility for the actions required by the *Program*, and to make command decisions about water-use restrictions and other response measures. The *Program Team shall* include one or more individuals selected from the following: the building *owner* or *designee*, employees, suppliers, consultants, or *building water systems* design professionals.

**5.2.5 Describe the Building Water Systems.** The *Program Team shall* identify and describe the *potable* and *nonpotable building water systems* within the building and on the building site, including:

a. a water quality report on the water supplied to the building, including *disinfectant* type(s) and *disinfectant residual*;
b. identification and description of *water use end points* of all *potable* and *nonpotable building water systems*;
c. identification and description of water processing equipment and associated components;
d. identification and description of how water is received and processed, including how water is conditioned, screened, filtered, stored, heated, tempered, cooled, recirculated, and delivered to *water use end points*; and
e. identification and description of other items and areas determined by the *Program Team*.

**5.2.6 Process Flow Diagrams.** The information from Section 5.2.5 *shall* be graphically described in *process flow diagrams*. The *process flow diagrams shall* have details that enable the identification, analysis, and management of the *risk* from physical, chemical, and *microbial hazards* throughout the *building water systems*. The *Program Team shall* confirm that the *process flow diagrams* are representative of the systems as built.

**5.2.7 Analysis of Building Water Systems.** The *Program Team shall* use the *process flow diagrams* in Section 5.2.6 to evaluate where *hazardous conditions* have the potential to occur in the *building water systems*. The analysis *shall* include the vulnerability of occupants and *shall* include the *building water systems* and associated devices identified in Section 5.2.5. The analysis *shall* include provisions to respond to *water service disruptions*.

**5.2.8 Control Measures.** Based on the results of the *analysis of building water systems* in Section 5.2.7, the *Program Team shall* determine the *control measures* to be maintained. *Control measures shall* include preplanning of physical design and equipment siting. *Control measures shall* include any treatment methods utilized and *shall* include all technical and physical processes, and procedures and activities or actions that

monitor or maintain the physical or chemical conditions of water to within established *control limits*.

a. ***Control Locations*.** The *Program Team shall* use the information from Section 5.2.7 and 5.2.8 to determine the locations in the *building water system* where *control measures* are required.

b. ***Control Limits*.** The *Program Team shall* determine a maximum value, minimum value, or range of values for chemical and physical parameters.

**5.2.9 Monitoring.** The *Program Team shall* establish a procedure for *monitoring* whether the measured physical and chemical characteristics of *control measures* are within the *control limits*. The procedures *shall* include the means, methods, and frequency for *monitoring* activities.

**5.2.10 Corrective Actions.** For each *control location*, the *Program Team shall* establish procedures for *corrective actions* to be taken when *monitoring* shows that *control measures* are outside of established *control limits*. The procedures for *corrective actions shall*:

a. include *remedial treatment* when the *Program Team* determines it *shall* be used,

b. comply with *AHJ* requirements,

c. include evaluation of the *water management program* by the *Program Team* to determine if change is needed, and

d. identify the person responsible for taking the *corrective action*, *shall* identify the required response time for taking the *corrective action*, and *shall* identify all persons to be notified.

**5.2.11 Program Confirmation.** The *Program Team shall* establish procedures to confirm, both initially and on an ongoing basis, that the *Program* is being implemented as designed. The resulting process is *verification*. The *Program Team shall* establish procedures to confirm, both initially and on an ongoing basis, that the *Program*, when implemented as designed, *controls* the *hazardous conditions* throughout *the building water systems*. The resulting process is *validation*. The *Program Team shall* determine whether physical, chemical, or *microbial testing* for *hazards shall* be performed, and if so, how test results will be used to validate the *Program*. If the *Program Team* determines that *testing shall* be performed, the *Program Team shall* establish procedures, including sampling frequency, number of samples, locations, sampling methods, and test methods. The *Program Team shall* include the following as part of the determination of whether to test for *hazards*:

a. *Program control limits* have not maintained in *building water systems*, including in water systems with *supplemental disinfection*.

b. A prior history of injury or illness from *hazards* associated with the *building water system*.

**5.2.12 Documentation and Communication.** The *Program Team shall* establish and maintain the *water management program* contained within one or more documents. These documents are allowed to contain information that is not part of the *water management program*. If multiple documents are used, a master document providing the location of all *Program documents shall* be maintained. The *Program documents shall* include the name, title, and contact information for the *Program Team* leader and the role and contact information for other *Program Team* members. The *Program Team shall* establish and implement documentation and communication procedures for:

a. all activities of the *Program*

b. coordination among subgroups covering different portions of the *building water system* and associated equipment

c. informing all affected parties identified by the *Program Team* of *Program* changes

d. *Program documents* revision control that identifies and replaces earlier document versions with the latest document version whenever *Program* changes are made, and

e. informing all affected parties identified by the *Program Team* of actions taken when the *Program Team* determines there is elevated *risk* of injury, illness, or disease caused by *building water system* physical, chemical, or *microbial hazards*.

## 5.3 Existing Building Review, New Construction, and Renovations

**5.3.1 Existing Building Review.** The *Program Team shall* review and update the *water management program* at

least once per year to incorporate any changes, if any, affecting Sections 5.2.6, 5.2.7, 5.2.8, 5.2.9, 5.2.10, 5.2.11, or 5.2.12.

**5.3.2 New Construction and Renovations.** For renovations or new construction, the *Program Team shall* review the scope of work, determine the *risk* associated with the project, and revise the *water management program* in places where the *Program Team* determines revision is needed. The *owner*, senior organizational leadership, or their *designee shall* require the building designer to comply with Section 7, "Requirements for Designing and Documenting Building Water Systems."

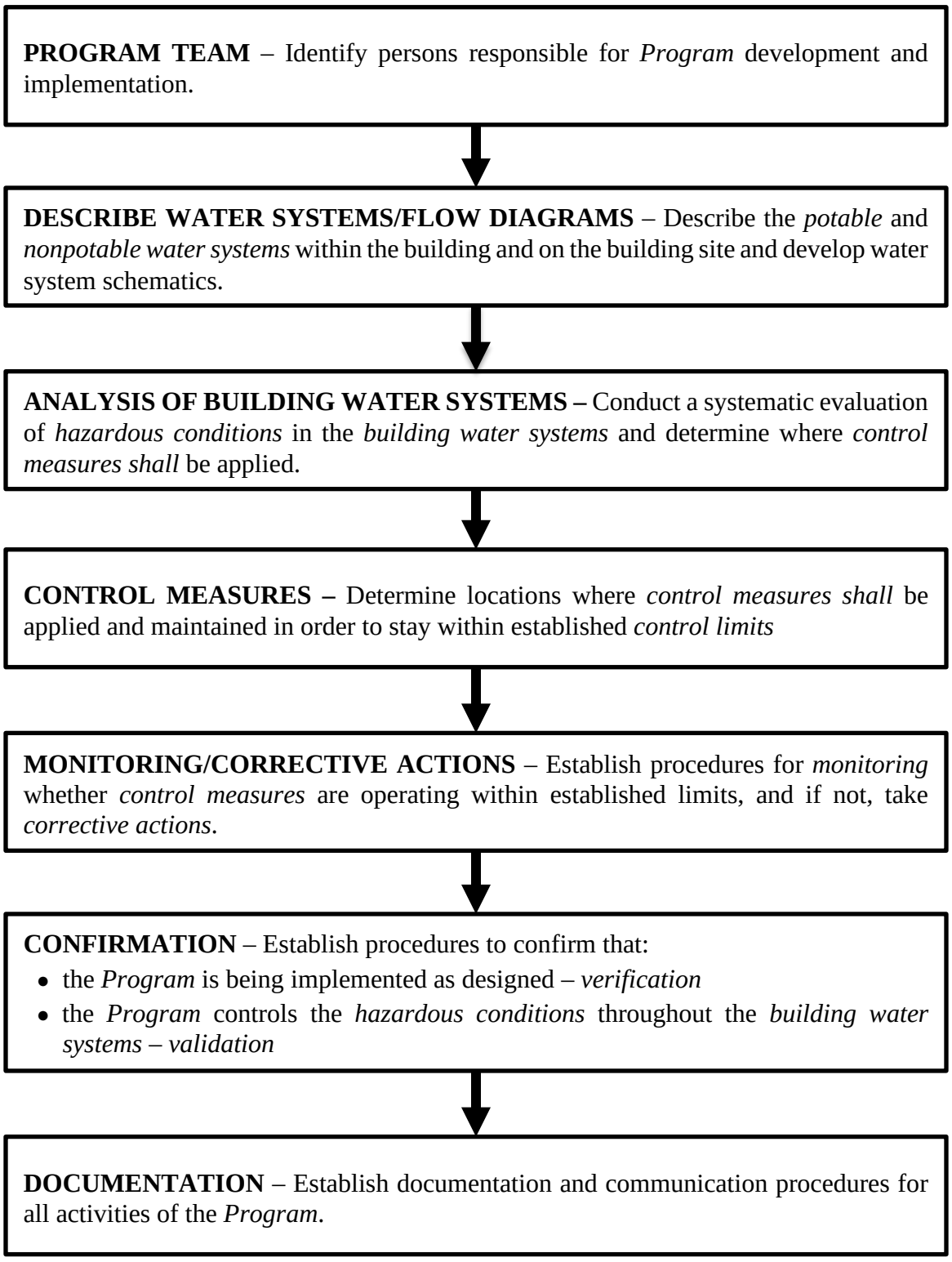


**FIGURE 5.1 Elements of a Water Management Program**

## 6. REQUIREMENTS FOR BUILDING WATER SYSTEMS

Required compliance with this section *shall* be determined by Sections 4.2 and 4.3.

All *building water systems* in Section 6 and all water treatments *shall* be installed, applied, and used in conformance to, and *shall* comply with, all applicable national, regional, and local regulations.

a. Section 6.1, "Potable Water Systems"
b. Section 6.2, "Public Pools and Spas"
c. Section 6.3, "Ornamental Fountains and Other Water Features"
d. Section 6.4, "Aerosol-Generating Misters, Atomizers, Air Washers, and Humidifiers"

***Informative Note:*** Recommendations and guidance on the design, maintenance, and operation of *building water systems* can be obtained from Informative Appendices B through J, from ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated With Building Water Systems*, and through informative documents, such as those listed in Informative Appendix A, "Bibliography."

**6.1 Potable Water Systems.** The *Program shall* comply with the requirements of Section 7.1, "Potable Water Systems" of ANSI/ASHRAE Standard 188, *Legionellosis: Risk Management for Building Water Systems*, and *shall* comply with the following additional requirements.

***Informative Note:*** Recommendations and guidance on the design, maintenance, and operation of *building water systems* can be obtained from Informative Appendices B through J, from ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated With Building Water Systems*, and through informative documents, such as those listed in Informative Appendix A, "Bibliography."

**6.1.1 System Start-Up and Shutdown.** The *Program documents shall* include procedures for:

a. the maximum duration after shutdown when pre-occupancy *disinfection* and flushing procedures must be implemented before occupancy;
b. reestablishing the *control measures* established in Section 5.2; and
c. any unplanned loss of operating energy, loss of water treatment, or system component repair or replacement.

**6.1.2 System Maintenance.** The *Program documents shall* include procedures for:

a. *monitoring* and maintaining system components identified by the *Program Team*, based on equipment manufacturer's instructions for cleaning, *disinfection*, replacement of system components, and additional measures the *Program Team* decides are necessary; and
b. *monitoring* and treatment following water supply interruptions or breaks in water supply piping.

**6.1.3 Water Treatment.** The *Program documents shall* include procedures for the application of water treatment products included in the *Program*, and confirmation that the products comply with applicable regulations.

**6.1.4 Contingency Response Plan.** For both hot-water and cold-water systems, the *Program documents shall* include:

a. procedures for *hazard* response sampling if the *Program Team* determines it is to be used;
b. procedures for responding to directives issued by national, regional, and local *authorities having jurisdiction*;
c. procedures for emergency identification and remediation of physical, chemical, and *microbial hazards* identified by the *Program Team*; and
d. procedures for additional actions as determined by the *Program Team* to prevent exposure to *hazards* caused by water from a *potable building water system*.

**6.2 Public Pools and Spas.** The *Program shall* comply with the requirements in Section 7.3, "Whirlpool Spas" in ANSI/ASHRAE Standard 188, *Legionellosis: Risk Management for Building Water Systems*.

***Informative Note:*** Recommendations and guidance on the design, maintenance, and operation of *building water systems* can be obtained from Informative Appendices B through J, ASHRAE Guideline 12, *Managing*

*the Risk of Legionellosis Associated With Building Water Systems*, the U.S. *CDC Model Aquatic Health Code*, the World Health Organization *Guidelines for Safe Recreational Water Environments*, and through informative documents, such as those listed in Informative Appendix A, "Bibliography."

**6.2.1 Microbiology**

The *Program documents shall* include procedures for the *microbiological* standards required by local, regional, and national health departments that are to be achieved by public pools and whirlpool spas.

**6.2.2 Microbiological Testing.** The *Program documents shall* include:

a. A minimum of monthly *testing* of pool or spa water for indictor organisms and *pathogens* identified by the *Program microbiological* standards or as required by national, regional, or local regulation.

b. Procedures for maintaining the levels of indicator organisms at or below the standard threshold, or as required by national, regional, or local regulation.

c. Procedures for responding to test results, including *disinfection* record review and repetition of *microbiological* tests as determined by the *Program Team* or notification as required by national, regional, or local regulation.

**6.2.3 Contingency Response Plan.** The *Program documents shall* include procedures to be followed if there are known or suspected cases of illness, disease, or injury caused by *microbiological hazards* associated with pools or whirlpool spas.

**6.3 Ornamental Fountains and Other Water Features.** The *Program shall* comply with the requirements in Section 7.4, "Ornamental Fountains and Other Water Features" in ANSI/ASHRAE Standard 188, *Legionellosis: Risk Management for Building Water Systems*.

***Informative Note:*** Recommendations and guidance on the design, maintenance, and operation of *building water systems* can be obtained from Informative Appendices B through J, ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated With Building Water Systems*, and through informative documents, such as those listed in Informative Appendix A, "Bibliography."

**6.4 Aerosol-Generating Misters, Atomizers, Air Washers, and Humidifiers.** The *Program shall* comply with the requirements in Section 7.5, "Aerosol-Generating Misters, Atomizers, Air Washers, and Humidifiers" in ANSI/ASHRAE Standard 188, *Legionellosis: Risk Management for Building Water Systems*.

***Informative Note:*** Recommendations and guidance on the design, maintenance, and operation of *building water systems* can be obtained from Informative Appendices B through J, ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated With Building Water Systems*, and through informative documents, such as those listed in Informative Appendix A, "Bibliography."

**6.4.1 Additional Chemical Water Treatment Requirements.** When chemical water treatment is used:

a. the *Program Team shall* select water treatment chemicals after *analysis of building water systems* as defined in Section 5.2.7 is completed; and

b. the *Program documents shall* include procedures for maintaining the level of treatment chemicals and chemical byproducts from water treatment applied on-site to within *control limits* established by the *Program Team* and in compliance with the *authority having jurisdiction*.

**6.4.2 Physical Barriers.** If physical barriers are used for *microbial control*:

a. filters must have a pore size of 0.2 µm or less and must comply with the requirements of ASTM F838, *Standard Test Method for Determining Bacterial Retention of Membrane Filters Utilized for Liquid Filtration* (with evaluation for complete *bacteria* retention $>10^7$ *bacteria*/$cm^2$)

b. the *Program documents shall* include procedures for maintaining the filters to include installation and replacement date; and

c. the *Program documents shall* include procedures and required frequency for cleaning and disinfecting water contacting equipment downstream of filtration

## 7. REQUIREMENTS FOR DESIGNING AND DOCUMENTING BUILDING WATER SYSTEMS

***Informative Note:*** Recommendations and guidance on the design, maintenance, and operation of *building water systems* can be obtained from Informative Appendices B through J, ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated With Building Water Systems*, and through informative documents, such as those listed in Informative Appendix A, "Bibliography."

Required compliance with this section *shall* be determined by Sections 4.1, 4.2, or 8.4.2.

