Shock Chlorination Guidance for Building Water Systems

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When buildings that are their own water system have been closed to the public or have had limited access for any reason. Please refer to the department's guidance on *Guidance for Legionella and Building Water Systems* 331-658. Prior to resuming full occupancy building managers ay detect unsatisfactory levels of bacteria, including *Legionella*, in their plumbing and decide to shock disinfect their building water systems. Shock chlorination may also be used as a precautionary step to protect building users.

This guidance is only intended for startup or remedial shock chlorination. If a building conducts routine batch chlorination more frequently, or operates continuous disinfection, the building water system is considered a public water system (*When an Institutional Building Becomes a Water System* 331-488) that is subject to the Washington State drinking water regulations WAC 246-290. This guidance is not intended for health care facilities.

There is no accepted standard for conducting whole building plumbing disinfection for existing buildings. Uniform Plumbing Code (UPC) and International Plumbing Code (IPC) require disinfection prior to occupancy. While both codes provide general requirements, detailed protocols for implementation are not provided. AWWA C651: Disinfection of Water Mains is often specified in construction documents, but is not intended for building water systems. The shock chlorination process described below uses a **continuous dose feed method for shock chlorination using sodium hypochlorite (free chlorine)** for potable water systems inside buildings. The information is purposely general in nature. Each building is different and will likely require slightly different actions based on its plumbing systems and source of water supply.

Preplanning and Equipment

Conducting effective whole building shock chlorination is a complex activity that requires knowledge of sodium hypochlorite and chemical handling and storage, dosing, pre-planning, and careful coordination between building staff and contractors. Certified water system professionals, water treatment contractors, and consulting engineers may have the skills and experience needed to assist building staff and should be employed as needed.

Secondary water quality effects including the release of accumulated biofilm, metals and sediments in the piping which might occur while shock chlorinating depending upon water quality and piping. Do not use this water for drinking or showering, toilet flushing is okay.

To ensure you and your employees' safety from both chemical and biological exposure while disinfecting and flushing the building plumbing, appropriate training and PPE should be utilized. You can find guidance on worker safety on the OSHA website.

To perform shock chlorination, all building water systems must have an accurate digital chlorine residual test kit that uses an EPA-approved test method for use in drinking water. Test strips and color wheels are not accurate and not recommended test methods for determining chlorine residual concentrations in potable water. Test strips and color wheels are only suitable for detecting the presence of chlorine in water.

Disinfection Basics

The effectiveness of microbial disinfection of water using free chlorine depends primarily upon the concentration of free chlorine and the amount of time the chlorine is in contact with the water. 'CT' is the term used in the drinking water industry to quantify disinfection. C stands for the 'concentration of free chlorine in milligrams per liter (mg/L)'. T stands for time in minutes. CT is the result of multiplying these two measurements. Example: If a free chlorine residual of 5 mg/L is measured in piping after 600 minutes (10 hours) of contact time, the CT equals 3,000 mg-min/L. (Note to readers – at low concentrations the terms 'mg/L' and parts per million (ppm) are equivalent).

Temperature and pH also impact chlorine disinfection efficacy against microbes, but these parameters may not be measured or easy to control in a building system. Consequently, we are recommending a CT target of 3,000 mg-min/L to account for ranges in temperature and pH, inactivation of different microbes and for biofilm growths. The chlorine concentration used in calculating CT is the lowest free chlorine residual measured throughout the building at the end of the hold time using an approved measuring device. For example, a free chlorine dose of 10 mg/L is applied. After 24 hours (1,440 minutes) you measure the free chlorine residual throughout the building and the lowest reading is 2.2 mg/L. The CT is 2.2 mg/l x 1440 min = 3,168 mg-min/L. At high chlorine doses, the sample may have to be diluted to accurately measure the residual with typical approved devices. Refer to your chlorine test kit instructions.

Using a high chlorine dose allows for shorter disinfection contact times. However, high doses require access control to avoid inadvertent exposure to people in the building. High dose disinfection can be appropriate for unoccupied buildings where access is limited and controlled, and where time constraints exist.

For situations where access to the water system is less controlled, consider using a lower initial dose and a longer contact time. There is little concern with inadvertent water contact with chlorine residuals less than 4 mg/L.

Cold and hot water systems may need to be handled separately. Fully disinfect the cold-water system by filling the pipes with super-chlorinated water achieving a CT of no less than 3,000 mg-min/L through all fixtures. Hot water systems can be disinfected by turning off the hot water heaters and boilers and disinfecting in a similar manner as described here.

