BRITISH COLUMBIA GUIDELINES (MICROBIOLOGICAL) ON MAINTAINING WATER QUALITY IN DISTRIBUTION SYSTEMS

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CONTENTS

1. OVERVIEW

Distribution systems are at risk of breaches in system integrity that could negatively impact the microbiological quality of the potable water. Water suppliers should focus on prevention and use a multi-barrier approach to protecting the water as it travels through the distribution system from the source/treatment facility to the consumer.

The best risk management practice (BMP) of maintaining a disinfectant residual in the drinking water as it travels through the distribution system is often referred to as “secondary disinfection” or “residual disinfection.” It is an important BMP that is strongly recommended for most systems due its unique ability to help the water supplier respond quickly to potential incidents of water quality degradation and its ability to control the growth of microorganisms. Drinking water officers and other issuing officials may require water suppliers to use secondary disinfection for distribution systems that are at risk for pathogen contamination and/or significant microbial growth.

1.1 OBJECTIVE

To provide provincial guidance to drinking water officers and water suppliers for making decisions related to implementing the multi-barrier approach to protecting and maintaining microbiological water quality in water supply distribution systems. This includes specific guidance for implementing the best risk management practice of secondary disinfection.

1.2 REGULATORY FRAMEWORK

Potable water is defined under section 1 of the *Drinking Water Protection Act* as water that is “safe to drink and fit for domestic purposes without further treatment.” Further to this, section 6 of the act requires potable water from the water supply system. The definition of a water supply system in the act includes the distribution system, which is the portion of the water supply system used to convey potable water from the treatment plant or source to the users served by the system. This means potability must be maintained, in accordance with section 6 of the act, as water travels through the distribution system to system users.

The use of disinfectants in the distribution system (secondary disinfection) is an industry practice to maintain the microbiological quality of the potable water because potable water in distribution systems is vulnerable to degradation and contamination (see Section 2.1 of this document). This practice is independent of the primary disinfection requirements based on source water quality as outlined in section 5(2) of the Drinking Water Protection Regulation, which requires a water supplier to disinfect water originating from a surface source or a ground water source that is at risk of containing pathogens.

The act and regulation give drinking water officers the flexibility and discretion to address public health risks. They do this on a case-by-case basis using available system-specific information (e.g., system records, source-to-tap risk assessment and documentation from qualified professionals).

A drinking water officer may request, require as a condition on the operating permit, or order a water supplier to use specific risk management practices, including the addition of a secondary disinfectant, to protect potable water as it travels through the distribution system.

1.3 PURPOSE AND SCOPE

This document provides general guidelines on using a preventative, multi-barrier approach to maintaining potable water in the water supply distribution system and includes specific guidance on the use of the best risk management practice of secondary disinfection. The guidelines are consistent with the act, regulation and *Guidelines for Canadian Drinking Water Quality* (Health Canada, 2012a).

This document does not address primary disinfection (i.e., "the application of a disinfectant in the drinking water treatment plant, with a primary objective to achieve the necessary microbial inactivation" (Health Canada, 2009a)). With respect to primary disinfection, the guidelines are based on the assumption that systems are in compliance with the act, regulation, policy, and any conditions on the operating permit. See Appendix A for further resources about these and other issues.

This document does not provide guidelines on water supply systems exempt from section 6 of the *Drinking Water Protection Act* (see section 3.1 of the Drinking Water Protection Regulation concerning non-potable water, and point-of-entry and point-of-use water supply systems).

Site-specific conditions may warrant a flexible approach to maintaining water quality in the distribution system. Such an approach should incorporate these guidelines in conjunction with a risk assessment of individual cases in collaboration with the drinking water officer.

2. BACKGROUND

2.1 FACTORS AFFECTING MICROBIOLOGICAL WATER QUALITY IN DISTRIBUTION SYSTEMS

The purpose of the distribution system is to convey potable water from the treatment plant or source (if treatment is not required) to the consumer. Potable water is a "perishable product" that is at risk of degradation and contamination as it travels through the distribution system. Degradation and contamination in the distribution system can affect the aesthetic quality of drinking water, as well as its safety if the water is at risk of contamination or regrowth/growth of pathogenic microorganisms (e.g., bacteria, protozoa and viruses).

