Chapter 3 - Developing a Building Potable Water System Flushing Program

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Contents

DISCLAIMER

This document was developed as a tool for control of Legionnaires' disease risk associated with starting / restarting building potable water systems. Legionella Risk Management, Inc. made every effort to ensure that this document contains the most up to date recommendations. We do not guarantee that using information in this chapter will result in no risk or that there are no omissions or errors in this document. As discussed in this document there are significant risks with allowing potable building water systems to be stagnant. Any who do not understand these recommendations or feel they are not competent in administering the protocols contained in this document should contact a building water system engineering consultant for proper implementation of a risk management program to comply with ASHRAE 188. In no event will Legionella Risk Management, Inc. be liable for damages related to use of this document.

OVERVIEW

This chapter is focused on how to start / restart the Building Potable Water Systems (BPWS) in buildings that have been stagnant (low or no flow) for some period of time or in response to a significant water event including; new building commissioning, municipal main break, turbid water event or a boil-out advisory.

This chapter;

1. provides details on key elements of, and practical steps for conducting a **Building Potable Water System (BPWS)** flushing plan to control risks associated with heavy metals and waterborne pathogens including Legionella.
2. discusses when to consider disinfecting the BPWS and
3. reviews data logs that will be useful in completing this process and for record keeping in documenting due diligence against claims of illness.

The greatest risk for *Legionella* growth in a BPWS is the hot water system. All buildings with a circulated hot water system should have a risk management plan to comply with ASHRAE Standard 188. If the building does not have a plan in place and has questions on any aspect of this flushing regime or development of a Legionella Risk Management plan, contact a building water system engineering consultant or contractor for assistance. Appendix N of IAPMO Code UPC 2021 details temperature ranges and associated *Legionella* growth risk.

A common misperception is that Legionnaires' disease outbreaks occur only in healthcare buildings because these buildings house a lot of immunocompromised people. In fact, more Legionnaires' disease outbreaks occur in hotels than hospitals and nursing homes combined. Potable water Legionnaires' disease outbreaks have also been associated with apartment buildings, condo buildings, office buildings, government buildings and manufacturing facilities, among others.

Potable water systems in buildings with small, uncirculated (no hot water return pump) hot water systems likely do not fall under the requirements of ASHRAE 188 to have a Legionella Risk Management plan. Buildings with small, uncirculated hot water systems may include restaurants, stores, small office buildings. Office buildings with leased office space and malls typically will have a small, uncirculated hot water system in each office / store space and do not have a central circulated hot water system. These smaller systems are much easier to flush and address waterborne pathogen issues. In these systems maintaining water temperature > 120°F at all fixtures and ≥ 140°F in storage water heaters is an effective method for reducing risk from Legionella that is relatively simple to implement in smaller systems.

ASHRAE Guideline 12 states, "The most effective control for most diseases, including Legionellosis, is prevention of transmission at as many points as possible in the disease's chain of transmission." In developing any flushing or risk management program this statement is critically important.

A good flushing program is intended to remove contaminants, not move them from outside to inside or from bigger pipes to smaller pipes.

Note: Most buildings will be on a municipal supply. Throughout this document 'municipal supply' will be the term used for the potable water source to a building.

TOOLS NEEDED[1]

1. Residual Disinfectant Test Kit
   a. Any test kit that is EPA-approved for potable water will suffice.
      i. Free chlorine test kit if the water supplier is using free chlorine or
      ii. Total chlorine test kit if the water supplier is using chloramine
      iii. Check the water supplier's water quality report to determine which one, free chlorine or chloramine is used for disinfection.
      iv. Recommendation: Hach DR300 Pocket Colorimeter.
      v. There are non-EPA approved methods that are simple, easy to use, inexpensive, and reliable that can be considered. One example is the FAS DPD Drop Test.
   b. If you are adding disinfectant to the drinking water while the water system is in use, an EPA approved kit must be used.
   c. Paper Chlorine Test Strips are acceptable for quick test during disinfection. Recommendations:
      i. Hi-range free chlorine example Hydrion (CM-240) chlorine Dispenser
      ii. Mid-range free chlorine example Industrial Water Works Free Chlorine High Range Test Strip
      iii. Lo-range free chlorine test strip example SenSafe Free Chlorine Water Check.