**7.1 Design Documents.** When designing for new construction, renovations, refurbishment, replacement, or repurposing of a facility, the following *shall* be documented for basis of design:

a. a system overview and intended mode of the *building water system* operation, including performance parameters
b. complete set of *construction documents*
c. schematic diagrams of water systems
d. *monitoring*, *control*, sampling, and flush point diagrams of water systems
e. local, regional, national code, and *authority having jurisdiction* (*AHJ*) compliance
f. building water contact materials
g. commissioning procedures
h. operating instructions and procedures
i. maintenance schedules, frequencies, and procedures
j. location of *sampling points* for incoming water at point of entry to evaluate incoming water quality, where the point of entry is within the scope of the project
k. incoming water quality report used for basis of design including anticipated incoming *disinfectant residual*, and
l. design provisions that address *hazardous conditions* for each of the following:
    1. *building water systems* in relationship in location of outdoor air intakes;
    2. building water equipment, as identified by Section 6;
    3. no-flow and low-flow portions of the piping and *building water systems* for all utilization cases included in the *building water system* design;
    4. impact of heat loss from hot water or heat gain by cold water in piping and water system components;
    5. *cross-connections* between *potable* and *nonpotable water*;
    6. connections between hot and cold water;
    7. access to water expansion tanks, water hammer arrestors, water storage tanks, water heaters, and other equipment and components that contain water;
    8. pipe size, length, and flow impact on *water age*;
    9. flushing, automatic or manual, for unavoidable *dead legs*; and
    10. *backflow* protections at *sampling points*.

**7.2 Final As-Built Installation Documents**

**7.2.1** Drawings and documents of the *building water systems* actual installation *shall* be provided to the building *owner* or *designee* and *shall* include:

a. the location of each piece of equipment associated with the *building water systems*;
b. a drawing and identification of the water distribution piping system, including system materials, pipe sizes, design flow rates, design temperatures, temperature *monitoring* points necessary to confirm design temperatures throughout the system, *fill* provisions, *blow-down* provisions, makeup provisions, *sampling points*, treatment points, and drain provisions;
c. the location of all outdoor air intakes;
d. size and options for each piece of water system equipment;
e. applicable *control* system wiring diagrams, schematics, equipment and component locations, calibration information, and operational sequences;
f. material specifications for all *building water system* components;

g. post-construction water quality report, as required by either the specification or the *AHJ*;
h. material specifications for all water systems insulation;
i. safety data sheets (SDS) for applicable materials used for *building water system* treatment, cleaning, flushing, disinfecting, and sealing;
j. installation requirements for all equipment;
k. start-up and shut-down requirements for all equipment and components;
l. operational requirements for all equipment and systems;
m. maintenance procedures for all equipment and water systems, including required actions, frequencies, and durations;
n. provide a copy of the *building water system* documentation required by the *AHJ* to obtain the building's certificate of occupancy.

**7.3 Balancing.** All water systems *shall* be balanced, and if water balancing is required by either the specification or the *AHJ*, a balance report for all water systems *shall* be provided to the building *owner* or *designee*.

**7.4 Commissioning Procedures.** Instructions for commissioning of all *building water systems shall* be provided to the building *owner* or *designee*, and *shall* include the following:

a. Procedures for testing testable *backflow* assemblies following the manufacturers' instructions within period specified by the *AHJ*, but not to exceed twelve months prior to *building water system* startup
b. Procedures for flushing and *disinfection*:
    1. Procedures *shall* comply with all applicable national, regional, and local codes and regulations.
    2. *Disinfection* and flushing of *potable building water systems shall* be completed within three weeks prior to whole or partial *beneficial occupancy*
        i. If *beneficial occupancy* of any part of the building is delayed more than two weeks but less than four weeks after *disinfection*, flushing of all fixtures *shall* again be completed.
        ii. If *beneficial occupancy* of any part of the building is delayed four weeks or more after *disinfection*, the need for *disinfection*, flushing, or both *disinfection* and flushing of unoccupied areas *shall* be determined by the *Program Team*.
    3. *Disinfection* and flushing following manufacturers' instructions *shall* be completed within three weeks prior to open-loop *nonpotable building water systems*, equipment, and components start-up; including the startup required prior to *beneficial occupancy*.
    4. Flushing and treatment following manufacturers' instructions, prior to closed loop *nonpotable building water systems*, equipment, and components start-up; including the startup required prior to *beneficial occupancy*.
c. Procedures for balancing the *building water system* documented in Section 7.3.
d. Confirmation that *building water system* performance meets design parameters documented in Sections 7.2.1.
e. Confirmation that *building water system* sensors specified in Sections 7.1 and 7.2 are communicating with the building automation system.

## 8. REQUIREMENTS FOR HEALTHCARE FACILITIES

These requirements are only applicable to healthcare facilities meeting the qualifications of Section 4.3.2.

***Informative Note:*** Recommendations and guidance on the design, maintenance, and operation of *building water systems* can be obtained from Informative Appendices B through J, from ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated with Building Water Systems*, and through informative documents, such as those listed in Informative Appendix A, "Bibliography."

**8.1 Principles of a Building Water System Risk Management Plan.** A *Program* utilizing the *risk management* principles in the following subsections *shall* be written and used to reduce the overall *risk* of illness or injury from *hazards* associated with *building water systems*.

## 8.2 Program Development

**8.2.1** A *Program shall* be implemented to manage the *risk* from physical, chemical, and *microbial hazards* associated with all of the *building water systems* and all associated devices.

**8.2.2** A summary of *Program* development steps is represented in Figure 5.1. The *Program shall* be detailed in a plan that embodies all of the principles described in Figure 5.1 and *shall* include the elements described in the following subsections.

**8.2.3 Designated Team.** The building *owner*, senior organizational leadership, or their *designee shall* select the members of the *Designated Team*. The *Designated Team shall* be delegated the responsibility for developing and implementing the *Program* and its tasks and any other activities assigned by the *owner*, senior organizational leadership, or their *designee*. The *Designated Team shall* be permitted to delegate *Program* tasks to subgroups. The *Designated Team shall* have knowledge of the *building water system* design and water management as related to physical, chemical, and *microbial hazards*, and associated *hazardous conditions*. A member of the team *shall* have building *owner* or senior organizational leadership authority and responsibility for the actions required by the *Program*, and to make command decisions about water restrictions and other response measures. The *Designated Team shall* include:

a. one or more individuals selected from the following: the building *owner* or *designee*, employees, suppliers, consultants, or *building water systems* design professionals;
b. a member of the facilities management staff with knowledge of the *building water systems*, if the facility has on-site facilities management staff;
c. an individual who has knowledge of the healthcare facility's infection prevention and *control* program;
d. a person responsible for clinical care at the healthcare facility; and
e. a member of Occupational and Environmental Safety Management (OES), if the facility has an OES program or a member of Environment of Care Management (EC), if the facility has an EC program.

***Informative Note:*** Recommendations and guidance on the design, maintenance, and operation of *building water systems* can be obtained from Informative Appendices B through J, from ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated with Building Water Systems*, and through informative documents, such as those listed in Informative Appendix A, "Bibliography."

**8.2.4 Describe the Building Water Systems.** The *Designated Team shall* identify and describe the *potable* and *nonpotable building water systems* within the building and on the building site, including:

a. a water quality report on the water supplied to the building, including *disinfectant* type(s) and *disinfectant residual*;
b. *water use end points* of *potable* and *nonpotable building water systems*;
c. water processing equipment and components;
d. how water is received and processed, including how water is screened, filtered, conditioned, stored, heated, tempered, cooled, recirculated, and delivered to *water use end points*;
e. areas where *hazardous conditions* in *building water systems* have the potential to contribute to the *risk* of illness or injury from physical, chemical, or *microbial hazards*, including clinical areas, dietary areas, central sterile support areas, patient care areas, resident care areas, and therapy areas; and
f. other items and areas determined by the *Designated Team.*

**8.2.5 Process Flow Diagrams.** The information from Section 8.2.4 *shall* be graphically described in step-by-step *process flow diagrams*. The *process flow diagrams shall* have details that enable the identification, analysis, and management of the *risk* from physical, chemical, and *microbial hazards* throughout the *building water systems*. The *Designated Team shall* confirm that the *process flow diagrams* are representative of the systems as built.

**8.2.6 Analysis of Building Water Systems.** The *Designated Team shall* use the *process flow diagrams* in Section 8.2.5 to evaluate where *hazardous conditions* have the potential to occur in the *building water systems*. The analysis *shall* include the vulnerability of occupants and *shall* include the *building water systems* and associated devices identified in Section 8.2.4. The analysis *shall* include provisions to respond to *water service disruptions*.

**8.2.7 Control Measures.** Based on the results of the *analysis of building water systems* in Section 8.2.6, the *Designated Team shall* determine the *control measures* to be maintained. *Control measures shall* include preplanning of physical design and equipment siting. *Control measures shall* include any treatment methods utilized, and *shall* include all technical and physical processes, and procedures and activities or actions that monitor or maintain the physical or chemical conditions of water to within established *control limits*.

a. ***Control Locations.*** The *Designated Team shall* use the information from Sections 8.2.6 and 8.2.8 to determine the locations in the *building water systems* where *control measures* are required.

b. ***Control Limits.*** The *Designated Team shall* determine a maximum value, minimum value, or range of values for chemical and physical parameters.

**8.2.8 Monitoring.** The *Designated Team shall* establish a procedure for *monitoring* each *control measure* to *control limits*. The procedures *shall* include the means, methods, and frequency for *monitoring* activities.

**8.2.9 Corrective Actions.** For each *control location*, the *Designated Team shall* establish procedures for *corrective actions* to be taken when *monitoring* shows that *control measures* are outside of established *control limits*. The procedures for *corrective actions shall*:

a. include *remedial treatment* when the *Designated Team* determines it should be used;

b. comply with *AHJ* requirements;

c. *shall* include evaluation of the *building water system risk management plan* by the *Designated Team* to determine if change is needed;

d. *shall*, if the facility has an infection control department (IC), establish procedures for *corrective actions* that follow established IC processes to be taken when the IC identifies cases of illness and injury caused by physical, chemical, or *microbial hazards* associated with *building water systems* that are *epidemiologically linked* to the healthcare facility; and

e. *shall* identify the persons responsible for taking the *corrective action*, *shall* identify the required response time for taking the *corrective action*, and *shall* identify all persons to be notified.

**8.2.10 Program Confirmation.** The *Designated Team shall* establish procedures to confirm, both initially and on an ongoing basis, that the *Program* is being implemented as designed. The resulting process is *verification*. The *Designated Team shall* establish procedures to confirm, both initially and on an ongoing basis, that the *Program*, when implemented as designed, *controls* the *hazardous conditions* throughout the *building water systems*. The resulting process is *validation*. The *Designated Team shall* determine whether *testing* for *hazards shall* be performed, and if so, how test results will be used to validate the *Program*. If the *Designated Team* determines that *testing* is to be performed, the *Designated Team shall* establish procedures, including sampling frequency, number of samples, locations, sampling methods, and test methods. The *Designated Team shall* include the following as part of the determination of whether to test for *hazards*:

a. *Program control limits* are not maintained in *building water systems*, including in water systems with *supplemental disinfection*;

b. a healthcare facility provides in-patient services to *at-risk individuals* or immunocompromised populations; and

c. a prior history of injury or illness from *hazards* associated with the *building water system*.

**8.2.11 Documentation and Communication.** The *Designated Team shall* establish and maintain the *risk management plan* contained within one or more documents. These documents are allowed to contain information that is not part of the *risk management plan*. If multiple documents are used, a master document providing the location of all *Program documents shall* be maintained. The *Program documents shall* include the name, title, and contact information for the *Designated Team* leader and the role and contact information for other *Designated Team* members. The *Designated Team shall* establish and implement documentation and communication procedures for:

a. all activities of the *Program;*

b. coordination among subgroups covering different portions of the *building water system* and associated equipment;

c. informing all affected parties identified by the *Designated Team* of *Program* changes;

d. *risk management plan* documents revision control system that identifies and replaces earlier document versions with the latest document version whenever *Program* changes are made; and

e. informing all affected parties identified by the *Designated Team* of actions taken when the *Designated Team* determines there is elevated *risk* of injury, illness, or disease caused by *building water system* physical, chemical, or *microbial hazards*.

### 8.3 Existing Building Review, New Construction, and Renovations

**8.3.1 Existing Building Review.** The *Designated Team shall* review and update the *risk management plan* at least once per year to incorporate changes, if any, affecting Sections 8.2.4, 8.2.5, 8.2.6, 8.2.7, 8.2.8, 8.2.9, 8.2.10, or 8.2.11.

**8.3.2 New Construction and Renovations.** For new construction, renovation, addition, or modification, the *Designated Team shall* review the scope of work, determine the *risk* associated with the project, and revise the *risk management plan* in places where the *Designated Team* determines revisions is needed. The *owner*, senior organizational leadership, or their *designee shall* require the building designer to comply with Section 7, "Requirements for Designing and Documenting Building Water Systems."

For a building that is a healthcare facility where patient stays exceed twenty-four hours, and for a building that is a facility that provides lodging, board, and nursing care, physical care, or both nursing and physical care, the *owner*, senior organizational leadership, or their *designee shall* require the designer and builder to:

a. work cooperatively with the *Designated Team* to evaluate where *hazardous conditions* have the potential to occur in the *building water systems*, and to address those *hazardous conditions* by modifying the *risk management plan* as necessary for the project (1) during early planning, (2) during each phase of design and construction, and (3) during commissioning;

b. to work cooperatively with the *Designated Team* to comply with all applicable portions of Section 7; and

c. to provide documented reports to the *Designated Team* confirming compliance with the *risk management plan*.

## 9. REFERENCES

1. ASHRAE. 2020. ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated With Building Water Systems*. Atlanta, GA: ASHRAE.

2. ASHRAE. 2018. ANSI/ASHRAE Standard 188, *Legionellosis: Risk Management for Building Water Systems*. Atlanta, GA: ASHRAE.

**(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)**

## INFORMATIVE APPENDIX A—BIBLIOGRAPHY

This bibliography provides sources for additional information about physical, chemical, and *microbial hazards*. The sources are provided for the reader's convenience; however, the sources are provided without confirmation of suitability for any particular purpose.

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WHO. 2011. 2011a, *Water Safety in Buildings*. Geneva, Switzerland: World Health Organization.

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## INFORMATIVE APPENDIX B—GUIDANCE IF MICROBIAL TESTING IS UTILIZED IN THE ABSENCE OF SUSPECTED OR CONFIRMED FACILITY-ASSOCIATED DISEASE

### B1 Reasons for Conducting Microbial Testing

*Testing* water samples for the presence of *microorganisms* is the most common way to confirm that a *water management program* (*Program*), when implemented as designed, effectively *controls* the *hazardous conditions* throughout the *building water systems* (*validation*). *Microbial testing* may also be useful for evaluating potential *growth* and *transmission* sources or confirming the results of *remedial treatment*. *Microbial testing* provides only a single snapshot in time, so it is not an appropriate predictor of health *risk* such as the likelihood of disease *transmission*. However, *microbial* test result trends, when reviewed over time, may be useful to indicate emerging deficiencies in *control measures* so that they can be addressed before disease *transmission* can occur.

### B2 Targets for Microbial Testing

It is unrealistic to expect a facility to test for every potentially *pathogenic microorganism* known to be associated with *building water systems*. Moreover, the test methods utilized to detect many of these *microorganisms* are not well-developed or are not commercially available. Thus, the user or the *Program Team* may elect to test for a limited set of *microorganisms* that can serve to indicate whether the conditions for *microbial growth* are well-*controlled*. If *testing* indicates these *microorganisms* are well-*controlled*, it is likely the *growth* of other *microorganisms* not tested is also *controlled*. This limited set of *microorganisms* is often call "indicator" or "sentinel" organisms and may or may not be potential *pathogens* themselves. The most common and commercially available test methods target the following organisms: general heterotrophic *growth*, *Legionella*, and *Pseudomonas*. Facilities that serve populations at greater *risk* for disease, such as healthcare, may benefit from *testing* for additional specific *pathogens* known to affect their patient population or known to be common to their location.