Several factors can impact or degrade microbiological water quality in the distribution system:

- Biological stability of the water.
- Conditions in the distribution system.
- Formation of biofilms.
- Contamination from outside the distribution system.

These risk factors can be threats to public health as demonstrated by documented outbreaks associated with distribution systems (Hrudey and Hrudey, 2004; Payment and Robertson, 2004; Wilson et al., 2009). The following sections provide further detail on these factors.

2.1.1 BIOLOGICAL STABILITY OF THE WATER

The potable water entering the distribution system is not sterile; it typically contains microscopic particles, nutrients, and live and inactivated microorganisms (Liu, Verberk and Van Dijk, 2013). The composition and quantity of this material in the water distribution system depends on the source water quality characteristics, technology used for disinfection and/or treatment, and storage conditions. The material often includes biologically available nutrients that support the growth and multiplication of bacteria and biofilm (see section 2.1.3), which increases the risk of degradation of the microbiological water quality (Ashbolt, 2015; LeChevallier et al., 2015b). For example:

- Potable water produced from surface water sources and some high-risk ground water sources is highly likely to contain biodegradable organic matter that can contribute to significant bacterial growth, particularly if treatment does not have the ability to remove it (LeChevallier et al., 2015b).
- Water chemistry can also indicate a source of nutrients (e.g., a significant concentration of biologically available nitrogen and/or phosphorus) (Ashbolt, 2015).

Biologically stable water is potable water that is "at low risk of supporting significant bacterial growth" (Liu, Verberk and Van Dijk, 2013). In other words, the nutrient levels in the potable water are reduced and/or maintained at a level that significantly reduces the ability of the water to support growth.

2.1.2 CONDITIONS IN THE DISTRIBUTION SYSTEM

Most bacteria need specific conditions to multiply, such as: nutrients, dark spaces, warmth, moisture and time. Water distribution systems can have many of these conditions. System design and operational practices can have a limiting effect on conditions to limit microbiological growth and biofilm formation. For example, retention time is an important factor associated with growth. The longer water remains in the distribution system, the more opportunity there is for bacterial growth. Systems with many dead ends or systems that do not have a high turnover of water[1] are at risk for having stagnant zones in the distribution system that contain "old water," particularly if they do not practice regular flushing.

2.1.3 FORMATION OF BIOFILMS

The particles, nutrients and microorganisms in potable water (as discussed in section 2.1.1 of this document) can attach to surfaces in the distribution system within a slime layer to form unique microbiomes referred to as biofilm. Technically, biofilm is a complex mixture of microbes, and organic and inorganic material accumulated amidst a microbially produced organic polymer matrix, which is attached to the inner surface of the distribution system (USEPA, 2002b). Most of the microorganisms and biomass in the potable water in distribution systems exists as biofilms (LeChevallier et al., 2015a).

Biofilms can be associated with water quality deterioration. They can affect the aesthetic quality of drinking water by having a negative impact on the taste, smell and visual qualities of the drinking water. They can also cause physical damage to the distribution system by corroding the inner surface of metal pipes and blocking valves (American Academy of Microbiology, 2012; USEPA, 2002a).

Biofilms can have a negative impact on human health when they contain pathogenic organisms. Biofilms provide environments in which pathogens can survive and accumulate, and are associated with the proliferation of opportunistic pathogens such as *Legionella pneumophila* (American Academy of Microbiology, 2012; USEPA, 2002a). Whenever the biofilm is disturbed, there is potential for these pathogens to be released back into the water in high concentrations.

2.1.4 CONTAMINATION FROM OUTSIDE THE DISTRIBUTION SYSTEM

Under certain circumstances, contact between the potable water in the distribution system and outside influences can provide a means for pathogenic contamination. Table 1 shows some common means by which pathogens can enter the distribution system (FCM, 2003; Kirmeyer et al., 2001; USEPA, 2002a).

[1] Systems with low turnover may be too large for the number of system users (e.g., communities with declining population) or may need a large capacity for occasional use (e.g., communities with large fluctuations in population during the year due to seasonal tourism or seasonal workers, and communities that retain large quantities of water for fire suppression).