NOTE: In measuring chlorine concentration in water, parts per million (i.e., "ppm") is equivalent to mg/L

2. pH Tester

3. Thermometer
   a. Any good thermometer will do.
   b. Recommendation: Thermapen is simple, fast, digital, accurate, and large enough to lay on a sink while flushing, if needed.

4. Personal Protective Equipment (PPE)
   a. If there is known or suspected biological contamination, or individuals flushing are immunocompromised or concerned about exposure, an N-95 respirator should be considered. Occupational health may require a respirator fit test and should be consulted prior to use.

5. Short hoses with NPT adaptors. Short hoses, 8 to 10 feet long, can be attached to shower arm after the shower head is removed. This will minimize splashing and potential for aerosol generation.

6. 5 Gallon Buckets. Buckets can be used for containing water and minimizing splashing and aerosol generation by placing hose under waterline.

[1] LRM has no financial relationship with any of these products; These are the tools LRM uses in onsite work

BUILDING POTABLE WATER SYSTEM FLUSHING RECOMMENDATIONS

SHORT-TERM STAGNANT CONDITIONS - 1 TO 2 WEEKS

1. Perform Building Water System Flushing only if:
   a. The disinfectant level in the municipal water at the closest tap entering building is ≥0.5 free or ≥1 ppm total chlorine.
2. Consider Disinfection in addition to flushing if any of the following are true;
   a. The disinfectant level in the municipal water at the closest tap entering building is <0.5 ppm free or <1 ppm total chlorine,
   b. There are known issues with the plumbing system,
   c. There are fixtures known to increase *Legionella* growth potential such as point of use mixing valves or electronic faucets,
   d. The building should, but does not have, a risk management plan to comply with ASHRAE 188,
   e. The system design and operation does not comply with ASHRAE Guideline 12.

MODERATE-TERM STAGNANT CONDITIONS - 2 TO 4 WEEKS

1. Perform Hydrant / Water Main Service Line Flushing then,
2. Perform Building Water System Flushing only if:
   a. Municipal water supply disinfectant level is ≥0.5 ppm free or ≥1 ppm total chlorine.
3. Consider Disinfection if;
   a. The municipal water supply disinfectant level is <0.5 ppm free or <1 ppm total chlorine,
   b. There are issues with the plumbing system,
   c. There are fixtures known to increase growth potential such as point of use mixing valves or electronic faucets,
   d. The building should, but does not have a risk management plan to comply with ASHRAE 188,
   e. The system design and operation does not comply with ASHRAE Guideline 12.

LONG TERM STAGNANT CONDITIONS - MORE THAN 4 WEEKS

1. Perform Hydrant / Water Main Service Line Flushing, then
2. Perform Building Water System Flushing then,
3. Perform Disinfection.

Note: Disinfection may be combined with flushing

WARNING

Building water systems that have been stagnant for two weeks or more are a high risk for growing waterborne pathogens including Legionella. Those who flush these systems will be exposed to this potentially dangerous aerosol. In addition to wearing PPE, the following precautions are recommended;

RISK FACTORS FOR LEGIONNAIRES' DISEASE

Anyone involved in flushing and exposed to the aerosol should be made aware of the risk factors. Selecting personnel without these risk factors will greatly reduce the risk.

CDC website states the following;

Risk factors for legionellosis include:

1. *Age ≥50 years*
2. *Smoking (current or historical)*
3. *Chronic lung disease (such as emphysema or COPD)*
4. *Immune system disorders due to disease or medication*
5. *Systemic malignancy*
6. *Underlying illness such as diabetes, renal failure, or hepatic failure*

RISK FACTORS FOR LEGIONELLA TRANSMISSION FROM BUILDING WATER FIXTURES

Below details a water risk potential from highest to lowest. All stagnant water presents a risk for growth of waterborne pathogens including Legionella and mycobacteria to disease causing levels, however some have a recognized higher risk potential;

a. Fixtures that generate a lot of aerosol,
   i. Shower heads
   ii. Spray type sink aerators
b. Fixtures with significant potential to allow mixing of hot and cold water
   i. electronic faucets,
   ii. point of use mixing valves,
   iii. janitors closet chemical mixing stations
c. Fixtures with potential to allow mixing of hot and cold water but less than the above,
   i. single handle shower valves
d. All other fixtures in hot and tempered water systems.
e. Cold water only fixtures where cold water is at temperatures above 85F
   i. Toilets
   ii. Urinals
   iii. Hose bibs
f. Cold water only fixtures where cold water is below 78 °F represent the lowest risk fixture