Overview of Building Plumbing Shock Chlorination

There are many different approaches for shock chlorination of a building plumbing system. The approach presented here can be used as a starting point and modified to fit your specific building. This procedure involves creating a chlorine feed solution of either 1,000 mg/L or 2,000 mg/L concentration. A chemical feed pump is used to inject chlorine solution into the building's main water inlet line as water flows to fixtures inside the building. The amount of solution to be injected will vary by flow, your selected target dose, and the size of your building.

Super-chlorinated water is dosed into the building plumbing and dispersed to all fixtures by opening or operating fixtures in a methodical manner. Free chlorine residuals are measured to determine when super-chlorinated water has reached all the fixtures. The chlorinated water stays in the piping for the time needed to achieve your desired CT value. Once an appropriate amount of time has passed, the chlorine concentrations are measured at the various taps and the lowest free chlorine concentration is multiplied by the contact time to determine CT. If the CT value is not met, the contact time can be extended. If a satisfactory CT value cannot be achieved, the entire process will need to be repeated with a higher chlorine dose.

After a satisfactory CT value is achieved, the building plumbing is flushed with utility water by repeating the steps that were used to bring super-chlorinated water into the building. Flushing continues until measured chlorine residuals are equal to or slightly less than utility water entering the building.

Identify the Building's Operation Requirements

The following operational requirements will need to be identified as part of the design and planning process.

1. Find a suitable injection point. This is the location where chlorine will be injected into the building plumbing system. This point needs to be near where the water enters the building prior to any branch lines and <u>must be located downstream of any premise backflow assembly</u>. Check the backflow assembly testing records to ensure it's been tested within the last year or have it tested for proper function. The injection point must be a location such as a blow-off, hose bibb, or other access point where a chemical metering pump line can be connected to the building plumbing. If no such point is available, have a licensed plumber install an injection point.

2. Determine the maximum system water pressure at the chlorine injection point. The chlorine feed pump must be able to pump against this pressure.
3. The approximate design flow rate of water to be treated at the injection point in gallons per minute (gpm) (Q_s) will need to be estimated. This flow rate will vary depending upon how many fixtures can be opened to produce flow, and upon plumbing and personnel constraints. Several methods are available to determine the flow rate. Direct measurement of flows using a water meter is the best method. Some buildings have utility smart meters or radio read meters that produce real time water flow data. An ultrasonic meter that straps on the water pipe can be easily temporarily installed to aid in accurate chemical dosing. If no meter is available, Appendix D.2 of the Water System Design Manual (331-123) shows how the UPC fixture count method can be used to estimate water demand.
4. Determine how you will achieve the recommended 3,000 mg-min/L CT, including what free chlorine concentration you will target (C_t). You must decide how long you can allow the chlorinated water to sit in the building plumbing (the contact time) or calculate contact time based on the maximum and minimum free chlorine residual you wish to use so that the combination of contact time and chlorine residual results in the desired CT value. See *Disinfection Basics* section above.
5. Estimate the chlorine demand, mg/L (C_d). Chlorine demand is the reduction of the chlorine concentration over time and it occurs due to reactions occurring with pipe/plumbing materials, biofilms, ammonia, organics, iron and manganese, or other inorganics. If you have no idea what the chlorine demand is you can assume at least a 2.0 to 3.0 mg/L demand as an estimate. (Anticipate that some individual fixtures may show significant chlorine residual decay during the holding period).
6. Determine the chlorine residual entering the building. Measure chlorine residual of the water received from your water utility at or near the injection point identified in step 1 above in mg/L (C_U).
7. Estimate the initial chlorine dose. The required chlorine dose in mg/L (C_s), can be estimated with the following equation:

$$(C_s = C_t + C_d - C_U)$$

8. Select the sodium hypochlorite strength that you will use (for example, 6%, 8.25%, 12.5%). (C_C) Verify that the sodium hypochlorite is NSF 60 certified by noting the NSF symbol on the container.

Select Chemical Feed Pump

Using a flow paced chemical feed pump that is controlled by a water meter is the best option for flow based shock chlorination of a building. A flow based system will ensure consistent chlorine dosing even as different numbers of water fixtures are turned on and off. Choosing a non-flow based approach will require manual adjustments to the chemical feed pump and a very methodical process of trying to maintain constant flow into the building as you open and close fixtures. We recommend you consult an experienced professional for best results.