Once pathogens are introduced to the distribution system, favourable conditions (e.g., temperature and dead ends) may provide a suitable environment for bacterial growth and pathogen survival in biofilms (USEPA, 2002b).

TABLE 1: POTENTIAL SOURCES OF CONTAMINATION TO POTABLE WATER IN THE DISTRIBUTION SYSTEM FROM OUTSIDE SOURCES

Source of Contamination	Explanation
Treatment breakthrough	• Pathogens may escape treatment and enter the distribution system.
Potable water storage reservoirs	• Storage reservoirs can be susceptible to outside contamination if they are not adequately designed and/or maintained.
Cross connections and backflow	• A major contamination event can occur during negative pressure and backflow events.
Transient contamination	• Intrusions can occur via leaky pipes, valves, joints and seals if there is a negative pressure event.
Water main installation, breaks and repair	• The interior of pipes can be contaminated during installation and repair, particularly if appropriate steps (e.g., flushing and/or chlorination) are not taken to decrease risk before, during and after construction.

3. GUIDELINES

Water suppliers should focus on prevention and take a multi-barrier approach to protecting the microbiological water quality in the distribution system (see section 3.1). The water supplier should use the information gleaned from a source-to-tap risk assessment to determine any system-specific factors (e.g., the design and installation of system components (see Appendix B) and the biological stability of the potable water) that could negatively impact the ability of the distribution system to protect the microbiological quality of the potable water. The water supplier should, in conjunction with the drinking water officer, use this information to determine the most appropriate combination of best risk management practices (BMPs) to implement, based on the system-specific risks.

From a public health perspective, the BMP of secondary disinfection is strongly recommended in most circumstances due its unique ability to help the water supplier respond quickly to potential incidents of water quality degradation and its ability to control the growth of microorganisms (see section 3.2).

The following sections provide information about the multi-barrier approach, and include specific guidance of the use of secondary disinfection as a component of the multi-barrier approach. Information about protective system-specific design elements and other BMPs can be found in other documents (see Appendix A and B). This guidance recommends water suppliers consult with a drinking water officer when conducting risk-management planning for their distribution systems.

3.1 THE MULTI-BARRIER APPROACH TO MAINTAINING WATER QUALITY IN THE DISTRIBUTION SYSTEM

The multi-barrier approach to safe drinking water involves implementing a series of integrated procedural and physical risk management practices throughout the water supply system. These practices work together to prevent or reduce the contamination of drinking water from source to tap in order to protect public health (Health Canada, 2002; Federal-Provincial-Territorial Committee on Drinking Water and CCME Water Quality Task Group, 2004).

A comprehensive multi-barrier system should have the ability to manage identified and unforeseen risks, and take action to minimize or prevent harm in the case of an event in which one or more of the risk management practices fail. This approach is considered the standard for protecting drinking water by the World Health Organization, Health Canada, and the Ministry of Health and regional health authorities in British Columbia.

There are several BMPs that, when used together, form a robust multi-barrier approach to protecting the drinking water as it travels through the distribution system. They include, but are not limited to:

- Employing knowledgeable certified (where applicable) operator(s), and ensuring their training is adequate and remains current.
- Operating system components as per good engineering and operational practices that include routine maintenance (Appendix B).
- Employing a cross-connection control program.

- Maintaining hydraulic integrity.
- Using secondary disinfection (FCM, 2003).
- Using an extensive distribution-system monitoring program.
- Maintaining comprehensive service-and-monitoring records to demonstrate due diligence.
- Implementing an asset management plan that includes a replacement and rehabilitation schedule.
- Creating and maintaining a comprehensive emergency response and contingency plan that includes a communication and risk assessment strategy to resolve issues with the distribution system.

The above BMPs aim to achieve the following goals:

- Promptly identify potential or actual risks, and take action to prevent or minimize harm to water users.
- Minimize biological growth and accumulation of other contaminants in the distribution system.
- Eliminate identified contamination of the drinking water from outside the distribution system network.
- Minimize harmful interactions between the drinking water and pipe material.