**B2.1 Heterotrophic Plate Count (HPC).** Heterotrophs are any *microorganism* that uses organic carbon as a food source, as opposed to auxotrophs that gain energy from sunlight or chemical reactions. Since well managed *building water systems* contain very little available organic carbon needed by heterotrophs to *grow*, the number of viable heterotrophs is considered a general measure of water quality and the effectiveness of the *water management program* to *control microbial growth*. *Microbial testing* to count the viable heterotrophs is always conducted by culture and may be performed on-site.

**B2.2 *Legionella*.** *Legionella bacteria* can cause *legionellosis*. *Testing* for *Legionella* in *building water systems* is covered extensively in ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated with Building Water Systems*.

**B2.3 *Pseudomonas aeruginosa*.** *Pseudomonas* can cause a variety of illnesses, including rashes, pneumonia, and sepsis. *Pseudomonas aeruginosa* (*P. aeruginosa*) is the most common *pathogenic* species. *Pseudomonas bacteria* are often central and underlying members of a *biofilm*, so *testing* for *Pseudomonas* can indicate whether conditions that promote establishment, *growth*, or persistence of *biofilms* exist within the *building water systems*. Commercial test methods specific for *Pseudomonas*, or *P. aeruginosa* directly, are available and may include culture, PCR, serology, and other technologies. *Pseudomonas* often *grow* on the media used for HPC but cannot be definitively identified with the HPC test method.

### B3 Microbial Test Methods

*Microbial* tests may be performed by a contracted laboratory or on-site by the user or *Program Team*. It is necessary for the user or the *Program Team* to fully understand test performance characteristics, such as sensitivity and specificity, in order to correctly interpret test results.

If the test is conducted by a laboratory, the laboratory should be accredited by a regional, national, or international accrediting body according to a nationally or internationally recognized standard that, at a minimum, requires the use of revision controlled standard operating procedures for *testing*, documentation of

the performance characteristics of the tests, periodic proficiency *testing*, and periodic independent audits verifying compliance. An example of such a recognized standard is ISO/IEC 17025, *Testing and Calibration Laboratories*. The laboratory should have the capability to meet the *testing* targets established by the user. It may be useful to consult with the laboratory in selecting the test methodology most appropriate for the specific circumstances.

In order to obtain accurate results if *microbial testing* is to be conducted on-site by the user or *Program Team*, it is important to follow all of the *microbial* test manufacturer's instructions for sample collection and transport and not to deviate from the test protocol.

**B3.1 Culture.** Culture is a broad term for test procedures that involve growing *microorganisms* on or in artificial media. Culture methods have historically been the most frequently used test methods to determine whether viable *microorganisms* are present in a sample. However, some stressors, such as the absence of adequate nutrients, exposure to *disinfectants*, and exposure to higher temperatures, can cause *microorganisms* to enter a state called "*viable but nonculturable*" (*VBNC*) where the *microorganisms* are not dead but cannot be detected by culture testing. Furthermore, some *microorganisms*, such as *Legionella* and *Pseudomonas aeruginosa*, require specialized artificial media for *growth* and identification, while others, such as heterotrophs, can *grow* on ordinary media. Many culture tests are performed in a laboratory, however, heterotrophic plate count (HPC) tests may be conducted on-site, if the conditions for incubation set by the test manufacturer can be met. The results from culture tests are expressed as either CFU (colony forming units) or MPN (most probable number) per unit volume tested (typically mL), and are typically available in two to fourteen days.

**B3.2 Polymerase Chain Reaction (PCR).** PCR *testing* is a procedure that detects the genetic material of organisms. PCR test may be specific to:

a. a single *microorganism*;
b. a subset of related *microorganisms* (for example, multiplex PCR tests can detect and distinguish between *Legionella pneumophila* serogroup 1, *Legionella pneumophila* serogroups 2 through 15, and all other *Legionella* species simultaneously); or
c. a broad class of *microorganisms* (for example: eubacteria, fungi, and protists).

**B3.3 Serology.** Serology *testing* uses antibodies in a way to indicate the presence of a *microorganism*. Serological *testing* may be performed by a laboratory or may be performed on-site by the user or the *Program Team*. The most common type of serological test is the lateral flow platform. In this test, capillary action wicks the sample fluid through a matrix impregnated with the antibody capable of reacting with a particular *microorganism* or with a small set of closely related *microorganisms*. The ability of the test antibody to react with a particular *microorganism* typically makes serological *testing* more specific than either culture or PCR *testing*. If target *microorganisms* are present, the antibody reaction is usually displayed by the serological test as a solid line. Although it is theoretically possible for the antibodies used in serological *testing* to detect parts of dead cells, the impact on test results is negligible because dead cells do not remain intact for very long. Determining if the target *microorganism* is present, qualitative results, can be accomplished in minutes using serological *testing*, such as the lateral flow platform. Laboratory based serological *testing* can return results that may indicate the quantity of target *microorganisms* present in the sample, quantitative results, in two to five days. Consult the *testing* laboratory for an explanation of the units in which results are expressed.

**B3.4 Emergent Test Methods.** Test methodologies are constantly evolving and improving. When considering the use of emergent test methods, consider the following:

a. test results turnaround time,
b. specificity: Does the method provide the desired ability to differentiate between *microorganisms*?
c. sensitivity: Does the method provide the ability to detect *microorganisms* at the expected *microbial* concentration?
d. ability to discriminate between live and dead *microorganisms*,
e. ability to determine the virulence (disease causing severity) of the target *microorganisms*, and
f. ability of the test method to be performed on-site.

When evaluating emergent technologies, the test method should be one validated by a third party that specialized in such *validations*, and the performance characteristics of the test method should be well-established.

## B4 Responses to Microbial Test Results

The user or the *Program Team* should determine the most appropriate responses to test results, in consultation with the *testing* laboratory or test manufacturer's instructions before *testing* is conducted. *Microbial* test results alone should never automatically trigger actions such as *remedial treatment*. Healthcare professionals may use *microbial* test results to inform clinical practices, such as the type of disease screening performed. *Microbial* test results may be useful to establish a baseline and to determine change over time. A user or the *Program Team* may use results to document and determine effectiveness of the *water management program* over time. *Microbial* test results should be reviewed at least annually. *Microbial testing* schedules may be modified in accordance with analysis of both *microbial* test results and water quality changes over time. The most common *microorganisms* that can serve to indicate whether the conditions for *microbial growth* are well-*controlled* are heterotrophs, *Pseudomonas aeruginosa*, and *Legionella*. A general guide for interpreting results from *testing* for *heterotrophs* and *Pseudomonas aeruginosa* is presented in Table B-1. Guidance for interpreting and responding to results from *testing* for *Legionella* is available in ASHRAE Guideline 12-2020, *Managing the Risk of Legionellosis Associated with Building Water Systems*, Appendix C4, "Interpretation of Test Results," and Appendix C5, "Responses to *Legionella* Test Results."

**Table B-1 Interpreting Microbial Test Results for Common Indicator Organisms[1,2,3,4]**

| Microorganisms | Well-Controlled | May Allow Growth | Poorly Controlled | Uncontrolled |
|---|---|---|---|---|
| Heterotrophs (HPC) | Not detected or <500/mL | 500/mL to 999/mL | 1,000 mL to 9,000 mL | >10,000 mL |
| *Pseudomonas aeruginosa* | 0/mL | | 1 to 10/100 mL | >10/100 mL |

## B5 References

1. GPO. 2016. Code of Federal Regulations, *Title 40 CFR 141.74*, "Analytical and monitoring requirements." Washington, D.C.: U.S. Environmental Protection Agency.
2. EU. 2020. Official Journal of the European Union, *Directive (EU) 2020/2184 of the European Parliament and of the Council of 16 December 2020 on the quality of water intended for human consumption.* Brussels, Belgium: European Union, European Parliament.
3. UK. 2016. Department of Health, *Health Technical Memorandum 04-01: Safe water in healthcare premises—Part C: Pseudomonas aeruginosa – advice for augmented care units.* London, United Kingdom: Department of Health and Social Care.
4. Italy Pool/Spa regulation – *P. aeruginosa*. Dipartimento di Ambiente e Connessa Pervenzione Primaria, Istituto Superiore di Sanita, Roma. http://www.iss.it/binary/publ/cont/13_46_web.pdf

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## INFORMATIVE APPENDIX C—BUILDING WATER SYSTEM PHYSICAL HAZARDS GUIDANCE

### C1 Physical Hazards

Water is a physical *hazard* in some *building water systems* because, under certain conditions, water can cause severe *scalding* burns. *Scalding* is a function of water temperature and exposure time (see Table C-1). The higher the water temperature, the shorter the exposure time that can cause burns. Everyone is susceptible to *scalding*. The severity and *risk* of *scalding* injuries increases with higher water temperature. The guidance in this appendix will focus on hot *potable building water systems*, since the majority of injuries and deaths caused by physical *hazards* associated with *building water system* involve *tap* water *scalds* to the elderly and children under the age of five.

*Building water systems* that are improperly designed, operated, and maintained can also contribute to the *risk* of *scalds* from hot water. All *building water systems* should be designed following the guidance in Informative Appendix G, "Building Designer Guidance" and should be designed, operated, and maintained in conformance with the manufacturer's instructions, and following the guidance contained in Informative Appendix F, "Potable and Process Building Water Systems Guidance," and in ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated with Building Water Systems*, Sections 5 through 12.

### C1.1 Temperature Control of Bacterial Growth

To *control bacterial growth* in *potable building water systems*, water heater thermostats, and hot water distribution controls should be adjusted to provide water temperatures above the range where *microbial growth* is likely to occur. Point-of-use temperature controls that limit the temperature of hot water discharge from *water use end points* should be considered in order to reduce the *risk* of *scalding* when bathing, showering, or washing.

Guidance on the impact of water temperature on *microbial growth* can be obtained from Informative Appendix E, "Building Water System Microbial Hazards Guidance," and through informative documents such as ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated With Building Water Systems*.

### C1.2 Temperature Actuated Mixing Valves

ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated With Building Water Systems*, recommends that water heaters with storage tanks should be maintained at 140°F (60°C) or higher to *control microbial growth*, unless other compensating *control measures* are used. Hot water distribution temperatures can change due to variables, such as differing use patterns and changes in water outlet temperature. A temperature actuated mixing valve should be installed downstream from the hot water source (water heater) to deliver a stable hot water temperature to the hot water distribution system. Temperature actuated mixing valves should be listed to ASSE 1017, *Performance Requirements for Temperature Actuated Mixing Valves for Hot Water Distribution Systems*, or CSA B125.3, *Plumbing Fittings*, "Temperature-Actuated In-line Mixing Valves."

When installing a temperature-actuated mixing valve to *control* water temperature in a hot water recirculation system, follow the manufacturer's instructions. It is important to pipe a concentration from the hot water return pipe, downstream from the recirculation pump, to the cold-water inlet or hot water return connection of temperature-actuated mixing valve. Without this connection, the temperature-actuated mixing valve may not function to limit water temperature to the established setpoint during periods when there is no hot water use at the *taps*. This is because the cold water required by the mixing valve for temperature regulation can only enter the mixing valve when hot water exits the *taps*. When no hot water is used at the *taps*, the only path for pumped hot water recirculation is through the hot water and forced through the hot port of the mixing valve, filling the recirculation loop with water approaching the temperature of the water heater outlet. This water at unregulated temperatures can cause *scalding* when *taps* are opened. The *risk* of

*scalding* will continue until regulated temperature water reaches the *tap* from the mixing valve (regulation enabled when opening the *tap* allows cold water to flow through the mixing valve) or the *tap* is closed. When the temperature-actuated mixing valve cold water inlet or hot water return is properly connected to the hot water recirculation return pipe, the temperature-actuated mixing valve is able to normally function to maintain the established water temperature setpoint, whether or not there is hot water use at the *taps*.

### C1.3 Recirculation, Temperatures Gauges, and Adjustments of Thermostatic Controls at Taps

A temperature gauge should be installed to indicate the blended water temperature from the temperature-actuated mixing valve installed downstream of the hot water source. If the *building water system* utilizes a recirculation loop to maintain hot water temperatures near the *water use end points*, a temperature gauge should be installed near the end of each circulated branch (near the balancing valve). Although not generally needed to address physical *hazards*, when hot water recirculation loops are used, a temperature gauge should be installed in the hot water return line near the water heater, or if the hot water return shares piping with the cold water supply to the water heater, the temperature gauge should be upstream from the cold water connection.

After the *potable building water system* is adjusted and balanced, all pressure balancing and thermostatic controls should be adjusted at each *tap* (showers, sinks, and lavatories) to address the *risk* of *scalding* when bathing, showering, or washing. Pressure balancing and thermostatic controls at each *tap* should be rechecked and readjusted as necessary at each *tap*:

a. on an established schedule (every 12 months is a common schedule);
b. whenever the water heater thermostat is adjusted or changed;
c. whenever the outlet temperature of the temperature-actuated mixing valve is changed; or
d. whenever adjustments or changes occur that can affect cold or hot water system pressure balance.

### C1.4 Scald Burn

Hot water *scald* burns can be very painful, debilitating, and sometimes a fatal form of thermal injury. Children, particularly those under five years old, the disabled, and the elderly tend to be more susceptible to *scalding*[1]. The reasons for this increased susceptibility vary, but include factors such as skin thickness, reaction time, movement restrictions, and cognitive ability. Model plumbing codes and some state codes have established a maximum temperature at the *tap* of 120°F (48.9°C)[2,3]. The maximum water temperature at the *tap* of 120°F (48.9°C) is based on burn studies that demonstrate the time versus temperature relationship for *scald* burns to adult male skin, and how long it takes for second or third degree burns to occur[4]. A maximum water temperature of 110°F (43.3°C) or lower may be advisable for those more susceptible to *scalding*.

**Table C-1 Time and Temperature Relationship to Severe Burns[4]**

Exposure Time to Burn Adult Skin at Elevated Water Temperatures (Exposure times for children, elderly, and those more susceptible can be shorter)

| Water Temperature | Second Degree Burn | Third Degree Burn |
|---|---|---|
| 170°F (76.7°C) | 0.30 seconds | 0.70 seconds |
| 165°F (73.9°C) | 0.35 seconds | 0.80 seconds |
| 160°F (71.1°C) | 0.40 seconds | 0.90 seconds |
| 155°F (68.3°C) | 0.65 seconds | 1.2 seconds |
| 150°F (65.6°C) | 0.90 seconds | 1.8 seconds |
| 148°F (64.4°C) | 1.0 seconds | 2.0 seconds |
| 140°F (60.0°C) | 2.8 seconds | 5.4 seconds |
| 133°F (56.1°C) | 10 seconds | 17 seconds |
| 130°F (54.4°C) | 18 seconds | 30 seconds |
| 127°F (52.8°C) | 35 seconds | 1 minute |
| 124°F (51.1°C) | 1.3 minutes (1 minute and 20 seconds) | 2 minutes |

**Table C-1 Time and Temperature Relationship to Severe Burns[4]**

| Exposure Time to Burn Adult Skin at Elevated Water Temperatures (Exposure times for children, elderly, and those more susceptible can be shorter) | | |
|---|---|---|
| **Water Temperature** | **Second Degree Burn** | **Third Degree Burn** |
| 120°F (48.9°C) | 4.8 minutes (4 minutes and 48 seconds) | 9.3 minutes (9 minutes and 18 seconds) |
| 115°F (46.1°C) | 30 minutes | 1 hour |
| 110°F (43.3°C) | 3.6 hours (3 hours and 36 minutes) | 6.7 hours (6 hours and 42 minutes) |
| 105°F (40.6°C) | Not usually associated with scalds | Not usually associated with scalds |

## C2 References:

1. K. Diller. 2006. *Adapting Adult Scald Safety Standards to Children*. Chicago, IL: American Burn Association.
2. IAPMO. 2018. *Uniform Plumbing Code*. Ontario, CA: International Association of Plumbing and Mechanical Officials.
3. ICC. 2018. *International Plumbing Code*. Washington, D.C.: International Code Council.
4. Moritz, A.R., Henriques, F.C. Jr. American Journal of Pathology. 1947 Sep; 23(5): 695–720. Studies of Thermal Injury II. The Relative Importance of Time and Surface Temperature in the Causation of Cutaneous Burns.