REDUCING AEROSOL TRANSMISSION RISK

Aerosol can travel long distances and stay airborne for a long period of time. Take precautions on limiting aerosol movement and reducing aerosol concentration;

a. Wear an N-95 respirator while conducting flushing
b. Central HVAC systems
    i. Open outside air to 100% or as high as possible.
    ii. Ensure filters are in place and in good condition.
    iii. Maintain HVAC fans running disable demand control ventilation
c. Bathrooms with exhaust fans
    i. Turn on and leave running bathroom exhaust fans.
    ii. Keep windows closed (the idea is to exhaust and remove the aerosol, opening windows could just stir up the air or bring outside air in pushing the aerosol out of the bathroom and into the hallway)
    iii. Keep bathroom doors closed.
    iv. Do not use hand blowers or any other fan that stirs up the air rather than exhausts the air.
d. Showers
    a. Remove shower head
    b. Attach hose to shower arm and place hose in drain, cover drain with towel.
    c. If drain cover is not removable secure hose to base of shower and cover stream with towel.
    d. Another option is to place a hose in a bucket with a large slit cut out to create a high flow weir.
e. Sinks
    a. Cover sink with towel (the wet towel is not a risk for Legionella transmission)

RISK FACTORS FOR LEGIONELLA GROWTH IN BUILDING WATER SYSTEMS

Low Risk – There are many factors that can impact risk. Below are key factors.

a. Cold Water
    a. Temperature at every fixture is equal to or less than 77F within 30 seconds or
    b. Chlorine residual at every fixture within 30 seconds is >0.2 ppm free or > 0.5 ppm total or
    c. Chlorine dioxide residual at every fixture within 30 seconds is > 0.1 ppm
b. Hot Water
    a. Temperature at every fixture is equal to or greater than 120F within 30 seconds or
    b. Disinfectant residual is as listed above.

PREPARATION – PRIOR TO FLUSHING

STEP 1 – COLLECTING MUNICIPAL WATER SUPPLY INFORMATION

Building owners should be aware of incoming municipal water supply characteristics prior to implementing a flushing protocol. Disinfectant residual varies throughout large municipal distribution systems. Buildings should contact the municipal supplier and ask what level (ppm) and what type of disinfectant (free chlorine or chloramine) they should expect to have in the water entering their building.

If the municipal water supply disinfectant level is <0.5 ppm free or <1 ppm total chlorine, there is a potential that flushing alone of the BPWS will provide only marginal benefit in waterborne pathogen reduction.

The key disinfectant criteria is the amount of disinfectant in hot water at the sinks and showers.

If the hot water disinfectant residual at all sinks and showers is >0.2 ppm free or >0.5 ppm total chlorine and the hot water system is functioning within control limits (i.e., meeting target temperatures and hot water returns are balanced), then flushing alone may control bacteria. However, if bacteria have multiplied in stagnant water then one flushing without added disinfectant or even with added disinfectant may not be adequate to control Legionella levels.

Quincy and Flint Example:

Both Flint, MI and Quincy, IL, Legionnaires' disease outbreaks identified issues with delivery or maintenance of municipal water disinfectant levels to be associated with the building water system outbreaks.[4,5] The Quincy outbreak resulted in 58 cases of illness and 12 deaths with 54 of those cases occurring at the Quincy Veterans Home and the Flint LD outbreak resulted in 90 cases and 12 deaths with 51 cases associated with McLaren Hospital. In the Quincy outbreak, Illinois changed state law in August of 2019 requiring 0.5 mg/L, free and 1.0 mg/L total chlorine in all parts of the municipal distribution system. These levels are higher than required by most state primacy agencies. Some states require only that a residual is "detectable" a certain percentage of the time, resulting in some parts of the distribution system receiving little to no disinfectant residual.