As no one BMP is capable of achieving all of the goals laid out above, a combination of BMPs is necessary, and should be tailored to a water supply system's particular needs, to protect drinking water as it travels through the distribution system.

3.2 OPERATING WITH SECONDARY DISINFECTION

3.2.1 WHAT IS SECONDARY DISINFECTION?

The BMP of maintaining a disinfectant in the drinking water as it travels through the distribution system is often referred to as "secondary disinfection" or "residual disinfection." It can be achieved by maintaining a residual of the primary disinfectant in the distribution system or by adding disinfectant to the distribution system.

Although this document uses the term "secondary disinfection," it pertains to both methods. Secondary disinfection differs from primary disinfection in that the concentration of disinfectant used will not necessarily be large enough, or have the necessary contact time, to deactivate pathogens to the extent needed to meet the definition of potability under section 6 of the act.

Not all disinfectants are capable of maintaining a residual as they degrade too quickly (e.g., ozone and chlorine dioxide), or do not produce a residual effect (e.g., ultraviolet light) (Health Canada, 2009b; Health Canada, 2012b). Currently, chlorine and chloramines[2] are considered the most effective secondary disinfectants (Black & Veatch Corporation, 2010; Federal-Provincial-Territorial Committee on Drinking Water and CCME Water Quality Task Group, 2004; Health Canada, 2012b).

3.2.2 WHY IS SECONDARY DISINFECTION RECOMMENDED?

Secondary disinfection contributes to the achievement of the best management goals described in section 3.1 by:

- Indicating potential breaches in distribution system integrity.
- Aiding in the control of biofilm growth.
- Inactivating some pathogens in the distribution system.

As with any other distribution system BMP, the use of secondary disinfection alone will not protect water quality. Many of the other BMPs are primarily aimed at preventing microbiological risks through physical controls on which secondary disinfection will have no effect. For example, secondary disinfection will not prevent contaminants from breaching the physical integrity of a water supply system.

Secondary disinfection, however, does provide a valuable, multifunctional layer of protection that is simple and cost effective. It is unique among other BMPs because it can help the water supplier respond quickly to potential incidents of water quality degradation if there is an unforeseen break-down in the preventative BMPs. In this capacity, it generally compliments a water supply system’s set of other BMPs for protecting the water in the distribution system. The following subsections provide a brief overview of the unique qualities and advantages to applying secondary disinfection.

INDICATING POTENTIAL BREACHES IN DISTRIBUTION SYSTEM INTEGRITY

Secondary disinfectants can be used as a sentinel to indicate potential breaches in water supply system integrity because the disinfectant concentration drops as it oxidizes constituents encountered in the distribution system water. With regular monitoring, a water supplier can establish a baseline secondary disinfectant concentration for different parts of the system during normal operating conditions. Any

[2] This is sometimes referred to as monochloramine. Chloramines are chemicals that form as a result of adding chlorine to ammonia. Monochloramine is usually the preferred type of chloramine formed during this process as it is the most effective biocide and produces the fewest taste and odour problems of the chloramines. (Health Canada, 1995)

observation of lower than expected concentrations could be an indicator of potential threats to the drinking water, such as:

- Biofilm or bacterial regrowth.
- An intrusion event.
- Stagnant water.
- Primary treatment process failure/emerging source water quality challenges.

Chlorine can be more effective in this capacity than chloramine because chloramine is a more stable compound that does not degrade as quickly as chlorine (USEPA, 2002a; Health Canada, 1995).

The Drinking Water Protection Regulation requires monitoring for specific bacteriological parameters that are indicative of fecal contamination or other water quality problems, but it can take several days to obtain test results from a sample. This lag time may expose system users to potentially contaminated water before warnings are issued.

Secondary disinfectant monitoring is not a specific indicator of fecal contamination, but real-time monitoring of fluctuations in disinfectant concentrations can provide immediate indications of potential hazards in the system. This gives the water supplier the opportunity to investigate and respond **immediately** to any threats to the system.