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## INFORMATIVE APPENDIX D—BUILDING WATER SYSTEM CHEMICAL HAZARDS GUIDANCE

**ACRONYMS**

| | |
|---|---|
| **AL** | Action level (USEPA) |
| **ASTM** | ASTM International |
| **CA-CPF** | California Cancer Potency Factor (CA) |
| **CMS** | United States Centers for Medicare and Medicaid Services |
| **DBP** | *disinfection* byproduct |
| **EPA** | United States Environmental Protection Agency |
| **IAQ** | indoor air quality |
| **LCR** | Lead and Copper Rule (USEPA National Primary Drinking Water Regulations) |
| **MAC** | Maximum Acceptable Concentration (Health Canada) – The highest level of a *contaminant* that is allowed in *potable water.* |
| **MCL** | Maximum *Contaminant* Level (USEPA) – The highest level of a *contaminant* that is allowed in *potable water*. MCLs are set as close to MCLGs as feasible, using the best available *disinfection* technology and taking cost into consideration. MCLs are enforceable standards. |
| **MCLG** | Maximum *Contaminant* Level Goal (USEPA) – The level of a *contaminant* in *potable water* below which there is no known or expected *risk* to health. MCLGs allow for a margin of safety and are non-enforceable public health goals. |
| **MMCL** | Massachusetts Maximum *Contaminant* Level (MA) |
| **MRDL** | Maximum *Residual Disinfectant* Level (USEPA). The highest *residual* level of a *disinfectant* allowed in *potable water*. |
| **MRDLG** | Maximum *Residual Disinfectant* Level Goal (USEPA). The *residual* level of a *potable water disinfectant* below which there is no known or expected *risk* to health. MRDLGs do not reflect the benefits of the use of *disinfectants* to *control microbial contaminants*. |
| **NL** | Notification Level (CA) |
| **NPDWR** | National Primary Drinking Water Regulations (USEPA) |
| **NSDWR** | National Secondary Drinking Water Regulations (USEPA) |
| **PHG** | Public Health Goal (CA) |
| **SMCL** | Secondary Maximum *Contaminant* Level (USEPA) |
| **TT** | Treatment Technique (USEPA) – A required *disinfection* process in a *water utility* treatment plant presumed to reduce the level of a *contaminant* in *potable water* to acceptable levels. |
| **USEPA** | United States Environmental Protection Agency |
| **SDWA** | United States Safe Water Drinking Act |
| **WHO** | World Health Organization |

### D1 Introduction

The waterborne disease burden from *pathogen*-colonized *building water systems* is significant and increasing,

both in the United States and worldwide. Attention has been primarily focused on *Legionella*, but disease from other *opportunistic pathogens* associated with *potable building water systems* is also considerable.[1,2,3]

In some cases, *microbial control* can be benefitted by continuous *supplemental disinfection* of a building's hot- and cold-*potable water systems* using antimicrobial chemicals. Antimicrobial chemicals that are used for *supplemental disinfection* of *potable water* in *building water systems* include chlorine, chlorine dioxide, monochloramine, and a combination of copper ions and silver ions (CSI).[4-9] All of these have potential unintended consequences, including the formation of *disinfection* byproducts, a subset of chemical *contaminants*. The addition of *supplemental disinfection* chemicals can cause a shift in the *microbial* community structure, a change in the relative abundance of different *microorganisms*. In some cases, the use of antimicrobial *disinfection* chemicals may promote *growth* of selected *pathogens* (*microbial contaminants*).[10-16] Other consequences of *supplemental disinfection* may include damage to *building water system* components, such as by corrosion of metals and degradation of plastics and elastomers.[17] Use of antimicrobial *disinfection* chemicals may cause an increase in levels of corrosion products, a subset of chemical *contaminants*, such as copper, iron, lead, nickel and cadmium.[18-21]

ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated with Building Water Systems*, Section 5.3.2.1, "Supplemental Disinfection Used to Treat Building Water Systems," provides a list of factors that should be considered when evaluating *supplemental disinfection* options.[22] These include potential unintended consequences, such as:

a. promoting *growth* of *microorganisms* (other than *Legionella*) that may cause infection or disease
b. formation of *disinfection* byproducts
c. significant adverse impact on materials, including metals and non-metals, such as plastics and elastomers.

### D2 Routes of Exposure

Exposure to chemical *hazards* in water may include one or more of three primary routes:

a. ingestion, primarily drinking
b. inhalation of chemicals that off-gas from the water or inhalation/*aspiration* of contaminated *aerosols*
c. dermal/mucosal contact with water/*aerosols* or vapor-phase chemicals

Physical and chemical characteristics of the water supplied to the building and in the *building water system*, such as pH, temperature, total organic carbon, type, and concentration of *disinfectant residual*, chemical constituents of the water, and *water age* may affect characteristics of the *disinfectant*, such as solubility, volatility, reaction mechanisms, and the type and extent of *disinfection* byproduct formation.

The physical, chemical, and *microbial* characteristics of water supplied to the building and water in *building water systems* are complex and variable. As a result, the nature of the chemical *hazards* and the routes of exposure change continuously, even from one part of a *building water system* to another. These characteristics affect the extent to which each potential route of exposure may contribute to potential *risk*.

To the extent that potential exposure to volatile compounds that are known to off-gas is of concern, refer to guidance documents and standards pertaining to indoor air quality, such as ASHRAE Standard 62.1, *Ventilation and Acceptable Indoor Air Quality*, and ASHRAE Standard 62.2, *Ventilation and Acceptable Indoor Air Quality in Residential Buildings*.[23,24]

### D3 Contaminants Occurrence

*Contaminants* listed in Table D-1 may, but do not necessarily, occur when the *disinfectant* with which they are associated is used for *supplemental disinfection* of *potable water* in a *building water system*. When these *contaminants* do occur, some or all may be present and may or may not be at concentrations of concern. Factors that may influence the occurrence of *contaminants* in *potable water systems* include:

a. the physical, chemical, and *microbial* characteristics of the water supplied to the building, such as temperature, pH, type, and concentration of *disinfectant residual*, *turbidity*, *water age*, and *microbial* community structure
b. *building water systems* materials (pipes, fitting, seals), pipe diameters

c. the physical and chemical characteristics of the water in the *building water system*, such as temperature, pH, type, and concentration of *disinfectant residual*, *turbidity*, *water age*, alkalinity, dissolved oxygen, natural organic matter, and *microbial* community structure.

The specific factors that determine the extent to which any or all of these *contaminants* occur are not fully known.[25,26] The occurrence of these *contaminants* also is likely to be variable, because the characteristics of the water supplied to the building and of the water within the building are variable.

### D4 Relative Toxicity of Chemical Contaminants

Rules, regulations, and guidelines from regulatory agencies and public health organizations, such as EPA, Health Canada, and WHO are cited in Table D-1 and associated footnotes solely to provide context for understanding the relative *risks* associated with *contaminants* in water intended for human consumption.[27-39] A subset of the *disinfection* byproducts listed in Table D-1 are carcinogenic. The relative cancer *risk* of these chemical *disinfection* byproducts is shown in Table D-2.

### D5 Adverse Effects on Materials

**D5.1 Metals.** All of the antimicrobial *disinfection* chemicals listed in Table D-1 may, under certain conditions, corrode metal pipes and other metal components used in *potable building water systems*. Different types of corrosion, such as uniform corrosion, pitting corrosion, selective corrosion, and tuberculation may occur. The relative degree and type of corrosion associated with different *disinfection* chemicals is a function of a number of complex factors, including water chemistry, *water age*, pH, temperature, alkalinity, dissolved oxygen, natural organic matter, and the type of metal substrate (e.g., iron, copper, brass).

**D5.2 Plastics.** All of the antimicrobial *disinfection* chemicals listed in Table D-1 may, under certain conditions, have adverse effects on plastics used in *potable building water systems*. Plastics used to make pipes for *water utility distribution piping* and for *building water systems* include polyolefins, a family that includes polyethylene (PE) and polypropylene (PP). The relative degradation of plastics is a function not only of the type and concentration of the *disinfectant*, but also of factors such as pH, temperature, and the specific plastic formulation. Exposure to chlorine dioxide has been shown to degrade polyolefin pipes to a much greater extent than does either chlorine or monochloramine. Plastics that demonstrate resistance to chlorine dioxide include fluoropolymers (PTFE, PVDF) and chlorinated polyvinyl chloride (CPVC).[40,41]

**D5.3 Elastomers.** All of the antimicrobial *disinfection* chemicals listed in Table D-1 may, under certain conditions, have adverse effects on elastomeric components used in *potable building water systems*. Elastomers commonly used in *building water systems* include ethylene propylene diene terpolymer (EPDM), nitrile (NBR), and styrene butadiene rubber (SBR, Buna-N). The relative degradation of elastomers is a function not only of the type and concentration of the *disinfectant*, but also of factors such as pH, temperature, and the specific elastomeric formulation. Exposure to monochloramine has been shown to degrade commonly used elastomers to a much greater extent than does exposure to chlorine, especially at higher temperatures and lower pH. Elastomers that demonstrate resistance to monochloramine include fluoropolymers (PTFE) and silicone.[21,42]

### D6 Rules, Regulations, and Guidance

When a *disinfection* chemical is added to *potable water* in a *building water system*, governmental rules and regulations may or may not apply. As part of determining whether to add any *disinfection* chemicals to a *potable water* in a *building water system*, the *authority having jurisdiction* should be consulted.[28-31]

**Table D-1 Antimicrobial Disinfection Chemicals Used for Supplemental Disinfection of Potable Water in Building Water Systems**

| Antimicrobial Disinfection Chemicals[a] | Typical Control Range (Residual) | Associated Chemical Contaminants[b] | Associated Corrosion Products[b] |
|---|---|---|---|
| Chlorine | 0.5 – 3.0<br>(MRDL: 4.0) | Bromate ion<br>Chlorate ion<br>Haloacetic Acids (HAA5)<br>*Trihalomethanes* (TTHM) | Cadmium<br>Copper<br>Iron<br>Lead<br>Nickel |
| Chlorine Dioxide | 0.1 – 0.8<br>(MRDL: 0.8) | Bromate ion<br>Chlorate ion<br>Chlorite ion | |
| Monochloramine | 2.0 – 3.0<br>(MRDL: 4.0) | Ammonia/Ammonium ion<br>Bromate ion<br>Chlorine<br>Nitrate ion<br>Nitrite ion<br>*N-Nitrosodimethylamine* | |
| Copper-Silver Ions | Copper: 0.2 – 0.8<br>Silver: 0.01 – 0.08<br>(MRDL: N/A) | Copper<br>Silver | |

**Notes:**

Units are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter in water are equivalent to parts per million (ppm).

a. See Section D7, "Antimicrobial Disinfection Chemicals"

b. See Section D8, "Chemical Contaminants"

**Table D-2 Relative Cancer Risk of Disinfection Byproducts**

| Disinfection Byproduct (DBP) | Molecular Formula | Concentration in Potable Water (µg/L) Resulting in a Cancer Risk of 1 in 10,000 |
|---|---|---|
| Bromate | $BrO_3^-$ | 5 |
| *N-Nitrosodimethylamine* (*NDMA*) | $C_2H_6N_2O$ | 0.07 |
| **HALOACETIC ACIDS (HAA5)** | | |
| Dichloroacetic acid | $C_2H_2Cl_2O_2$ | 70 |
| Trichloroacetic acid | $C_2HCl_3O_2$ | 50 |
| **TRIHALOMETHANES (TTHM)** | | |
| Bromodichloromethane | $CHBrCl_2$ | 60 |
| Bromoform | $CHBr_3$ | 400 |
| Dibromochloromethane | $CHBr_2Cl$ | 40 |

***Note:*** USEPA has not evaluated chloroform, dibromoacetic acid, monobromoacetic acid, or monochloroacetic acid for cancer *risk*. The *disinfection* byproducts in this table are not exhaustive. USEPA methodology includes consideration of lifetime oral consumption and includes numerous other factors and considerations.

## D7 Antimicrobial Disinfection Chemicals

### D7.1 Chlorine

Rules, regulations, guidance, etc.:

USEPA, MRDL = 4.0 mg/L

Analytical Method(s):

Standard Methods 4500-Cl

***Note:*** Chlorine maintains a persistent *residual* in water. In *water utility* treatment facilities, chlorine is used as a primary *disinfectant* and as a *secondary* (*water utility distribution piping*) *disinfectant*.

**D7.2 Chlorine Dioxide**

Rules, regulations, guidance, etc.:

USEPA, MRDL = 0.8 mg/L

Analytical Method(s):

Standard Methods 4500-$ClO_2$-E

ChloridoX Plus (Amperometry using disposable sensors) (EPA Approved 2013)

***Note:*** Chlorine dioxide, a fast-acting *disinfectant*, maintains a relatively short-lived *residual* in water. In *water utility* treatment facilities, chlorine dioxide is used as a primary *disinfectant*. Chlorine dioxide is typically not used for (*water utility* distribution system) *secondary disinfection*.

**D7.3 Monochloramine**

Rules, regulations, guidance, etc.:

USEPA, MRDL = 4.0 mg/L (total sum of monochloramine, dichloramine, nitrogen trichloride)

Analytical Method(s):

Standard Methods 4500 Cl

ASTM Method D-1253-14

***Note:*** Monochloramine, a slow-acting *disinfectant*, maintains a highly persistent *residual* in water. In *water utility* treatment facilities, monochloramine is used as a primary *disinfectant*. Monochloramine is typically used for (*water utility* distribution system) *secondary disinfection*.[9,43]

**D7.4 Copper Ions and Silver Ions (CSI)**

Rules, regulations, guidance, etc.:

USEPA, AL = 1.3 mg/L (copper), SMCL = 1.0 mg/L (copper), SMCL = 0.1 mg/L (silver)

Analytical Method(s):

Copper – EPA Method 200.8; Standard Methods 3113B, 3120B; ASTM Method D1688-12C

Silver – EPA Method 200.8

***Note:*** Copper and silver ions are not used by *water utilities*, either as a primary *disinfectant* or for (*water utility* distribution system) *secondary disinfection*.[6]

**D8 Chemical Contaminants**

The maximum allowable levels of some chemical *contaminants* in public drinking water supplies are regulated, for example by the USEPA under the Safe Water Drinking Act (SDWA). Some are on the USEPA Candidate *Contaminant* Lists (CCL), some are regulated by individual states, and some are the subjects of other rules, regulations, and guidance, such as by Health Canada and the World Health Organization. The nature of the potential adverse health effects of chemical *contaminants* vary from one to another. The chemical *contaminants* associated with antimicrobial *disinfectant* chemicals applied to *potable water* in *building water systems* in any particular jurisdiction may or may not be subject to rules or regulations, including regulations that cover public drinking water supplies. Referenced rules, regulations, and guidance are provided solely for context. Whether or not covered by rules and regulations, potential adverse health effects of chemical *contaminants* associated with antimicrobial chemicals used to *disinfect potable water* in *building water systems* should be considered.

**D8.1 Ammonia/Ammonium Ion**

Rules, regulations, guidance, etc.:

Health Canada, guidance: To help prevent *nitrification*, limit excess free ammonia entering the distribution system to below 0.1 mg/L, and preferably below 0.05 mg/L, measured as nitrogen.

Health Effects:

There are no known significant adverse health effects associated directly with ammonia/ammonium ions in *potable water*; however, there are adverse health effects associated with certain reaction products of

ammonia/ammonium ions (see: nitrite, nitrate, *NDMA* below).