STEP 2 – PREPARING FOR BUILDING POTABLE WATER SYSTEM (BPWS) FLUSHING

3. Identify all water mains entering the building.
4. Review site plans and identify if any hydrants are on the building property and whether they are owned by the building owner or the water provider. Show the location of hydrants owned by building owner on a map of the site.
5. Review plumbing schematics (if available) and review system design and operation.
6. Review plumbing and equipment;

    a. Building Cold Water and Hot Water Supplies
    Identify hot and cold water trunks and main branches (risers and headers) and separate them into different services areas or "zones" within the building.

    b. Potable water use end points
    Identify and generate a list of points supplied with potable water in the building in each zone, in order, from closest to furthest from the main plumbing branch. Organize the list by zone. This includes; sinks, showers, toilets, ice machines, hose bibs, safety showers, drinking fountains, soda dispensers etc.

    c. Equipment List - Potable Water
    Identify all equipment in the potable water system; pumps, filters, mixing valves, water heaters, etc. Again, locate these in the appropriate zones.

    d. Equipment List - Non-Potable Water
    Identify all non-potable branch lines off of the potable water system supplying equipment including cooling towers, boilers, closed loops, swimming pools, etc. Check that the backflow preventer maintenance is up-to-date.

    e. Equipment List - Equipment where any high level disinfection is a concern
    Identify all equipment where any high disinfectant level could negatively impact equipment or health and safety of users including; filters, RO membranes, dialysis equipment, etc. This equipment may need extra precautions or to be isolated during disinfection.

NOTE: There may already be documents available with water use end points / fixture list readily available with minor edits needed (e.g., a hotel likely has a room and room type list that includes all fixtures). If the building has a preventative maintenance software program, it should have a listing of all equipment supplied by potable water.

FLUSHING RECOMMENDATIONS

Prior to flushing water inside the building, ensure that the municipal supply water is good quality. If the water in the municipal supply and service lines has been stagnant there may be little to no disinfectant residual and high bacteria levels and lead levels. Flushing this stagnant water through the building could exacerbate rather than improve conditions. If the municipal supply lines near the building were in use while the building water system was experiencing stagnant conditions, then only the service line to the building will require flushing.

Water velocity in feet per second (fps) is critical for effective flushing. Water velocity can be calculated from the pipe diameter and water flow rate. At the end of this chapter is a discussion on velocity and flow with data tables comparing the two. The minimum water velocity for flushing should be >3 fps. Flushing multiple fixtures simultaneously will be required to develop >3 fps in branch supply lines. However, when too many fixtures are opened at the same time there may be a reduction in water velocity or pressure.

NOTE: If turbid (discolored) water appears at any point during flushing, continue flushing until the water becomes clear and then flush an additional 10 minutes. Turbid water indicates potential for high amounts of particulates that may contain bacteria or metals.

STEP 1 - HYDRANT / WATER MAIN SERVICE LINE FLUSHING:

Note: This step is recommended only if a significant amount of municipal supply lines in the area has been stagnant 2 weeks of longer.

Flush all items below at maximum possible velocity with a minimum of 3 fps until either;

a. there is a disinfectant residual that is representative of the water main, as indicated by the water service provider (if testing for chlorine is possible), or
b. there is <0.5°F change in temperature over 2 minutes while flushing. This can be used as indicator that the building is receiving new water from the distribution system.

1. Open hydrant slowly to highest velocity practical.
2. Flush hydrants for a minimum of 5 minutes.
3. If there are multiple hydrants on your property, start flushing the hydrants furthest from the building and end with those closest to it.
4. If, while flushing hydrants any turbid (discolored) water appears at any point during flushing, continue flushing until the water becomes clear and then flush an additional 5 minutes.

Note: Hydrant flushing requires notification to, and approval from the municipal supplier, even if the hydrants are owned by the property owner. If not owned by property owner, contact the municipal supplier and ask if/when they will conduct hydrant flushing. Where possible, perform Step 2 of the flushing recommendations immediately after municipal supplier hydrant flushing.

Note: Hydrant flushing may cause a pressure drop at the building and set off an alarm on the building water fire system. Notify alarm company prior to flushing.