AIDING THE CONTROL OF BIOLOGICAL GROWTH

Secondary disinfectants can contribute to the biological stability of potable water because they can break down biodegradable organic matter and inhibit the growth of biofilm. Although both chloramines and chlorine can resist biofilm growth in systems, chloramines are more effective at penetrating existing biofilm to reduce growth (USEPA, 2002a). The concentration of secondary disinfectant needs to be high enough to outweigh the natural growth tendency.

INACTIVATING PATHOGENS IN THE DISTRIBUTION SYSTEM

Secondary disinfectants can inactivate some pathogens in the distribution system (USEPA, 2002a). Secondary disinfection is most effective against minor contamination events (e.g., marginal intrusions and pathogens sloughing away from biofilm). The concentration of disinfectant used in the distribution system will not necessarily be large enough or have the necessary contact time to control a major contamination event. Additionally, secondary disinfectants are not considered to be effective at inactivating protozoan pathogens.

3.2.3 WHEN IS SECONDARY DISINFECTION RECOMMENDED?

Drinking water officers and other issuing officials have discretionary authority to require secondary disinfection for distribution systems that are at risk for pathogen contamination and/or significant biofilm/microbial growth. It is generally expected that new water supply systems and new system components (e.g., reservoirs) provide secondary disinfection. Existing systems requiring secondary disinfection should develop a continuous improvement plan for implementation. See section 3.3 for information about circumstances in which water supply systems may be allowed to operate without it.

The type of disinfectant used for secondary disinfection depends on the characteristics of the distribution system. For example, a physically long system, or one with long retention times, may need chloramine because it is a more stable chemical disinfectant and will not degrade as quickly as chlorine.

Water suppliers considering the addition of a secondary disinfectant should conduct an analysis of the potable water and distribution system components to determine any potential unintended consequences due to potential chemical interactions. For example, water with high iron and/or manganese concentrations can form a precipitate in the presence of chlorine under certain conditions (Black & Veatch Corporation, 2010). Consequently, water suppliers should ensure they understand the consequences of their specific water chemistry and consult with their drinking water officer before using a secondary disinfectant.

3.2.4 WHAT IS THE RECOMMENDED OPERATIONAL RANGE FOR DISINFECTANT CONCENTRATION?

The concentration of the disinfectant will depend on the type of disinfectant used and the individual system characteristics (e.g., biological stability of potable water, physical infrastructure characteristics and operational practices). Systems that use most (if not all) of the BMPs listed in section 3.1 and have protective factors built into the design (see appendices B and C), may have the ability to operate with a minimal concentration; whereas, other water supply systems may require a higher concentration due to the absence of some BMPs or other factors.

Water suppliers should maintain secondary disinfection at concentrations that will maximize benefits while minimizing the impact on the aesthetic quality of the drinking water (e.g., taste and smell) and disinfection by-product formation.

CHLORINE

The *Guidelines for Canadian Drinking Water Quality* (Health Canada, 2009a) state that there is no evidence to demonstrate that free chlorine is toxic to humans at the concentrations needed to maintain distribution system integrity, normally less than 5 mg/L. The guidelines suggest that chlorine "concentration be determined on a system-specific basis to ensure effectiveness of disinfection and maintenance of an appropriate residual, while minimizing by-product formation and aesthetic concerns" (Health Canada, 2009a).

A generally accepted target range concentration for free chlorine at distribution system end points is at least detectable to 0.2 mg/L for control of bacterial growth (LeChevallier, Welch and Smith, 1996). Due to individual characteristics between systems, most distribution systems in Canada operate with a free chlorine concentration in the range of 0.4 to 2.0 mg/L leaving the treatment plant, and 0.04 (detectable) to 0.8 mg/L at distribution system end points (Health Canada, 2009a).

Individual sensitivities to chlorine in the population vary widely. Sensitive individuals may notice it at levels as low as 0.6 mg/L, but the majority of people will not likely detect it at the concentrations discussed in this guideline (Health Canada, 2009a). At these concentrations, taste and odour related to chlorine or its by-products are generally within the range of acceptability for most consumers.

CHLORAMINE

Health Canada (1995) recommends a maximum acceptable concentration of 3.0 mg/L for chloramines in drinking water. A generally accepted target concentration for chloramines as they enter the distribution system is at least 2.0 mg/L with a residual of no less than 0.5 mg/L throughout the distribution system (Health Canada, 1995).