Analytical Method(s):

EPA Method 50.1

Standard Methods 4500-$NH_3$

***Note:*** Ammonia/ammonium ions are decay products of monochloramine.[9] Ammonia/ammonium ions can be used as nutrients by certain *microorganisms*, including clinically significant *building water system*-associated *pathogens* such as *Acinetobacter, Burkholderia, Elizabethkingia, Klebsiella,* non-tuberculous mycobacteria (NTM), *Pseudomonas*, *Sphingomonas,* and *Stenotrophomonas.*

Because ammonia/ammonium ions can be metabolized by these *pathogens*, ammonia/ammonium ions can promote their *growth*. In addition, certain *microorganisms* called nitrifying *bacteria* that are generally present in *potable water* are able to oxidize reduced nitrogen compounds (primarily ammonia) to form nitrite and nitrate. Nitrite and nitrate also can be metabolized by the above-listed *pathogens*.[16,44-46] *Legionella* are not known to metabolize ammonia/ammonium ions, nitrate, or nitrite. (See Informative Appendix E, "Building Water Systems Microbial Hazards Guidance," for information about specific *pathogens*.)

**D8.2 Bromate Ion**

Rules, regulations, guidance, etc.:

USEPA/SWDA, MCL = 0.010 mg/L, MCLG = 0

Health Canada, MAC = 1.0 mg/L

WHO, provisional guidance = 0.01 mg/L

Health Effects:

Increased *risk* of cancer (See Table D-2, Relative Cancer Risk of Disinfection Byproducts)

Analytical Method(s):

EPA Method 300.1

Standard Methods D6581-00

***Note:*** Bromate ion can be formed in reactions where bromide ion (in salt) is oxidized during the electrolytic production of sodium hypochlorite solution. Sodium hypochlorite solution (bleach) is the form of chlorine most often used for *supplemental disinfection*, and also is used as a precursor chemical in the on-site generation of chlorine dioxide and monochloramine. Bromate ion also can be formed in reactions where bromide ion (in salt) is oxidized during the electrolytic production of sodium chlorite, a precursor chemical used to generate chlorine dioxide.

**D8.3 Cadmium**

Rules, regulations, guidance, etc.:

USEPA, MCLG = 0.005 mg/L, MCL Action Level = 0.005. The relevant EPA Rule/Regulation is the Chemical *Contaminant* Rule, Phase II, Inorganic *Contaminants*

Health Canada, MAC proposed guideline = 0.005 mg/L

Health Effects:

Kidney damage

Analytical Method(s):

Standard Methods 3500-Cd

ASTM Method D3557A

***Note:*** Cadmium in *potable water* is associated with corrosion of galvanized pipe.

**D8.4 Chlorate Ion**

Rules, regulations, guidance, etc.:

USEPA, listed on CCL

Health Canada, MAC = 0.1 mg/L

WHO guidance = 0.7 mg/L

Health Effects:

Oxidative stress, anemia

Analytical Method(s):

EPA Methods 300.0 and 300.1

Standard Methods 4110 and 4110B

ASTM Method D6581-08

***Note:*** Chlorate ion is a decomposition product of sodium hypochlorite solution and of chlorine dioxide. Chlorate ion also can be produced in the on-site generation of chlorine dioxide. Chlorate ion also can be formed in reactions during the electrolytic production of sodium hypochlorite and of sodium chlorite, a precursor chemical used to generate chlorine dioxide. Chlorate ion also may be present as a *contaminant* in commercial sodium hypochlorite solution, which is the form of chlorine most often used for supplemental chlorination, and which is also used as a precursor chemical in the on-site production of monochloramine and of chlorine dioxide. Chlorate ion also may be present as a *contaminant* in commercial sodium chlorite, which is used as a precursor chemical in the on-site production of chlorine dioxide.

**D8.5 Chlorite Ion**

Rules, regulations, guidance, etc.:

USEPA, MCL = 0.1 mg/L, MCLG = 0.8 mg/L

Health Canada, MAC = 1.0 mg/L

Health Effects:

Oxidative stress, anemia

Analytical Method(s):

EPA Methods 300.0, 300.1, and 327 Rev 1.1

Standard Methods 4500-$ClO_2$-E

***Note:*** Chlorite ion is a reaction product of chlorine dioxide. Sodium chlorite is used as a precursor chemical in the on-site production of chlorine dioxide.

**D8.6 Copper Ion**

Rules, regulations, guidance, etc.:

USEPA, MCLG = 1.3 mg/L, MCL Action Level = 1.3 mg/L. The relevant EPA Rule/Regulation is the Lead and Copper Rule (LCR)

Health Canada, MAC = 2.0 mg/L

WHO, guidance = 2.0 mg/L

Health Effects:

Short term exposure: Gastrointestinal distress; Long term exposure: Liver or kidney damage

Analytical Method(s):

EPA Methods 200.9, 300.1, 317 Rev. 2.0, and 326 Rev 1.0

Standard Methods 3500-Cu

ASTM Methods D1688-90A, D1688-90C, and D6581-08A

***Note:*** Copper ion in *potable water* typically is a corrosion product and can also be introduced intentionally; for example, in connection with *disinfection* by copper-silver ionization.[5,6]

**D8.7 Haloacetic Acids**

Rules, regulations, guidance, etc.:

USEPA, MCL = 0.06 mg/L

Health Canada, MAC guideline = 0.08 mg/L

Health Effects:

Increased *risk* of cancer (See Table D-2, “Relative Cancer Risk of Disinfection Byproducts)

Analytical Method(s):

EPA Methods 552.3 Rev 1.0 and 557

Standard Methods 6251B

***Note:*** The five haloacetic (HAA5) regulated by USEPA under SDWA are (1) monochloroacetic acid, (2) dichloroacetic acid, (3) trichloroacetic acid, (4) monobromoacetic acid, and (5) dibromoacetic acid. Other haloacetic acids not regulated by USEPA under SDWA may also result from use of chlorine-containing *disinfectant* chemicals.

**D8.8 Iron**

Rules, regulations, guidance, etc.:

USEPA, SMCL = 0.3 mg/L. The relevant EPA Rule/Regulation is the USEPA National Secondary Drinking Water Regulations (NSDWR)

Health Effects:

Adverse health effects are only at extremely high doses.

Analytical Method(s):

Standard Methods 3500-Fe

***Note:*** The sources of iron contamination in *potable water* include corrosion of *building water systems* materials, such as galvanized iron. Iron may also be a *contaminant* in water supplied to the building. Iron produces rust-colored water with metallic taste.

**D8.9 Lead**

Rules, regulations, guidance, etc.:

USEPA, AL = 0.015 mg/L. The relevant EPA Rule/Regulation is the Lead and Copper Rule (LCR)

Health Canada, MAC guideline = 0.005 mg/L

Health Effects:

Infants and children: delays in physical or mental development; children could show slight deficits in attention span and learning abilities; Adults: kidney problems; high blood pressure

Analytical Method(s):

Standard Methods 3500-Pb

***Note:*** The sources of lead in *potable water* include corrosion of *building water systems* materials, such as leaded solder, brass, galvanized iron, and lead service lines. Lead may also be a *contaminant* in water supplied to the building. There is no known safe level of lead in *potable water*.

**D8.10 Nickel**

Rules, regulations, guidance, etc.:

USEPA, MCLG, and MCL rule of 0.1 mg/L was remanded in 1995 and revised to a 0.1 mg/L lifetime health advisory

Health Effects:

At very high doses: headaches, gastrointestinal manifestations, respiratory manifestations, lung fibrosis, cardiovascular diseases, lung cancer, nasal cancer, and epigenetic effects.

Analytical Method(s):

Standard Methods 3500-Ni

***Note:*** The sources of nickel in *potable water* include corrosion of *building water systems* materials, such as stainless steel and non-ferrous alloys that contain nickel.

**D8.11 Nitrate Ion**

Rules, regulations, guidance, etc.:

USEPA, MCL = 10 mg/L (as N), MCLG = 10 mg/L (as N)

Health Canada, MAC = 10 mg/L (as N)

WHO Guideline = 11.3 mg/L (as N)

Health Effects:

Methemoglobinemia (Blue Baby Syndrome)

Analytical Method(s):

EPA Method 300.1 Rev. 1.0

Standard Methods 4500-$NO_3^-$

ASTM Method D6508-15

***Note:*** *Nitrification* is a *microbial* process by which reduced nitrogen compounds (primarily ammonia) are sequentially oxidized to nitrite and nitrate. Ammonia can be present in source water used by some *utility water* treatment facilities. *Nitrification* in *potable water* is often associated with the use of monochloramine for *secondary disinfection*.[9] Nitrate can be used as a nutrient by certain *microorganisms*, including clinically significant *building water system*-associated *pathogens* such as *Acinetobacter*, *Burkholderia*, *Elizabethkingia*, *Klebsiella*, non-tuberculous mycobacteria (NTM), *Pseudomonas*, *Sphingomonas*, and *Stenotrophomonas*. Because nitrate can be metabolized by these *pathogens*, it can promote their *growth*.[16,44-46] *Legionella* are not known to metabolize nitrate. (See Informative Appendix E, "Building Water System Microbial Hazards Guidance," for information about specific *pathogens*.)

**D8.12 Nitrite Ion**

Rules, regulations, guidance, etc.:

USEPA, MCL = 1.0 mg/L (as N), MCLG = 1.0 mg/L (as N)

Health Canada, MAC = 1.0 mg/L (as N)

WHO Guideline = 1.0 mg/L (as N)

Health Effects:

Methemoglobinemia (Blue Baby Syndrome)

Analytical Method(s):

EPA Method 300.1 Rev. 1.0

Standard Methods 4500-$NO_2^-$

ASTM Method D4327-11 and D-650815

***Note:*** *Nitrification* is a *microbial* process by which reduced nitrogen compounds (primarily ammonia) are sequentially oxidized to nitrite and nitrate. Ammonia can be present in source water used by some *utility water* treatment facilities. *Nitrification* in *potable water* is often associated primarily with the use of monochloramine for *secondary disinfection*.[9] Nitrite can be used as a nutrient by certain *microorganisms*, including clinically significant *building water system*-associated *pathogens* such as *Acinetobacter*, *Burkholderia*, *Elizabethkingia*, *Klebsiella*, non-tuberculous mycobacteria (NTM), *Pseudomonas*, *Sphingomonas*, and *Stenotrophomonas*. Because nitrite can be metabolized by these *pathogens*, it can promote their *growth*.[16,44-46] *Legionella* are not known to metabolize nitrite. (See Informative Appendix E, "Building Water System Microbial Hazards Guidance," for information about specific *pathogens*.)

**D8.13 *N-Nitrosodimethylamine* (*NDMA*)**

Rules, regulations, guidance, etc.:

USEPA, listed on CCL

California, NL = 0.00001 mg/L, PHG = 0.000003 mg/L, CA-CPF = 0.0000022 mg/L

Massachusetts, MMCL = 0.00001 mg/L

Minnesota, guidance value = 0.000005 mg/L

Health Canada, MAC = 0.00004 mg/L

WHO Guideline = 0.0001 mg/L

Health Effects:

Increased *risk* of cancer (See Table D-2, "Relative Cancer Risk of Disinfection Byproducts).

Analytical Method(s):

EPA Method 521

Standard Methods 6450

***Note:*** Other nitrosamines listed on CCL are *N*-nitrosodiethylamine (NDEA), *N*-nitroso-di-n-propylamine (NDPA), *N*-Nitrosodiphenylamine, and *N*-nitrosopyrrolidine (NPYR).

### D8.14 Silver Ion

Rules, regulations, guidance, etc.:

USEPA, SMCL = 0.1 mg/L

Health Effects:

Ingestion of excessive levels of silver may cause skin discoloration.

Analytical Method(s):

EPA Method E200.8

Standard Methods 3500-Ag

### D8.15 Total *Trihalomethanes* (TTHM)

Rules, regulations, guidance, etc.:

USEPA, MCL = 0.08 mg/L

Health Canada, MAC = 0.1 mg/L

Health Effects:

Increased *risk* of cancer (See Table D-2, "Relative Cancer Risk of Disinfection Byproducts).

Analytical Method(s):

EPA Method 502.2 Rev. 2.1, 524.2 Rev. 4.1, 524.3, 524.4, 551.1 Rev. 1.0

Standard Methods 2320

ASTM Methods D1067-16B

***Note:*** The four *trihalomethanes* regulated under SDWA are (1) chloroform, (2) bromodichloromethane, (3) dibromochloromethane, and (4) bromoform. Other *trihalomethanes* not regulated by USEPA under SDWA may also result from use of chlorine-containing *disinfectant* chemicals.

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**(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)**

## INFORMATIVE APPENDIX E—BUILDING WATER SYSTEM MICROBIAL HAZARDS GUIDANCE

This informative appendix provides information and guidance about *building water system microbial hazards.*

### E1 What is a Microbial Hazard?

A *microbial hazard* is a *microorganism* (*bacterium*, fungi, or protozoa) that can cause human disease (i.e., a *pathogen)*. *Building water systems* can create an ideal environment for these *microorganisms* to survive and *grow*. Water is a natural reservoir for *microbial hazards*. The ecology and characteristics of *microorganisms* that facilitate their *growth* in water include *biofilm* formation and attachment to surfaces; survival and *growth* in amoebae; *growth* with low oxygen and organic levels; thermal tolerance; resistance to *disinfectants*; and stress-induced life states. *Building water system* conditions favorable to *microbial growth* include poor system cleanliness; lack of adequate *disinfectant residual*; high surface area to volume ratio (increased surface area for *biofilm growth* to occur); excessive *water age*; stagnant or no flow conditions; intermittent water usage; availability of nutrients; lack of maintenance; and presence of water temperatures supporting *microbial growth*. When these *hazardous conditions* are present in the *building water system* without appropriate *control measures*, *microorganisms* can *grow* and individuals may be exposed to these *pathogens* resulting in illness, especially in those with weakened immune systems.

*Building plumbing system pathogens* are different from fecal source *pathogens*, such as *E. coli*, *Cryptosporidium*, and *Giardia*, that inhabit the gastrointestinal tract of humans. Fecal source *pathogens* can contaminate *building water systems* due to inadequate treatment of water supplied to the building or *intrusion* of sewage into *potable* water. The primary path for fecal source *pathogens* to enter the body is through ingestion, not inhalation or *aspiration*. Fecal source *pathogens* are not naturally found in *building water systems*, but can infect healthy adults, generally causing gastrointestinal illnesses similar to food poisoning, which can be severe.

While *microorganisms* can certainly lead to other water quality issues in *building water systems*, such as *microbially* induced corrosion and *nitrification* of the *building water system*, this appendix addresses *microbial hazards* in *building water systems* that can cause human illness.

### E2 How Do People Get Sick from Microbial Hazards?

In order for a *microbial hazard* to cause illness or disease, a series of six conditions must be met, commonly referred to as the "chain of infection." For *building water systems*, this chain of infection consists of:

1. **Pathogen.** The presence of a *pathogen*.
2. **Reservoir.** A reservoir is where a *pathogen* naturally lives or what it lives in. Reservoirs include water, sediment, *biofilms*, and other *microorganisms* located within *building water systems* and medical equipment.
3. **Portal of Exit.** A portal of exit is the way a *pathogen* leaves its reservoir. Examples are portals of exit include *pathogens* separating from a *biofilm*, a shower head, a water fixture, and a water feature, such as a fountain. A *pathogen* may leave one reservoir and enter another reservoir, such as exiting a *biofilm* and entering water in pipes or the *pathogen* may exit both the reservoir and the *building water system*.
4. **Mode of Transmission.** The mode of *transmission* is the way a *pathogen* can be passed to a human host. This can be done by:
    a. direct physical contact with water containing *pathogens*, such as drinking, bathing, or showering;
    b. indirect contact with *pathogens* on surfaces, such as devices, injectables, hands of healthcare works, and countertops that have been contaminated by water containing *pathogens*;
    c. direct injection; and
    d. *aerosols*, such as can occur when water exits shower heads; *taps*; misters; water features, such as fountains; and when water splashes on a sink.

In general, people do not spread disease caused by *building water system pathogens* to other people.