STEP 2 – FLUSH SERVICE LINE (MAIN SUPPLY) TO BUILDING

1. Flush each water main at the point nearest to the building entry
   a. Strainers are good places to do this.
   b. Flush at full flow, until water is clear, then for an additional 5 minutes. See Supplementary Information – Flushing Service Lines for details
2. Continue flushing while opening and closing the valve rapidly several times.

Note: This surge in flow and velocity will help loosen debris and contaminants, but the mechanical action and potential for water hammer could damage piping that is old or not in good condition. Check with an engineer to determine if this step can be implemented.

3. Flush again at full flow, until the water is clear for at least 5 minutes.

Note: Testing for chlorine is preferred over temperature to determine water quality.

4. Flush at moderate flow for an additional 10 minutes.

At this point, the disinfectant residual entering the service line (water main) to the building should be representative of the residual in the distribution system where the building is located. However, the disturbed sediment needs to be flushed from the service line prior flushing building outlets.

STEP 3 – FLUSH MECHANICAL ROOM COLD WATER MAINS

Flush all items below at maximum possible velocity with a minimum of 3 fps until either;

a. there is a disinfectant residual that is representative of the water main, as indicated by the water service provider (if testing for chlorine is possible), or
b. there is <0.5°F change in temperature over 2 minutes while flushing. This can be used as indicator that the building is receiving new water from the distribution system.

NOTE: Testing for chlorine is preferred over temperature to determine water quality.

NOTE: If turbid (discolored) water appears at any point during flushing, continue flushing until the water becomes clear and then flush an additional 10 minutes. Turbid water indicates potential for high amounts of particulates that may contain bacteria or metals.

1. Flush the main plumbing including supplies to potable and non-potable equipment, and cross connections, targeting highest velocity possible. Equipment strainers are good places to do this.
2. Flush the potable cold water riser drains (if installed and operable)
3. Cycle or flush equipment supplied by potable water targeting ≥3 fps flushing velocity.
   a. Softeners should be regenerated.
      i. If softeners are supplying hot water supply and the water heater is set for > 140°F then bacterial issues associated with the softener are less of a concern. If however, softeners are providing cold potable water to the building or supplying water to the heater not set for > 140°F then bacteria generated in the softener poses a significant risk and should have a flushing and disinfection plan.
      ii. If there is no detectable disinfectant in the building cold water supply to the softener, consider cleaning and disinfecting the resin per manufacturers recommendations.
      iii. If there is disinfectant in the water supply to the softener and after regeneration the disinfectant residual is reduced by more than 25% consider cleaning and disinfecting the resin and determine the reason for disinfectant loss.
   b. Filters & equipment strainers should be cleaned or replaced. If filters are dirty, the organic matter may reduce disinfectant level, and they should be replaced prior to flushing.
      i. Carbon filters must be removed as they will destroy disinfectant residual and provide a media for bacteria growth.
      ii. When installing new filters consider using media filters instead of carbon filters.
   c. Pressure tanks should be flushed.
   d. Cycle or flush non-potable water equipment supplied by cold potable water.
      i. Cooling towers, swimming pools, spas, hose bibbs etc. are typically supplied by the building cold water supply. Flush each of these supply lines. The water before the backflow preventer supplying this equipment can represent a significant dead-leg in the cold water system if not flushed.

At this point the disinfectant residual in all cold water mechanical room equipment and main cold water plumbing serving the rest of the building should be representative of the residual in the municipal water supply.

STEP 4 – FLUSH MECHANICAL ROOM POTABLE HOT WATER EQUIPMENT AND PIPING

1. Flush cold water through water heaters and water storage tanks until the water runs clear for at least 5 minutes.
2. Flush the hot water circulation loop and return piping by opening a valve downstream of hot water return (circulation) pump(s) and flush to the drain. Flush until:
   a. there is a disinfectant residual similar to the residual in the hot water supply, or
   b. there is <5°F change in temperature at the hot water return compared to the hot water supply.

NOTE: a detectable disinfectant residual is preferred, but the steady temperatures serves as an indicator that the hot water is being distributed throughout the main recirculating lines in the building.