Work with a feed pump vendor, water treatment contractor, certified water system operator, or consulting engineer to select the appropriate chemical feed pump(s), and confirm that the selected feed pump will perform under the expected range of operating conditions.

A. Identify the pump's discharge pressure range, and confirm that the maximum pressure capacity of the pump is compatible with the maximum water pressure in the pipe at your injection point.
B. Identify the pump's volumetric discharge range in gallons per hour (gph), and confirm that the maximum and minimum capacities are compatible with the maximum and minimum range of flow to be treated at the point of injection. (Chemical feed pump discharge is usually specified in gph).
C. Confirm wetted parts of the feed pump are compatible with chemical solution being pumped (hypochlorite).
D. Identify the size of the chlorine feed tank that will be used with the feed pump. (Typical sizes are 15 and 30 gallons).

Mixing the Chlorine Feed Solution

Use the tables below to mix the indicated number of cups (1 cup = 8 oz) of chlorine stock with potable water in your feed tank.

Feed Solution of 1,000 mg/L (ppm)						
Chlorine Solution Strength	**6% chlorine**		**8.25% chlorine**		**12% chlorine**	
Tank Size (gal)	15	30	15	30	15	30
Chlorine Volume (cups)	4	8	3	6	2	4

Feed Solution of 2,000 mg/L (ppm)						
Chlorine Solution Strength	**6% chlorine**		**8.25% chlorine**		**12% chlorine**	
Tank Size (gal)	15	30	15	30	15	30
Chlorine Volume (cup)	8	16	6	12	4	8

Select Initial Chemical Feed Pump Setting

The values given in the tables below show the required feed rate (gal/hour) to provide example chlorine doses a several system flow rates. You may need to use a higher feed solution concentration depending upon individual building size and flows. It is advisable to check the feed pump rate using a stopwatch and calibration cylinder by pumping potable water with the chemical feed pump into the injection point under actual operating conditions. Measure the volume pumped during a set time.

For example, you fill a 1000 mL cylinder with water to the top and start the feed pump. When the level in the cylinder reaches the 1000 mL line you start the stopwatch. After 5 minutes you stop the pump and measure the amount of water remaining in the cylinder. When you stop the pump 250 mL is left in the cylinder. The feed pump rate is 2.4 gallons per hour.

$$\text{Feed pump rate (gph)} = \frac{\dfrac{1000\text{mL} - 250\text{mL}}{3785\,\dfrac{\text{mL}}{\text{gallons}}}}{5\text{ min x }60\text{ min/hour}}$$

		Feed Pump Rate (gph)							
	Feed Solution mg/L (or ppm)	1000				2000			
	Target Chlorine Dose (Cs) in mg/L	6	8	10	15	6	8	10	15
System Flow Rate (gpm)	5	1.8	2.4	3	4.5	0.9	1.2	1.5	2.3
	10	3.6	4.8	6	9	1.8	2.4	3	4.5
	15	5.4	7.2	9	13.5	2.7	3.6	4.5	6.8
	20	7.2	9.6	12	18	3.6	4.8	6	9
	25	9	12	15	22.5	4.5	6	7.5	11.3
	50	18	24	30	45	9	12	15	22.5

Estimating the initial pump setting can provide a good starting point but the pump settings will need to be adjusted while dosing based on the chlorine demand of the system and variability in flow rate while performing the shock chlorination.

Feed pump installation and operation should follow manufacturer's recommendations.

Checklist of Additional Items and Pre-event Actions

1. Based upon your understanding of the building plumbing system and using building mechanical and plumbing drawings, plan a logical method to draw water to every fixture. For example, some large buildings have a "backbone" of larger piping to convey water to various points of use. The chlorination strategy will need to consider the best way to convey super-chlorinated water through the larger piping and then the smaller feeder lines to the various taps. One approach, for a multi-story building with a central riser pipe, is to start at the end of the main riser pipe (or header) and open taps to draw the super-chlorinated water to the end of this pipe first. Once the measured free chlorine concentration at the end of the riser matches the measured injection dose concentration, then begin on the lowest floors drawing the chlorinated water out to each fixture and systematically work up through each successive floor in the building. If you are not using a flow paced feed pump you must try your best to keep flows in the building as constant as you can and periodically verify the chlorine concentration after the injection point for consistency.

   The hot water plumbing system will present additional challenges such as hot water tanks that will have to be considered.