3.2.5 WHAT ARE THE RECOMMENDED MONITORING PRACTICES?

In addition to the microbiological monitoring requirements of Schedule A of the Drinking Water Protection Regulation, the water supplier should monitor for the secondary disinfectant. The drinking water officer may specify monitoring locations and frequencies that differ from those listed in the regulation for microbiological monitoring. Records should be kept for inspection and to provide a context by which the operator may identify water quality issues by a change in disinfectant residual for a particular location.

Water supply systems using chloramines should consider monitoring for *N*-nitrosodimethylamine (NDMA), which is a by-product of chloramination. The *Canadian Guidelines for Drinking Water Quality* recommend a Maximum Acceptable Concentration of 0.04 µg/L of NDMA in drinking water. Other recommended monitoring parameters for chloraminated systems include: ammonia, monochloramine, dichloramine, nitrite, nitrate, HPC, pH and alkalinity.

3.3 OPERATING WITHOUT SECONDARY DISINFECTION

3.3.1 IS THERE AN OPPORTUNITY TO OPERATE WITHOUT SECONDARY DISINFECTION?

Water supply systems may be allowed to operate without secondary disinfection if they demonstrate to the satisfaction of the drinking water officer that the physical characteristics of the system and the other BMPs in place adequately protect the microbiological water quality. Water suppliers should be able to say yes to the following questions and provide sound rationale (as confirmed by the drinking water officer) to demonstrate their ability to protect the water without secondary disinfection:

1. Does the system select or produce biologically stable water?
2. Do the physical characteristics (e.g., design elements) of the system in conjunction with the use of a comprehensive set of the other BMPS provide the ability to proactively manage risks to the distribution system?
3. Does the system transport microbiologically safe water to system users as demonstrated by the water supplier’s monitoring records (e.g., no history of recurring or persistent indicator organisms)?

4. Does the system display an ongoing commitment to meet the BMPs as demonstrated by the water supplier's monitoring records, compliance with conditions on permit, annual reports and inspection records?

The use of a comprehensive set of the BMPs listed in section 3.1 (e.g., maintaining hydraulic integrity and using a cross-connection control program) is highly recommended. Appendix B provides a list of BMPs for designing, building, operating and maintaining distribution system components for maintaining water quality. Appendix C provides some examples of protective factors related to design elements and operations. Section 3.1 and these appendices provide information for water suppliers to consider when developing the rationale to support question #2.

No one factor outweighs the others. A water supplier should have the ability to demonstrate the use of a well-rounded suite of BMPs and protective factors, and that they work together to protect microbiological water quality.

3.3.2 ONGOING EVALUATION OF WATER SUPPLY SYSTEMS OPERATING WITHOUT SECONDARY DISINFECTION

Systems operating without secondary disinfection need to be re-evaluated on a recurrent basis to ensure they continue to function within an acceptable range of risk. Reasons a water supply system may be required to implement secondary disinfection include, but are not limited to:

- The system is experiencing the recurring or persistent presence of indicators that demonstrate the BMPs in place are no longer effective or that contamination risks are not being managed to the satisfaction of the drinking water officer.
- The drinking water officer notes a lack of commitment or ability on the part of the water supplier to meet the BMPs.

APPENDIX A: SOURCES OF FURTHER INFORMATION

DISTRIBUTION SYSTEM HAZARDS AFFECTING MICROBIOLOGICAL WATER QUALITY

WATER-BORNE ILLNESSES ASSOCIATED WITH DISTRIBUTION SYSTEMS

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Federal-Provincial-Territorial Committee on Drinking Water and the CCME Water Quality Task Group. (2004). *From Source to Tap: Guidance on the Multi-barrier Approach to Safe Drinking Water*. Retrieved from http://www.ccme.ca/files/Resources/water/source_tap/mba_guidance_doc_e.pdf.

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APPENDIX B: DESIGN, INSTALLATION AND OPERATION OF DISTRIBUTION SYSTEM COMPONENTS

The following is a list of best risk management practices (BMPs) for designing, building, operating and maintaining distribution system components for maintaining water quality (FCM, 2003).