At this point, all hot & cold potable water mechanical room equipment and piping have been flushed, cold water disinfectant residuals should be representative of the residual provided by the municipal supplier, temperature at hot water return should be within 5°F of hot water supply.

If multiple mechanical rooms start with rooms closest to main supply.

For mechanical rooms on upper floors ensure high flow to drains does not cause flooding on lower floors.

Completing the above Steps 1-4, aimed at flushing the central portions of the building hot and cold water systems, will maximize the efficiency of flushing and minimize the contamination of end use fixtures and equipment with metals, pathogens, nutrients, and particulate from unflushed water.

No end use fixtures (sinks, showerheads, ice machines, drinking water fountains, etc.) have been flushed.

STEP 5 – FLUSH ALL END POINTS (SINKS, SHOWERS, TOILETS, HOSE BIBBS, ETC.)

Using the fixture list generated in **Preparation Step 2**, proceed to end point flushing. As stated above, flushing should always start at the biggest pipes and closest to supply mains and end with the end points with the smallest flow rates and those furthest from the supply mains.

1. Remove shower heads and faucet flow restrictors (aerators)
   a. By design, shower heads and faucet flow restrictors reduce water velocity. Flow rates of ≤1 gpm at showers and sinks result in drop leg velocities dramatically lower than the minimum desired 2 fps. These very low velocities significantly increase risk for waterborne pathogen growth.
   b. Removing showerheads and faucet flow restrictors will allow higher velocities and dramatically improve flushing results. Also, shower heads and restrictors have built-in strainers that may capture some of the particulates and bacteria stirred up in flushing.

NOTE: *Legionella* is a waterborne pathogen, if sink aerators and shower heads / hoses are removed and allowed to completely dry the Legionella will die. If reassembling the fixtures immediately after flushing, consider soaking these fixture components in a dilute bleach solution. Approximately 0.25 Tablespoons of household bleach (2.25%) per 1 gallon of water will make ~50 ppm of free chlorine. Do not add more bleach per gallon that this, as it can decrease the efficacy.

2. Fixture flushing
   a. First, flush hot water through the fixture at high velocity,
      i. Open fixtures as needed, simultaneously on the same branch supplying multiple fixtures, to yield greater than 3 fps in the branch piping.
      ii. If the bathroom sink and shower on two back-to-back rooms are all on the same branch, then open and flush all four fixtures at the same time.
      iii. Flushing at high velocity will result in the greatest impact on turning over water, removing particulates and scouring the pipe.
      iv. Turn off water.

NOTE: Hot water temperature should be within 5°F of the hot water supply / return temperatures if there is not point-of-use mixing valves and the hot water system is adequately balanced.

   b. Second, flush cold water through the fixture at high velocity,
      i. Repeat the same process as 2.a.i-iv above

NOTE: Cold water temperature should be within 5°F of the municipal water supply and disinfectant levels (if checked when desired) should be similar to the levels in the municipal water supply

   c. Flush 'point of use' mixing valves and electronic faucets
      i. Repeat the same process as 2.a.i-iv above
      ii. These end use devices prevent high velocity flushing of drop legs and also are a recognized higher risk for bacterial growth. To flush the drop legs to these devices, remove the supply hoses to the fixtures and flush to drain.
      iii. Also perform any maintenance and disinfection as recommended by the manufacturer.

BUILDING POTABLE WATER SYSTEM (BPWS) DISINFECTION

If considering BPWS chemical disinfection, you should contact a contractor with expertise in potable building water disinfection such as a water treatment provider, a local public water system operator, or a qualified plumbing contractor.

ASHRAE 188 provides a good standard of care for potable water disinfection. It requires new buildings be disinfected within 3 weeks of significant occupancy. If occupancy is delayed between two to four weeks after disinfection, then flushing is required. And if occupancy is delayed 4 weeks or longer after disinfection, then an additional disinfection is required.

In some cases flushing alone and in some cases flushing and low level on-line disinfection may be adequate for Legionella control. However, in some cases flushing and high level disinfection may not be sufficient and provide only temporary control of Legionella and long term treatment may be required.