5. **Portal of Entry.** A portal of entry is the way the *pathogen* enters a human host. Portals of entry associated with water from *building water systems* include, but are not limited to:
   a. broken skin;
   b. breathing water droplets into the respiratory tract (inhalation);
   c. getting water "down the wrong pipe" directly into the lungs (*aspiration*);
   d. ingestion (eating or drinking) into the gastrointestinal tract;
   e. direct contact with mucous membranes, such as when rinsing contact lenses or during nasal irrigation (neti pot); and
   f. by direct insertion through the use of medical instruments or other invasive devices, such as catheters, intravenous lines, implants, tools in tattoo parlors or nail salons, or through the use of a mechanical respirator or ventilator, such as a continuous positive airway pressure (CPAP) device.
6. **Susceptible Host.** Presence of a susceptible human host, in which the entering *pathogen* can *grow* and cause disease. A susceptible host can be any individual, but the most vulnerable are:
   a. those receiving healthcare services for chronic health conditions;
   b. those who have invasive medical devices; and
   c. *at-risk individuals*, such as people with weakened immune systems; such as those who are current or former smokers; have chronic lung disease; are taking medications for cancer, solid organ transplantation, or HIV; have underlying conditions such as diabetes, kidney failure, or liver failure; are infants under the age of six months; or are elderly.

*Microbial hazards* in *building water systems* can cause infection through this "chain of infection" pathway when susceptible human hosts are exposed to water containing waterborne *pathogens*. Breaking any single link in the chain of infection can stop *transmission* of the *microbial hazard* to an individual. The most effective *water management programs* interrupt the chain at multiple points and can be applied generally to prevent exposure to many *microbial hazards* and not just one specific *pathogen*.

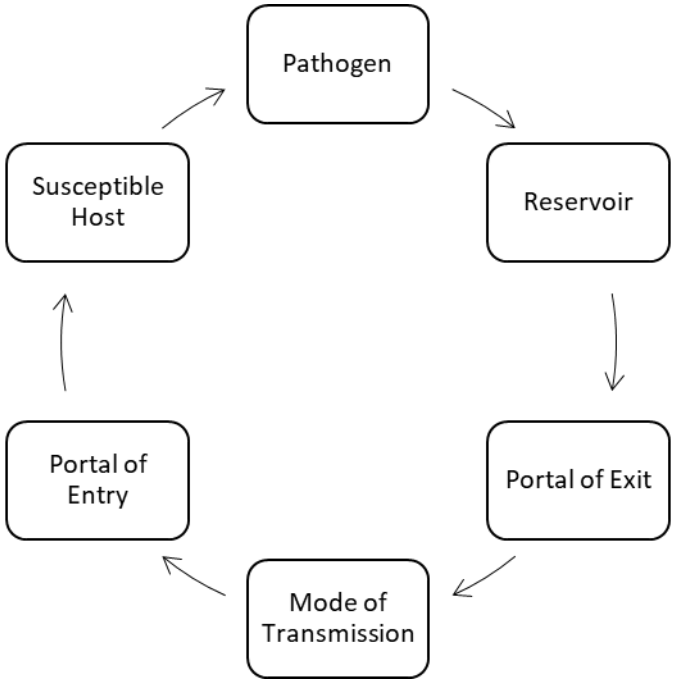


**Figure E2 The Chain of Infection**

### E3 What Microbial Hazards Are Most Commonly Associated with Disease?

In the United States, the *microbial hazards* most commonly associated with *building water systems* that cause infections and disease are nontuberculous mycobacteria (NTM), *Pseudomonas aeruginosa* (*P. aeruginosa*), *Legionella*, *Acanthamoeba*, and *Naegleria fowleri*. More specific details on these five microbes can be found below.

In healthcare environments, patient susceptibility to *opportunistic pathogens* commonly associated with *building water systems* is often greater than in the general population. Because patients are more susceptible, there are more *pathogens*, including *bacteria* and fungi, that can cause infections and disease in patients than in the general population. Patients are often more susceptible due to conditions such as non-intact skin, open wounds, immune suppressing drugs or diseases, or the presence of invasive devices.[1] Examples of *pathogens* commonly associated with healthcare *building water systems* include: certain NTM species (*Mycobacterium abcessus* clade, *Mycobacterium avium* complex, *Mycobacterium mugogenicum*, *Mycobacterium phocaicum*, *Mycobacterium gordonae*, *Mycobacterium kansasii*, and *Mycobacterium xenopi*) and other *bacteria* including *Legionella*, *P. aeruginosa*, *Stenotrophomonas maltophilia*, *Elizabethkingia*, *Burkholderia cepacia* complex, *Sphingomonas*, *Acinetobacter*, and fungi (*Aspergillus* and *Fusarium*). A more complete list of the waterborne *pathogens* associated with healthcare exposure can be found on the *CDC*'s "Reduce Risk from Water" website.

Public health resources, including the *CDC* or World Health Organization (WHO), should be consulted for additional information about the *pathogens* mentioned here, and to obtain a more comprehensive listing of organisms associated with infections and disease from *building water systems*, especially if these infections are identified as being associated with the building and its use.

### E4 What Types of Infections Do These Microbial Hazards Cause?

Different *building water system microbial hazards* can infect different human body systems, and which body system is infected can depend on where and how the *pathogen* enters the body. The *pathogens* listed in Section E3 can cause a range of infections and disease, including those of the eyes, ears, lungs, skin, soft tissues, heart, urinary tract, bones and joints, and of the brain and spinal cord. Although some *pathogens* are predominantly associated with one type of disease (e.g., *Legionella*, *Pseudomonas aeruginosa* [*P. aeruginosa*], and NTM often cause pneumonia), some can cause other infections and disease, (e.g., *P. aeruginosa* can also cause rashes and ear infections), even in healthy individuals. With the appropriate mode of *transmission* and portal of entry into a susceptible human host, most waterborne *pathogens* can infect many different human body systems, not only those which the *pathogens* are most commonly known to infect.

**E4.1 Nontuberculous Mycobacteria (NTM).** These are about 190 species of NTM, 70 species of which have been found to cause infections. Most disease caused by NTM occurs in the general population; however, illness also occurs in patients in healthcare settings, usually among older people, those with preexisting lung disease, and those with weakened immune systems, especially those with cystic fibrosis, chronic obstructive pulmonary disease (COPD), and chronic inflammatory lung disease. Most of these infections are pulmonary, affecting the lungs, and caused by *opportunistic pathogens* belonging to *Mycobacterium avium* complex or to *Mycobacterium abcessus* clade. However, NTM can cause a variety of infections and disease depending on the route of exposure, including infections of the cervical lymph nodes, skin and soft tissue, bone and joint infections, and disseminated disease (disease spread to multiple areas of the body). *Outbreaks* due to NTM have been associated with medical devices, cosmetic procedures, contaminated medications given by injection, medical tourism, and with exposures such as tattoo parlors, hot tubs, swimming pools, and nail salons. NTM are not typically transmitted from human-to-human.

**E4.2 *Pseudomonas aeruginosa.*** *Pseudomonas aeruginosa* (*P. aeruginosa*) *bacteria* can cause "hot tub rash" or "swimmer's ear" in healthy human hosts after exposure to contaminated water, especially from hot tubs and swimming pools with inadequate disinfection. *P. aeruginosa* and other species of *Pseudomonas* can cause infections in the blood, lungs (pneumonia), or other parts of the body after surgery. Eye infections have occasionally been reported in persons using extended-wear contact lenses. Healthcare-associated infections can include sepsis, catheter-associated bloodstream infections, urinary tract infections, skin and soft tissue infections following wound debridement, surgical wound infections, and infections associated with contaminated devices, such as ventilator-associated pneumonia. Unfortunately, *Pseudomonas* can be

resistant to many antibiotics, and therefore can be difficult to treat. *Risk* factors for *Pseudomonas* infection include individuals with cancer or with weakened immune systems, patients in the intensive care unit, patients in the neonatal intensive care unit or patients in the burn unit, and surgical patients. In hospitals, where often the most serious infections occur, *Pseudomonas* can be spread by equipment and by the hands of healthcare workers that become contaminated and are not properly cleaned.

**E4.3** ***Legionella*.** *Legionella bacteria* can cause *legionellosis*. Guidance information on *Legionella* in *building water systems* is provided in ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated with Building Water Systems*[2].

**E4.4** ***Acanthamoeba*.** *Acanthamoeba* are a *microorganism* that can cause *Acanthamoeba* keratitis, an eye infection that has been linked to contact lens use, although people who do not use contact lenses can also become infected. Poor contact lens hygiene or wearing of contact lenses during swimming, hot tub use, or showering may increase the *risk* of *Acanthamoeba* entering the eye and causing infection. *Tap* water should never be used to rinse contact lenses or to dilute lens cleaning solutions. *Acanthamoeba* can also cause infection throughout the body by entering the skin through a cut, wound, or through the nostrils. Once inside the body, the *Acanthamoeba* travel through the bloodstream to other parts of the body, including the lungs, brains, and bones. There have been no reports of *Acanthamoeba* infections being spread from one person to another. *Acanthamoeba* can also serve as a host for other *pathogens*.

**E4.5** ***Naegleria fowleri*.** *Naegleria fowleri* (*N. fowleri*) is a *microorganism* that can infect people when water containing the amoeba enters the body through the nose. The amoeba migrates to the brain and begins to destroy brain tissue. There is no standard treatment for *N. fowleri* infections and they are almost always fatal. Infection with *N. fowleri* does not occur by drinking contaminated water. Most infections are associated with swimming in natural water such as lakes or ponds. Although *N. fowleri* has been detected in some *potable building water systems*, documented infections from exposure to *potable water* containing *N. fowleri* are very rare[4]. An example of the mode of *transmission* of *N. fowleri* in *potable water* to a human host includes when sinuses are irrigated using contaminated *tap* water. *N. fowleri* has not been shown to spread via water vapor or *aerosols*, such as from a shower head or *humidifier*. *N. fowleri* infection cannot be spread from one person to another.

## E5 How Do We Control These Microbial Hazards?

To *control* the *growth* and spread of *microbial hazards* (*pathogens*) in *building water systems*, *control* over water temperature, system cleanliness, and water quality conditions should be maintained by:

1. keeping hot water hot and keeping cold water cold;
2. keeping the *building water system* clean; and
3. keeping water moving and maintaining adequate *disinfectant residual*.

These measures are not mutually exclusive. The more detailed guidance below is useful for *controlling microbial hazards* and for developing and maintaining a *water management program*.

**E5.1 Water Temperature.** Water temperature plays an important role in *controlling* the *growth* of *microorganisms* in *building water systems*. Many of these *microorganisms* that can produce disease (*pathogens*) in susceptible individuals *grow* best in moderate temperature (neither too hot nor too cold). In general, many of these *pathogens grow* best between 68°F and 113°F (20°C and 45°C). Cold water temperatures below 68°F (20°C) will slow the *growth* of, but not typically kill, *pathogens*. *Growth* of *pathogens* also slows as water temperatures increase above 113°F (45°C). As water temperatures continue to increase toward 140°F (60°C) and higher, most *pathogens* begin to die. The higher the water temperature, the faster these *pathogens* die.[5] If these *microorganisms* are present in *biofilms* in the *building water system*, the *biofilm* can insulate them from higher temperatures that could kill free floating *microorganisms*. When considering water temperature as a *microbial control measure*, it is important to keep cold water cold at all times throughout the cold *building water system* and to keep hot water hot at all times throughout the hot *building water system*. Also, when using elevated hot water temperatures to *control microbial growth*, controls, such as pressure balancing and thermostatic controls, should be installed, adjusted ,and maintained to address the *risk* of *scalding* (see Informative Appendix C, "Building Water Systems Physical Hazards Guidance").

**E5.2 System Cleanliness.** Particles of organic material and heavy metals in *potable building water systems* can provide nutrients, surface area, or protection for *microorganisms* to *grow*. Particle-associated *bacteria* are also a source of biomass entering the *potable building water system* and can function as "seeds" for *bacterial* re-*growth*. The volume of particles typically increases as a result of *disinfection* of the *building water system*, because *disinfection* can cause *biofilm* detachment and material corrosion. The volume of particles can also increase when portions of *biofilm* detach by themselves, due to flushing of the *building water system*, or due to changes in pressure inside or outside the building, such as caused by water hammer or fire hydrant flushing. Properly sized, cleaned, and maintained filtration can be used as a barrier against particulate matter entering and seeding the *building water system* with suspended particles during construction and installation, and maintains cleaner pipework, fittings, valves, and fixtures. Sediment, organic material, corrosion products, and other particles can accumulate in storage tanks, which should be periodically inspected and cleaned. Removing particles from *building water systems* through filtration, cleaning, or through other maintenance improves the physical and chemical quality of water and reduces *microbiological growth* by limiting available nutrients[6].

**E5.3 Water Quality Conditions.** Presence of a *disinfectant residual* in water helps prevent the *growth* of *microorganisms* and can help *control biofilm* build-up. The level of *disinfectant residual* present in water supplied to the building point of entry will depend on many factors not controlled by the building *owner* or their *designee*, so the *water utility* should be requested to provide an analysis of the water quality, including *disinfectant* type and *residual* level, and to be provided notice when maintenance or alteration to the *water utility distribution piping* could affect the quality of supplied water. There is no universal recommendation for the *disinfectant residual* level that should be maintained in *building water systems*, but there is evidence that shows, in general, that even low *disinfectant residual* levels provide a healthier water system compared to one where no *disinfectant* is detected[7]. Tracking water quality and *disinfectant residual* level trends can serve as an effective tool in establishing operational *disinfectant residual* ranges and in determining when *corrective action* is needed. *Disinfectant residual* levels should be checked near the point where water enters the building, and at points upstream and downstream of where water is stored or processed, such as before and after storage tanks, water softeners, and recirculating lines. *Disinfectants* in water entering the building are consumed by the chemical demand placed on it by the water being *disinfected* as the water moves through different areas of the *building water system* to the *water use end points*. At some point, there may be little or no *disinfectant residual* left to provide *microbial control* for the rest of the *building water system.* In areas with little or no *disinfectant residual, supplemental disinfection* or some other *control measures* should be considered. See Informative Appendix D, "Building Water Systems Chemical Hazards Guidance" for additional information and guidance about *disinfectants* and other *building water system* chemical *hazards.*

*Building water system* water quality characteristics, such as temperature and *disinfectant residual*, may deteriorate in low-flow or no-flow conditions. Such condition can occur where there are *dead legs*; during periods when the building is shut down; when there is low or no occupancy; and during periods where portions of the *building water system* are not used. If these conditions occur, system flushing and other actions to return *microbial control* should be applied.

## E6 References

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## INFORMATIVE APPENDIX F—POTABLE AND PROCESS BUILDING WATER SYSTEMS GUIDANCE

***Informative Note:*** Recommendations and guidance on the design, maintenance, and operation of *building water systems* can be obtained from Informative Appendix B through Informative Appendix J, from ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated With Building Water Systems*, and through informative documents, such as those listed in Informative Appendix A, "Bibliography."

### F1 POTABLE WATER SYSTEMS

Characteristics of both hot and cold *potable water systems* influence *colonization* and subsequent *growth* of *microbial hazards*. Components of *potable water systems* that may transmit *microbial hazards* include, but are not limited to, showerheads, faucets, aerators, spray nozzles, ice machines, and water fountains.

Information and recommendations in this section apply to every portion of the hot and cold *potable water systems*, including all components, from intake to *taps*. Methods for limiting *microbial hazard growth* in *potable water systems* include:

a. keeping the system clean and free of sediment
b. controlling hot-water and cold-water temperatures
c. minimizing *water age* (the residence time of the water in the system)
d. maintaining a *disinfectant residual*

Cases of illness and injury have been linked definitively to both hot and cold *potable water systems* in many types of facilities.

Additional information and guidance to address *microbial hazards* in *potable building water systems* can be found in ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated with Building Water Systems*, including, but not limited to:

**Section 4, "Legionellosis and *Legionella*"**

1. Infection and Disease
2. *Legionella*
   a. Habitats
   b. *Legionella* in Building Water Systems

**Section 5, "Potable Water Systems"**

1. System Description
2. System Design/Engineering, Installation, Commissioning
   a. Piping system design
   b. Plumbing component design, selection, installation, and other considerations
   c. Competing objectives
3. *Legionella* Control Measures
   a. Temperature control
   b. *Supplemental disinfection*
   c. Physical barriers
   d. Routine flushing
   e. Hot water recirculation
   f. Routine cleaning and maintenance
4. Remedial Treatment

a. Chemical shock
b. Thermal shock

## F2 WHIRLPOOL SPAS

Apply the principles of guidance in ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated with Building Water Systems*, Section 7, "Heated Whirlpool Spas/Hot Tubs," to address *microbial hazards* in spas.