This list is based on a policy statement of the American Water Works Association (AWWA, 2012), research from the Water Research Foundation, the *Guidelines for Canadian Drinking Water Quality* (Health Canada, 2012a), documents from the U.S. Environmental Protection Agency, and a document produced by the Federation of Canadian Municipalities (FCM, 2003).

AWWA's suite of practice manuals and standards provide information on many of the BMPs listed below.

DESIGN

- Design distribution system and storage facilities in accordance with engineering best practices, including:
  - Minimizing water age and dead ends.
  - Maintaining sufficient physical separation from sources of underground contamination (e.g., sewers).

INSTALLATION

- Use certified materials (i.e., NSF/ANSI standard 61).
- Properly install and disinfect distribution system components (AWWA Standard C651) and storage facilities (AWWA Standard C652).

OPERATION

- Operate distribution system and storage facilities in accordance with best practices.
- Flush and swab water mains.
- Regularly inspect and maintain valves and hydrants.
- Regularly monitor, inspect and maintain storage facilities.
- Control internal corrosion.
- Control blending of water sources.
- Communicate and engage regularly with stakeholders (e.g., system users and drinking water officer).
- Promptly respond to and communicate water quality issues.
- Use a calibrated water quality model of the distribution system.

APPENDIX C: PROTECTIVE FACTORS ASSOCIATED WITH DESIGN ELEMENTS AND OPERATIONS OF WATER SUPPLY SYSTEMS

In addition to using the best risk management practices listed in section 3.1 of these guidelines, the following protective factors should be considered when a water supplier is developing rationale for operating without secondary disinfection.

TABLE 2: PROTECTIVE FACTORS ASSOCIATED WITH DESIGN ELEMENTS AND OPERATIONS OF WATER SUPPLY SYSTEMS

Protective Factor	Description
System design: short retention time	• Systems with short retention times throughout the distribution system may be able to demonstrate that water quality is adequately protected through source protection and treatment. • The longer water remains in the system, the more opportunity there is for pathogen contamination and re-growth. • Systems at risk for having "older water" include, but are not limited to: o Large systems[3]: the larger the system, the higher the risk. o Underutilized systems (e.g., capacity is greater than is needed or there is seasonal variation). o Systems with multiple dead ends.
System design: simple distribution system	• Simple distribution system design allows an operator to reasonably manage each of the system components. • Complex systems (e.g., many pressure zones) generally have difficulty maintaining water quality in the distribution system as there are many components to manage.
System design: few sources of contamination	• System design should avoid, to the extent possible, predisposing the system to increased risks of contamination. • This includes minimizing submerged mains and maintaining sufficient vertical and horizontal separation from sanitary and storm sewers.

[3] As per the Drinking Water Protection Regulation, a small system is a water supply system that serves up to 500 individuals during any 24-hour period.

Protective Factor	Description
System operation: flushing and/or shock chlorination	• The use of regular flushing and/or shock chlorination can help control biological growth.
Maintenance: low leakage	• Systems with low rates of water loss from leakage are at lower risk for contamination via intrusions during pressure differentials than systems with higher rates.
Monitoring: alternative microbial and real-time parameters	• Monitoring is necessary to continually demonstrate that distribution system barriers are consistently maintaining the microbiological quality of the water. • Systems operating without secondary disinfection could use additional monitoring parameters (in addition to legislated parameters) in lieu of monitoring for residual. • This could include: o Using a comprehensive combination of microbial indicators that are specifically indicative of biofilm growth (e.g., heterotrophic plate count (HPC) bacteria, Pseudomonas and Aeromonas). o Using alternative real-time parameters (e.g., turbidity, pressure, flow, conductivity, pH and temperature). • Water suppliers should establish background levels of the different parameters at normal operating conditions. Observed changes in background levels of any of these parameters could indicate a reduction in distribution system integrity, requiring further investigation.
Asset management	• As systems age, they are increasingly at risk for breaches in integrity. • Adherence to a defined asset management plan as well as adhering to the BMPs listed in section 3.1 and appendix B ensures that aging infrastructure is regularly maintained and replaced in order to manage this risk.

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