LOW LEVEL ON-LINE DISINFECTION

This can be performed while the water is being used for potable use. If there are any concerns with system piping, length of stagnant conditions or disinfectant level in the municipal supply then adding disinfectant while flushing is a simple and low-cost measure. All it takes is a small chemical feed pump (~$400 each) and NSF approved sodium hypochlorite i.e. bleach (~$25 for 5 gallons). Also, an injection quill should be used to inject chemical into the water stream. Chemical should be fed downstream of the building cold water supply backflow preventer and also downstream of the potable water heater. Target residual of 3 to 4 ppm free chlorine or 0.5 to 0.8 ppm chlorine dioxide throughout the entire building water system should be maintained for a minimum of 4 hours. If desired, this level can be maintained for days, typically without any significant impact on equipment or piping.

If the building water supply is chloramine, then low level on-line free chlorine disinfection is possible but chlorine dioxide is strongly recommended.

HIGH LEVEL DISINFECTION HYPERCHLORINATION

Perform high level disinfection if;

1. The building water systems have been stagnant for 4 weeks or longer.

Consider high level disinfection if;

1. Building has been stagnant for longer than 2 weeks.
2. After a turbid water event or main break.
3. If building has no water management plan and no audit of their building water system by a qualified engineer.
4. If building has identified plumbing issues such as stratification in hot water tank, poorly balanced hot water return and cross connections.
5. If building has a significant number of point of use devices such as local mixing valves and electronic faucets.

Potable water equipment that has been offline such as ice machines should be drained, cleaned, disinfected and flushed prior to use following manufacturers recommendations.

Disinfectant level should never exceed 100 ppm free chlorine; above this level could damage plumbing system components.

Hyperchlorination should target a minimum contact time of 50 mg-hr/l. pH should not exceed 8.5. Sodium hypochlorite is an alkaline solution and may slightly increase water pH. Desired contact time can be achieved in any of the below combinations of disinfectant residual over time.

Minimum Free Chlorine Contact Time Disinfection		
mg/L	Hours	mg-hr/l
2	25	= 50
5	10	= 50
25	2	= 50

Hyperchlorination should not exceed an average of 50 ppm free chlorine during disinfection period and should not exceed 100 ppm free chlorine at any time during disinfection.

Maximum Free Chlorine Concentration		
PPM	Hours	mg-hr/l
50	2	= 100
50	3	= 150
50	4	= 200

Chlorine dioxide disinfection should target a minimum contact time of 10 mg-hr/l. pH should not exceed 9. Chlorine dioxide is in an acidic solution and may slightly decrease water pH. Desired contact time can be achieved in any of the below combinations of disinfectant residual over time.

Minimum Chlorine Dioxide Contact Time Disinfection		
PPM	Hours	mg-hr/l
2	5	= 10
2.5	4	= 10
5	2	= 10

Chlorine dioxide should not exceed an average of 5 ppm chlorine dioxide disinfection period and should not exceed 10 ppm chlorine dioxide at any time during disinfection.

Maximum Chlorine Dioxide Concentration		
PPM	Hours	mg-hr/l
5	2	= 10
5	3	= 15
5	4	= 20

If the water supplier uses chloramine there are two ways to achieve disinfection residual at all fixtures,

1. With Free Chlorine - Add sufficient chlorine to achieve breakpoint chlorination and destroy all the chloramine then, develop the desired free chlorine residual over planned contact time or
2. With Chlorine Dioxide - Chlorine dioxide does not react with chloramine, eliminating need for breakpoint chlorination. Chlorine dioxide is much more effective than chlorine. However, chlorine dioxide should only be handled by an expert.

If the building is not occupied and disinfectant level is below 20 ppm free chlorine, it does not need to be flushed out of the system until shortly before occupancy. Then prior to occupancy and reconnecting hoses and aerators there should be a final high velocity flush to bring the residual disinfectant levels down to below 4 ppm.

A log sheet should be kept of all fixtures disinfected. The log sheet should include the following for each fixture;

1. Start - Time, Temperature and Residual – Time, temperature and residual in ppm at initial flush to achieve desired disinfectant residual
2. Finish - Time, Temperature and Residual – Time, temperature and residual in ppm at final calculated contact time.
3. As pH variability in the system will be minor, only a small amount of pH tests are necessary to document conditions at beginning and end of disinfection. Testing pH once per hour and at one location per floor would be sufficient.
4. EPA approved digital tester should be used routinely throughout disinfection to validate results from test strips.