***Informative Note:*** Recommendations and guidance on the design, maintenance, and operation of *building water systems* can be obtained from Informative Appendix B through Informative Appendix J, from ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated With Building Water Systems*, and through informative documents, such as those listed in Informative Appendix A, "Bibliography."

**F2.1** Consider application of *disinfectants* to whirlpool spas utilized in temporary settings or display units to avoid the potential *growth* and *transmission* of *microbial hazards*.

## F3 ORNAMENTAL FOUNTAINS AND OTHER WATER FEATURES

Apply the principles of guidance in ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated with Building Water Systems*, Section 6, "Ornamental Water Features," to address *microbial hazards* in ornamental water features.

***Informative Note:*** Recommendations and guidance on the design, maintenance, and operation of *building water systems* can be obtained from Informative Appendix B through Informative Appendix J, from ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated With Building Water Systems*, and through informative documents, such as those listed in Informative Appendix A, "Bibliography."

## F4 AEROSOL-GENERATING MISTERS, ATOMIZERS, AIR WASHERS, AND HUMIDIFIERS

Apply the principles of guidance in ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated with Building Water Systems*, Section 9, "Direct Evaporative Air Coolers, Misters (Atomizers), Air Washers, and Humidifiers," to address *microbial hazards* in direct evaporative air coolers, misters (atomizers), air washers, and *humidifiers*.

***Informative Note:*** Recommendations and guidance on the design, maintenance, and operation of *building water systems* can be obtained from Informative Appendix B through Informative Appendix J, from ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated With Building Water Systems*, and through informative documents, such as those listed in Informative Appendix A, "Bibliography."

## F5 INDIRECT EVAPORATIVE AIR COOLERS

Apply the principles of guidance in ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated with Building Water Systems*, Section 10, "Indirect Evaporative Air Coolers," to address *microbial hazards* in indirect evaporative air coolers.

***Informative Note:*** Recommendations and guidance on the design, maintenance, and operation of *building water systems* can be obtained from Informative Appendix B through Informative Appendix J, from ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated With Building Water Systems*, and through informative documents, such as those listed in Informative Appendix A, "Bibliography."

## F6 IRRIGATION SYSTEMS

This section describes guidance for *irrigation systems*. The document specifying this guidance for a specific facility should include identification of the responsible persons for every step of each requirement listed below for *irrigation systems*.

***Informative Note:*** Recommendations and guidance on the design, maintenance, and operation of *building water systems* can be obtained from Informative Appendix B through Informative Appendix J, from ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated With Building Water Systems*, and through informative documents, such as those listed in Informative Appendix A, "Bibliography."

**F6.1 Irrigation System Type.** The documents should include procedures for identifying the type of *irrigation*

*system*.

**F6.2 Source Water.** The documents should include procedures for all potential sources of water for the *irrigation systems*, including, but not limited to:

a. *potable water*
b. alternate water sources

**F6.3 Irrigation System Design.** The documents should include:

a. instructions for how to adjust *irrigation system* frequency of operation
b. confirmation that there is *backflow* prevention from the *irrigation system* to other water systems and comply with the requirements defined by the *AHJ*
c. procedures for minimizing the opportunity for water to stagnate in the *irrigation system* beyond the number of idle days specified, including those *irrigation systems* utilizing controls and sensors to conserve water and prevent overwatering

**F6.4 Irrigation System Siting.** Prior to beginning construction for installation of new, replacement, or temporary *irrigation systems*, *construction documents* should be reviewed, and the following items addressed:

a. the potential for contamination from source water, building systems, facility processes, or other sources
b. potential for *aerosols* from the *irrigation system* to discharge into occupied spaces, trafficable areas, pedestrian thoroughfares, outdoor air intakes, and building openings
c. access to sprinklers, spray nozzles, pumps, valves, and other *irrigation system* equipment for maintenance and inspection
d. the potential for external heat sources, such as sunlight and ambient heat, which may cause water temperatures favorable for *microbial growth*

**F6.5 New System Start-Up.** The documents should have procedures for cleaning that is required when commissioning the *irrigation system*.

**F6.6 Irrigation System Maintenance.** The documents should include procedures for:

a. a maintenance schedule and instructions for maintaining the *irrigation system* and any other associated equipment and components
b. maintenance procedure documentation, inspection documentation, and *corrective actions*

**F6.7 System Shutdown and Start-Up.** The documents should include procedures for:

a. *irrigation system shutdown*, including any required chemical pretreatment or pump cycling, and procedures for shutdown periods that exceed the number of idle days specified
b. *irrigation system* start-up from a drained condition
c. *irrigation system* start-up from an undrained or stagnant condition that exceeds the number of idle days specified

**F6.8 Contingency Response Plan.** The documents should include:

a. procedures to be followed if there are known or suspected cases of *Legionellosis* associated with the use of potable or reclaimed water from the *building water systems*
b. directives issued by national, regional, and local health department authorities
c. if *microbial testing* is to be performed, the procedures and criteria for when and where the tests are to be performed
d. procedures for emergency flushing
e. procedures for other actions as identified to prevent exposure to contaminated water

## F7 CAR WASHES

The *Program shall* comply with the requirements of Section 7.5, "Aerosol-Generating Misters, Atomizers, Air Washers, and Humidifiers" in ANSI/ASHRAE Standard 188, *Legionellosis: Risk Management for Building Water Systems*.

***Informative Note:*** Recommendations and guidance on the design, maintenance, and operation of *building water systems* can be obtained from Informative Appendix B through Informative Appendix J, from ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated With Building Water Systems*, and through informative documents, such as those listed in Informative Appendix A, "Bibliography."

## F8 ULTRAPURE AND HIGH-PURITY WATER SYSTEMS

***Informative Note:*** Recommendations and guidance on the design, maintenance, and operation of *building water systems* can be obtained from Informative Appendix B through Informative Appendix J, from ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated With Building Water Systems*, and through informative documents, such as those listed in Informative Appendix A, "Bibliography."

**F8.1 System Identification and Description.** Documents for these systems should include:

a. the name, location, and purpose of all ultrapure and high-purity water systems
b. the location of *backflow* prevention devices used to prevent *intrusion* between ultrapure and high-purity water and water in other *building water systems*
c. the type of *disinfectant* (if any)
d. a list of the intended purposes of the ultrapure and high-purity water (UHPW) and the steps to be taken to prevent UHPW use for other purposes

**F8.2 Source Water.** Documents should include procedures for:

a. using *potable water* as system source water
b. if applicable, using alternate water sources as system source water
c. *control measures* to *control microbial growth* within ultrapure systems (e.g., chemical or steam *disinfection*, ultrafiltration, ozonation, flushing)

**F8.3 System Design.** Documents should include procedures for:

a. maintaining water quality throughout the system
b. providing *backflow* prevention to other water systems

**F8.4 System Maintenance.** Documents should include the following:

a. a maintenance and inspection schedule for each ultrapure water system and any associated equipment and components
b. procedures for removal of scale and other *contaminants*
c. procedures for maintaining established levels of chemicals following any RO or filtration units
d. procedures for maintaining established water velocities in the distribution system
e. procedures for the collection and maintenance of records on system maintenance, inspections, and *corrective actions*

**F8.5 System Shutdown and Start-Up.** Documents should include procedures for:

a. system shutdown and start-up, and procedures for shutdown periods that exceed the established number of idle days
b. system start-up from a drained condition
c. system start-up from an undrained or stagnant condition that exceeds the established number of idle days

**F8.6 Contingency Response Plan.** Documents should include the following:

a. procedures to be followed if there are known or suspected cases of disease associated with the use of potable or reclaimed water from the *building water systems*
b. directives issued by national, regional, and local health department authorities
c. procedures to be followed if *microbial testing* is to be performed. The procedures should include criteria for when and where the tests should be performed
d. procedures for emergency *disinfection*

e. procedures for other actions as identified to prevent exposure to contaminated water

## F9 SYSTEMS FOR COLLECTING OR RECYCLING BLACKWATER, GRAYWATER, AND RAINWATER WATER FOR NONPOTABLE USE (BGR)

This section provides guidance for systems that collect or recycle water for *nonpotable* use.

***Informative Note:*** Recommendations and guidance on the design, maintenance, and operation of *building water systems* can be obtained from Informative Appendix B through Informative Appendix J, from ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated With Building Water Systems*, and through informative documents, such as those listed in Informative Appendix A, "Bibliography."

**F9.1 System Identification.** Documents should be maintained to include:

a. the name, water source, purpose, and location of each *water use end point*, and the *control measures* used to treat all *BGR* systems
b. a list of the intended purposes of *BGR* use and the steps to be taken to prevent *BGR* use for other purposes, including preventing use for human consumption or exposure
c. identification of *BGR* system water piping labeling. Piping should be labeled to identify the *BGR* water contained and should comply with the requirements of the *AHJ*

**F9.2 Water Treatment.** Documents should be maintained to include:

a. procedures for maintaining *BGR* systems in accordance with state and local regulatory requirements
b. procedures, where applicable, for achieving and maintaining the established minimum treatment *control measures* for the reduction of exposure to *microbial*, chemical, and physical *hazards* in *BGR* systems
c. procedures for validating each *BGR* system treatment process

**F9.3 Monitoring.** Documents should be maintained to include procedures for:

a. *monitoring BGR* systems in accordance with state and local regulatory requirements
b. performing water quality *testing* following the guidance contained in Informative Appendix B, "Guidance if Microbial Testing is Utilized in the Absence of Suspected or Confirmed Facility-Associated Disease"
c. *monitoring BGR* flow rate, temperature, and treatment parameters
d. *monitoring* water quality parameters required by permits. In the absence of requirements, water quality parameters should be monitored at a frequency based on how the water is used.

**F9.4 System Design.** Documents should be maintained to include procedures for:

a. maintaining and inspecting all connections to the *potable water system*. A connection to the *potable water* supply should not be used as a backup or supplemental water source for a *BGR* system unless the connection between all systems is protected by an air gap or *backflow* prevention device
b. maintaining and inspecting all connections to the sewer. Sewer connections should be separated by an air gap or other *backflow* prevention device
c. conducting a *cross-connection* evaluation. The *cross-connection* evaluation should be completed prior to operation of the system and at intervals thereafter as required by the state or local agency and at least annually. All *cross-connection testing* should be conducted in accordance with the requirements of the *AHJ*
d. documenting any replacement, repair, refurbishment, or changes in *BGR* systems and equipment

**F9.5 User Guidance.** Documents should be maintained to include procedures for:

a. posting signage in all areas where *BGR* systems are accessible to personnel. The signage should describe the site-specific *risk* of *BGR* systems
b. controlling *BGR* system water to a rate that does not result in ponding or pooling, or causing runoff, other than incidental runoff, across property lines, or on to any paved surface when used for purposes such as irrigation or dust suppression

c. preventing *BGR* system water from entering a municipal storm water drainage system or other water system, unless allowed by the *AHJ* and in compliance with the Clean Water Act
d. minimizing public exposure when *BGR* system water is used for irrigation

## F10 OTHER BUILDING WATER SYSTEMS WHERE MICROBIAL HAZARDS MAY GROW

In the absence of *control*, *microbial hazards* can *grow* in almost any system or equipment containing non-sterile water at temperatures conducive to *microbial hazard growth* (See Informative Appendix E, "Building Water System Microbial Hazards Guidance" and ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated With Building Water Systems*). When establishing a *water management program*, particularly where *at-risk individuals* may be exposed, evaluate all building systems and equipment that contain or utilize water, to determine under whether their conditions of use or disuse may result in *growth* and *transmission* of *microbial hazards*. The following are examples of systems and other locations where *microbial hazards* may *grow*:

1. Storage and use of recycled water (*gray water*, etc.)
2. Collection, storage, and use of *rainwater*
3. Storage and use of ground water
4. Storage of water to supplement high demand or for emergency use
5. Solar water heating systems
6. Examples of other locations where *microbial hazards* may *grow*:
   a. Undrained water hoses, including hoses used for fire suppression
   b. Machine and metal working lubrication and coolant systems
   c. Safety showers and eyewash stations
   d. Spray washers
   e. Dental water units, including ultrasonic water scalers
   f. Medical devices, such as CPAP machines, bronchoscopes, heater-cooler units
   g. Ice machines

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## INFORMATIVE APPENDIX G—BUILDING DESIGNER GUIDANCE

### G1 Overview

Section 7, "Requirements for Designing and Documenting Building Water Systems," contains the minimum building designer requirements for designing and documenting *building water systems*. This informative appendix provides guidance to help the design team develop specifications and designs that reduce the potential for illness and injury from physical, chemical, and *microbial hazards* associated with all *building water systems* and associated devices, and to comply with the requirements of Section 7.

The design team should consult with the building *owner* during design review to determine if the *building water systems* meet the requirements of Section 4, "Compliance." When the design falls within the requirements of Section 4.2, "Building Owner Requirements," the building *owner* should have or should establish a *Program Team* that complies with the requirements of Section 5, "General Requirements." For healthcare facilities that fall within the requirements of Section 4.3, "Healthcare Facility Requirements," the building *owner* should have or should establish a *Designated Team* that complies with the requirements of Section 8, "Requirements for Healthcare Facilities." If the *Program Team* or *Design Team* has not previously established the guidance necessary to comply with this standard and the building *water management program* and to inform the *building water systems* design, it should be established through interaction with the building design team for the project. This interaction should improve *building water system* design performance by collecting and integrating available design requirements and factors into the design from project inception.

In the absence of a building water *Program Team* or *Designated Team*, the additional background and guidance within this appendix should stimulate additional conversations with the building *owner*, or the *owner's designee*, to inform the design decision making process.

### G2 Pre-Design Consultation

The building designer should consult with the building *owner* or their *designee* to determine and document the following:

a. Is there an existing *water management Program Team* or *Designated Team*?
b. Does the building *owner* or *designee* want the designer to work with the *Program Team* or *Designated Team* in the design of the *building water systems*?
c. If there is no *Program Team* or *Designated Team*, the designer should recommend that the building *owner* should comply with the requirements of Section 4, "Compliance."
d. The designer should obtain and document the following information from the *Program Team*, the *Designated Team*, the building *owner*, or their *designee*, if it has not already been provided:
    1. The intended use and operating schedule of the building and associated areas
        i. Is uninterrupted water supply required?
    2. Is on-site *supplemental disinfection* or other water treatment intended? If yes, define.
    3. Routine hot water control temperatures (for storage type heaters) to *control microbial growth*:
        i. Are water temperature *control* strategies above 140°F (60°C) at the outlet of the water heater intended? If yes, define.
        ii. Are water temperature *control* strategies above 120°F (49°C) at the end of hot water recirculation runs intended? If yes, define.
        iii. Are there provisions or policies on how to address *scalding risks*? If yes, define.
    4. Measures to address *water age*:
        i. Is automatic flushing intended? If yes, provide schedule.
        ii. Is there an established maximum *dead leg* volume or length? If yes, define.

iii. Is there an established maximum time for hot water delivery to fixtures? If yes, define.

iv. Is the design to include *building water system* provisions for future expansion? If yes, define.

v. Are there redundancy requirements for *building water system* equipment or storage? If yes, define.

vi. Are there established minimum and maximum lavatory faucet or other fixture flow rates? If yes, define.

vii. Are sensor operated (metering) faucets to be used? If specific types or models, define.

viii. Are there established fixture spray patterns (to determine if they create *aerosols*)? If yes, define.

5. Mitigation and emergency response measures:

i. Are there established *microbial hazard* mitigation response measures for either or both the cold and hot *building water systems*? If yes, define.

ii. If the capability for using high-temperature water for *remedial treatment* is intended, the designer should advise the building *owner* that the use of high-temperature water for *remedial treatment* carries significant *risks*, including *scalding* and increased levels of *microbial colonization*. The designer should also advise the building *owner* that the *CDC*, ASHRAE Guideline 12, and some *AHJs* recommend against the use of high-temperature water for use as a *remedial treatment*. If the use of high-temperature water for *remedial treatment* is intended, define (e.g., temperature, duration, and flow rate).

iii. Is *monitoring* incoming water parameters intended? If yes, define.

iv. Is automatic emergency shutdown of the primary water source desired (only recommended if the facility has a secondary water source)? If yes, define the emergency shutdown conditions (such as when a water *main* breaks).