THERMAL DISINFECTION

Thermal disinfection will only disinfect the hot water portion of the building water system. For thermal disinfection to be effective;

1. There can be no issues in the cold water plumbing and
2. The chlorine level should be above 0.5 ppm throughout the cold water system. If there is little to no chlorine in the building cold water supply, then Legionella in the cold water may re-contaminate the hot water system at potential points for cross connection such as single handle shower valves, single handle faucets, electronic faucets and point of use mixing valves.

Thermal disinfection for larger buildings is very time consuming and very difficult to do and it has a high probability of failure. Each hot water fixture has to be flushed with hot water above 160°F for a minimum of 7 minutes for longer periods of time at lower temperatures, such as 30 minutes at140°F.

However, for small buildings thermal disinfection is a simple, inexpensive and very effective tool provided disinfection temperatures can be maintained.

A log sheet should be kept of all fixtures disinfected including,

1. Temperature
2. Time flushed at desired temperature

SUPPLEMENTARY INFORMATION

There are several concepts that must be understood prior to flushing a building water system.

VALIDATION TESTING

Culture testing using a CDC ELITE certified lab is the best method for validating control of Legionella in building water systems. PCR testing is also a useful tool. If samples are collected post disinfection they should be collected no sooner than 36 hours post disinfection. Legionella levels should be <1 CFU/ml. If levels are 1 CFU/ml or higher, actions should be taken based on review of system and water management plan recommendations.

Culture testing for Heterotrophic Plate Count (HPC) is an effective tool for analyzing water system conditions. Dipslides while useful in cooling towers are not recommended as a monitoring tool for potable water. Legionella is not directly related to HPC. However HPC can be used as a tool for system monitoring and analysis. High HPC levels in one part of the system may indicate issues with flow or usage. High HPC levels post disinfection may indicate issues with the disinfection. HPC levels in building water systems less than 500 CFU/ml are excellent and less than 1,000 CFUs/ml are very good. However, HPC levels can be expected above 1,000 CFU/ml. Even with very good HPC levels less than 100 CFUs/ml there could still be issues with Legionella. Legionella testing is the only way to validate Legionella control.

PLUG FLOW

Plug flow is the concept of water moving like a plug through a pipe, displacing all water in front of it. At plug flow, the amount of water to completely replace all existing water from a pipe with all new water is equal to the volume of water in the pipe (1x). Flushing a system at plug flow requires the least amount of time, the least amount of water and results in the greatest impact. True plug flow does not exist, but you can get close to it by higher velocities or, be very far from it by lower velocities. Below 2 fps is considered stagnant flow.

TURBULENT FLOW

Laminar flow is when the water is moving in a straight line through the pipe. Turbulent flow is when the water is moving so fast it is bouncing off the pipe walls and itself. And when it goes around a bend or through a restrictor it bounces a lot more. Turbulent flow occurs when the water velocity is higher than laminar flow. At turbulent flow you will likely hear noise in the pipe. The faster and more turbulent water is moving, the better it will scour solids laying on the bottom of the pipe and potentially remove biofilm from the walls of the pipe.

WATER VELOCITY AND FLOW RATE

Water velocity is measured in feet / second, it is the speed water is moving.

Flow rate and pipe diameter can be used to determine velocity.

The table below depicts estimated required flow rates in gallons per minute (gpm) to achieve 3 fps and not exceed 10 fps.

Pipe Size	Gallons per Minute flow (gpm)	
	@ 3.0 fps	@ 10 fps
½"	2.0	6
1"	7.3	24
2"	28	94
4"	109	364
6"	242	807
8"	422	1408
10"	656	2186
12"	940	3134

FLUSHING HYDRANTS

The table below depicts estimated required flow rates in gallons per minute (gpm) to achieve 3 fps and not exceed 10 fps for larger diameter pipes common in water mains.

Pipe Size	Gallons per Minute flow (gpm)	
	@ 3.0 fps	@ 10 fps
4"	109	364
6"	242	807
8"	422	1408
10"	656	2186
12"	940	3134
16"	1880	6267
24"	4230	14100

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