6. Other information the designer should obtain and document from the *Program Team*, the *Designated Team*, the building *owner* or *designee*, if it has not already been provided:

i. Is the building intended to achieve any energy or water conservation goals? If yes, define.

## G3 Potable Building Water System Design

*Potable building water system* design is an integral part of building design. Professional plumbing engineers are trained and experienced in this field and there are numerous publications, such as the ASPE *Plumbing Engineering Design Handbook Volumes 1 and 2*, and the ASPE *Domestic Water Heating Design Manual*. The following guidance is intended to supplement existing *building water system* design decisions and to manage the *risk* from physical, chemical, and *microbial hazards*:

a. **Physical, Chemical, and Microbial Hazard Risk Management Design Guidance Documents**

1. The primary physical *hazard* to be addressed is high water temperature at *water use end points* that can *scald*. Informative information on *scalding* can be found in Informative Appendix C, "Building Water System Physical Hazards Guidance," and in ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated with Building Water Systems*, Section 5, "Potable Water Systems."

2. Managing the *risk* of chemical *hazards* from *potable building water systems* can be quite complex. Chemicals, metals, and toxic compounds in *potable water* can come from numerous sources, such as from the water provided to the building from the *water utility*, from the inner surfaces of pipes and other plumbing components through corrosion or leaching, and if *supplemental disinfection* is applied, from those *disinfectants* and from the resulting *disinfection* byproducts. Informative information on chemical *hazards* can be found in Informative Appendix D, "Building Water System Chemical Hazards Guidance," and in ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated with Building Water Systems*, Section 5, "Potable Water Systems."

3. Managing the *risk* of *microbial hazards* from *potable building water systems* is quite complex. Numerous *microbial hazards* can be contained in *potable building water systems*; however, the same design elements applied to manage the *risk* of *Legionella* will typically address most other *microbial hazards*. Informative information on *microbial hazards* can be found in Informative Appendix E, "Building Water System Microbial Hazards Guidance," and in ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated with Building Water Systems*, Section 4, "Legionellosis and *Legionella*." Guidance that directly addresses managing the *risk* from *Legionella* in *potable building*

*water systems* can be found in ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated with Building Water Systems*, Section 5, "Potable Water Systems."

b. **Potable Building Water System Design Elements.** The designer should use the information from the building, the building site, and the building use or intended use and the pre-design consultation to establish the *potable building water system* design elements. In the absence of contrary design information, consider the design guidance and elements for *potable building water systems* contained in ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated with Building Water Systems*, Section 5, "Potable Water Systems," Informative Appendix C, "Building Water System Physical Hazards Guidance," Informative Appendix D, "Building Water System Chemical Hazards Guidance," Informative Appendix E, "Building Water System Microbial Hazards Guidance," and Informative Appendix F, "Potable and Process Building Water Systems Guidance," and should include the following design guidance and elements:

1. Both hot and cold *potable building water systems*
    i. Consider provisions to maintain the *building water systems* physical parameters (such as pH, temperature, chemical compositions, hardness, etc.) within the intended ranges to support the intended *disinfectant*(*s*) efficacy.
    ii. If *supplemental disinfection* is not included in the building specifications, consider the addition of provisions to address future needs.
    iii. If a water softener is not included in the building specifications, and the building is located in an area of known hard water, consider the addition of provisions to address future needs.
    iv. For more than one or redundant equipment, provide a suggested automatic or manual rotation procedure and schedule and consider whether signage is needed.
    v. Hot- and cold-water pipes should be routed, sized, and designed to minimize or eliminate *dead legs* and to facilitate routine flushing.
    vi. Where *dead legs* cannot be eliminated, a means for flushing is recommended.
    vii. A means for flushing is recommended for the ends of piping lines.
    viii. Use of pass through connections to promote flow through branches to infrequently used fixtures is recommended.
    ix. Shut-off valves for future branches should be located no more than five times the branch pipe diameter away from the *building water system main* to which it is connected.
    x. Normally closed branches (such as a bypass) should be provided with a drain and shut-off valves on each end.
    xi. Wherever there is need for flushing, consider incorporating automatic flushing capability.
    xii. Hot- and cold-water pipes, tanks, and equipment should be located and routed and/or insulated to help keep water from cooling or warming into a temperature range that supports *microbial growth*.
    xiii. Reducing the *risk* of hot- and cold-water system *cross-connections*, such as by adding check valves to fixtures or by using fixtures or angle stops with built-in check valves is recommended.
    xiv. Minimize water volume of infrequently used branches (such as fire protection systems) between their *backflow* preventers and circulated *mains*.
2. Cold water system
    i. Means for *monitoring* cold water temperatures, such as temperature sensing devices, should be located near the point where water from the *water utility* enters the building, in cold water storage tanks, and at the most distant points of the cold water sub-*main* on each floor.
3. Hot water system
    i. Means for *monitoring* hot water temperatures, such as temperature sensing devices, should be located in the piping at the following locations:
        - at the water heater outlet
        - at the master temperature actuated mixing valve outlet
        - in the hot-water return lines before connection to the cold-water line to the water heater, or the hot-water return line just before connecting to the hot water storage tank(s)

- at each hot-water return balancing valve

ii. Confirm the water heater(s) have sufficient output capacity and temperature capability to maintain a minimum temperature throughout the hot *building water system*, including hot-water return, of 120°F (49°C). To maintain a minimum of 120°F (49°C) usually requires the system to be designed and adjusted to a target minimum water temperature of 124°F (51°C) or higher.

iii. Water at handwashing *end use points* should utilize thermostatic mixing valves to reduce water temperature below 120°F (49°C).

iv. The volume of water that is lower than 120°F (49°C), such as downstream of thermostatic mixing valves, at all *water use end points* should be minimized.

v. If the building *owner* accepts responsibility, potentially adverse consequences for high temperature water remediation, the following should be considered:

- Note and record the positions and temperatures of thermal balancing valves and thermostatic mixing valves that must be readjusted to their proper positions and temperatures after high temperature *remedial treatment*.
- Systems with thermostatic mixing valves may require a bypass or adjustment to allow delivery of the water temperatures used for high temperature *remedial treatment*.
- Systems with thermostatic balancing valves may require a bypass or adjustment to allow delivery of the water temperatures used for high temperature *remedial treatment*.
- All equipment, piping materials, and their attachment and support means should be rated for the peak water temperature at peak building water pressure and for the resulting thermal expansion for the duration of the high temperature *remedial treatment*.
- Water heater and hot water storage should be calculated to be adequate to maintain the necessary temperature and flow at the intended number of simultaneous *water use end points*. The calculation should consider all heat loss during high temperature *remedial treatment*, including heat loss from the water heater outlet to the *water use end points*. A typical high temperature *remedial treatment* protocol for hot *building water system*-wide treatment for *microbial hazards* require maintaining enough flow through *water use end points* to maintain water temperature at or above 158°F (70°C) for twenty minutes at all fixtures simultaneously being *remedially treated*.

### G4 Nonpotable Building Water System Design

*Nonpotable building water system* design is an integral part of building design. The principal *risk* to be managed for *nonpotable building water system* is *microbial* and the primary *microbial risk* to be addressed by design is *Legionella*. Informative guidance on *microbial hazards* can be found in Informative Appendix E, "Building Water System Microbial Hazards Guidance," and in ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated with Building Water Systems*, Section 4, "Legionellosis and *Legionella*." Guidance that directly addresses managing the *risk* from *Legionella* in *nonpotable building water systems* can be found in ASHRAE Guideline 12, *Managing the Risk of Legionellosis Associated with Building Water Systems*, Section 6, "Ornamental Water Features," Section 7, "Heated Whirlpool Spas/Hot Tubs," Section 8, "Open-Circuit Cooling Towers, Closed-Circuit Cooling Towers, and Evaporative Condensers," Section 9, "Direct Evaporative Air Coolers, Misters (Atomizers), Air Washers, and Humidifiers," Section 10, "Indirect Evaporative Air Coolers," Section 11, "Cooling Coils and Condensate Collection," and Section 12, "Other Building Water Systems Where *Legionella* May Grow," and in Informative Appendix F, "Potable and Process Building Water Systems Guidance," Sections F2 through F10.

### G5 Other Building Water System Design Guidance

To provide a successful *building water system* design, additional information may be needed to address the variety of building *owner* requirements, building occupants, occupant use, occupancy levels, seasonal use patterns, quality, and variability of water supplied by the *water utility*, and other variables. Some or all of the following information may be useful in designing a successful *building water system*:

a. water supplied by the *water utility*

1. service line piping materials and size, and distance from circulated *main*
2. nearby fire protection laterals' (if they share the same *main*) sizes and distance from the circulated *main* to the *backflow* preventer
3. distribution piping materials and size
4. meter type and size
5. service line pressure
6. service line temperature
7. water composition, including *turbidity*, *microbial* content, and chemical content, including the *disinfectant residual*

**G6 Balancing**

All *building water systems* should be balanced. Procedures for the following temperature and flow *verification* should be included in the balancing instructions and should be provided to the building *owner* or *designee*. If water balancing is required by either the specification or the *AHJ*, a balance report for all water systems should be provided to the building *owner* or *designee*.

**G7 Commissioning Procedures**

*Potable water systems* and many *nonpotable* water systems are overlooked in the commissioning of *building water systems* unless they are directly related to the *HVAC* or mechanical systems that they may be serving. The requirements of Section 7.4, "Commissioning Procedures," apply to all *building water systems*, including the hot and cold *potable water system*. Section 7.4 contains the minimum compliance requirements; however, there may be additional areas, based on the nature of the design, that the designer, the *Program Team*, the *Designated Team*, the building *owner*, or the *designee* may deem important, and that may require additions to the commissioning documents. A third-party commissioning professional should be included during the design process to assist in developing a successful commissioning program.

All procedures, tasks, and instructions developed for commissioning the *building water systems* to confirm that they are operating as designed should be provided to the building *owner* or *designee*.

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## INFORMATIVE APPENDIX H—HEALTHCARE FACILITY GUIDANCE

***Note to Reviewers:*** This informative appendix is reserved for future informative guidance for healthcare facilities.

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## INFORMATIVE APPENDIX I—GUIDANCE FOR U.S. REGULATIONS ON DRINKING WATER TREATMENT AND ON CHEMICALS USED FOR POTABLE AND NONPOTABLE WATER TREATMENT

### Safe Drinking Water Act (SDWA)

The Safe Drinking Water Act (SDWA) applies to drinking water in the United States. Building *owners* who are considering treatment of the building's *potable water* should consult with the authority having primary responsibility for drinking water regulations (primacy agency) to determine any federal, state, or local regulations that may apply before any treatment is implemented. Additional information is available from EPA by contacting the appropriate EPA regional office; by calling the EPA Drinking Water Hotline at 1-800-426-4791; by email at safewater@epa.gov; and at the EPA's Safe Drinking Water Act (SDWA) website. A list of Safe Drinking Water Act primacy agencies can be found at the Sustainable Infrastructure Management Program Learning Environment (SIMPLE) website on the "Safe Drinking Water Act Primacy Agencies" webpage.

### Federal Insecticide, Fungicide and Rodenticide Act (FIFRA)

All pesticides (including antimicrobials used to treat *potable* and *nonpotable water*) distributed or sold in the United States must be registered (licensed) by EPA under *FIFRA*. Registered pesticides are required to be properly labeled and must be used in accordance with their approved labeling.

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## INFORMATIVE APPENDIX J—GUIDANCE ON PERSONAL PROTECTIVE EQUIPMENT FOR USE WHEN THERE IS POTENTIAL FOR EXPOSURE TO CONTAMINATED AEROSOLS

The United States Occupational Safety and Health Administration (*OSHA*) requirements described in this appendix are unique to the United States; however, other countries may have similar applicable local, regional, or national requirements. In the absence of such requirements, complying with the *OSHA* requirements is recommended.

*OSHA* has not established permissible exposure limits for *Legionella*. However, the "Control and Prevention" element of the *OSHA* Safety and Health Topic "Legionellosis: (Legionnaires' disease and Pontiac Fever)" webpage provides best practices and other requirements for the use of personal protective equipment (PPE) when performing routine work on *building* hot and cold *potable water systems* and components, such as water heaters, faucets, showers, cooling towers, *humidifiers*, evaporative coolers, and spas that may be contaminated with *Legionella*.[1] The "Hazard Recognition" element of the *OSHA* Safety and Health Topic "Legionellosis (Legionnaires' disease and Pontiac Fever)" webpage states that if a *legionellosis outbreak* exists in a workplace when confirmed *legionellosis* cases are associated with a common exposure, workers performing water system sampling must wear appropriate PPE as described on the Control and Prevention webpage.[2] Local regulations may require the use of PPE when there is potential for exposure to *contaminated aerosols*.

Individuals may voluntarily choose to wear respiratory protective equipment, even when not required. Although voluntary use of a respirator does not require the establishment and maintenance of a formal respiratory protection program, *OSHA* and other local regulatory bodies require that workers who voluntarily wear respirators be provided with information on their proper fitting and use.[3] A NIOSH[4] (The National Institute for Occupational Safety and Health) approved N95 or better respirator should be considered for protection against *Legionella*. A N95 respirator has 95% efficiency in removing particles 0.3 microns or larger. If chemical vapors are present in significant concentrations, a respirator with a filter for both particulates and the chemicals being used should be selected.

If an *outbreak* of *legionellosis* has been identified and there is a significant potential for exposure to high concentrations of contaminated *aerosol*, *OSHA* requires that investigators wear appropriate respiratory protection during investigation of the *building water systems*.[3] A half-face piece respirator equipped with a High Efficiency Particulate Air (HEPA) filter certified by the Mine Safety and Health Administration (MSHA) or a similar type of filter media capable of effectively collecting particles in the one micron size range is considered appropriate respiratory protection under these conditions. When respirator use is required, rather than voluntary, the employer must satisfy all of the requirements of both the "Control and Prevention" and "Hazard Recognition" elements of the *OSHA* Safety and Health Topic "Legionellosis (Legionnaires' disease and Pontiac Fever)" webpage and the *OSHA* respiratory protection requirements of CFR 29, subpart I, standard number 1910.134, including a formal written respiratory protection program, medical evaluation, fit *testing*, and training[1,2,3].

Workers can be at increased potential for exposure to airborne *bacteria* when cleaning water systems, especially when cleaning in enclosed spaces. *Legionella bacteria* may be located in *biofilms* attached to wetted surfaces. Power washing and other cleaning activities may cause *biofilm* to become airborne. Cleaning, repair, and maintenance should be performed in a way that minimizes the generation of *aerosols* and airborne debris.

Chemicals are often used to treat recirculating water. Safe handling of these chemicals may require the use of PPE. Follow all national, regional, and local guidelines for handling these chemicals. Additional PPE, such as gloves, goggles, and chemical resistant clothing or coverings may be appropriate when treating water systems.

**References:**

1. OSHA. *Legionellosis (Legionnaires' disease and Pontiac Fever) – Control and Prevention*. Washington, D.C.: Occupational Safety and Health Administration. https://www.osha.gov/legionnaires-disease/control-prevention.

2. OSHA. *Legionellosis (Legionnaires' disease and Pontiac Fever) – Hazard Recognition*. Washington, D.C.: Occupational Safety and Health Administration. https://www.osha.gov/legionnaires-disease/hazards.

3. OSHA. Code of Federal Regulations, *Title 29 CFR 1910 Subpart I, "Personal Protective Equipment," – standard number 1910.134, "Respiratory Protection."* Washington, D.C.: Occupational Safety and Health Administration.

4. CDC. 2020. The National Personal Protective Technology Laboratory (NPPTL), *NIOSH-Approved Particulate Filtering Facepiece Respirators*. Atlanta, GA: Centers for Disease Control and Prevention.