2. Identify all chlorine residual sampling locations:
   a. Utility supply water.
   b. Initial treated water, far enough downstream from the injection spot for complete

mixing of the chlorine. A pump, valve, elbow, or other fitting will also provide mixing. Use this location to verify your injection dosing concentration.

   c. Representative locations for drawing water throughout the entire building. Initial and end of hold time chlorine residuals at these sites will be measured, recorded and used to determine if the CT goal is met. You may want to include critical taps or features such as ice machines or shower heads.

3. Identify existing water piping, water taps, toilets and water using devices including ice machines and dish washers that will need to be operated to bring super-chlorinated water to them.
4. Create data sheets for recording chlorine residuals and locations. You will want initial and final chlorine residuals. For each measurement, include the time the measurement was made and who took the measurement.
5. Make sure that primary sink and shower locations used to draw chlorinated water into the water lines and to flush the system after batch chlorination have functioning drains that can handle expected flows without overflowing.
6. Likewise, if your building is not served by a sewer system be sure that your drain field can handle the expected volume of water. Check with your local authority to determine if dechlorination is needed.
7. Communication devices for all staff – two way radios, if using cell phones check reception.
8. A method for staff that are flushing to estimate flow rates if needed. (A bucket of known size or quart container and stopwatch may be sufficient).
9. Approved chlorine test kits. DOH recommends using only a digital colorimetric testing device employing an EPA-approved analytical method for measuring chlorine residual concentrations. Document the make and model of your chlorine residual test kits, and the type and expiration date of your testing reagents.

Conducting Shock Chlorination

1. Notify building occupants.
2. Don't forget worker safety. You can find guidance on worker safety on the OSHA website.
3. Measure and record utility chorine residual.
4. Open initial taps to ensure that water is flowing into the building.
5. Start the chlorination feed system and measure chlorine residual downstream from injection point. Adjust chlorination system to get approximate target dose. This will be approximate. Additional adjustments will be necessary as flows change and chlorine demand is satisfied. Periodically recheck the chlorine concentration downstream from the

injection point through the shock chlorinating procedure to ensure the chlorine feed is consistent.

6. Continue to flush the initial taps until chlorinated water is measured at the target concentration. This may take a while and need adjustments to the chemical feed pump rate. Opening more taps at the end of the main riser pipe will increase flows and decrease time needed to complete this step.
7. Once super-chlorinated water reaches initial taps, begin moving through the building opening and closing taps following your plan. Trying to keep approximately the same number of open taps will help keep feed pump dosing constant. Flushing personnel may use a visual presence/absence method using DPD reagent or test strips to signal that super-chlorinated water has reached every single tap / fixture. Actual chlorine residual concentrations must be measured at the pre-determined sampling sites identified in step 2C in the pre-event action items section above.
8. Measure and record chlorine residuals as you continue to pull super-chlorinated water through the building to verify the desired concentration of chlorinated water has been distributed to all parts of the building plumbing system. Remember to rinse your chlorine test sample vial 3 times to eliminate residual chlorine remaining in the vial from the previous test that may affect results.
9. When the desired chlorine residual has been reached at all sample taps, shut down the flow in the taps, and turn off the chlorine feed system if not using a flow paced system.
10. At the end of the hold time check chlorine residuals at critical points of the building plumbing system and verify the target minimum residual was met. Generally this would be at several locations with the longest residence time (most distal). If the chlorine level is too low, you may be able to extend the hold time to achieve the desired CT.
11. After the shock chlorination procedure and all testing is complete, flush the super-chlorinated water out of the plumbing using the same flushing approach that you used initially (without using the chlorine feed pump) until chlorine residual throughout the building is about the same as the level entering the building from the utility indicating that the shock chlorinated water has been removed. Record these chlorine residuals.
12. Walk through the building and make sure all fixtures are turned off and all features are operable.
13. You may return to service following verification that water throughout the building has the same or lower chlorine residual as the chlorine residual of the utility water.

Follow-up Actions

1. Write up a brief summary – stating target chlorine dose applied, initial chlorine residuals measured, final chlorine residuals measured, contact time and CT value achieved. Include any lessons learned.
2. Microbial testing, after an appropriate number of days, is often performed following shock chlorination. The type of organisms to test, the number of samples, sample locations, sample collection timing and interpretation of results are determined in a large part by what the reasons were for conducting the shock chlorination. Since this guidance is focused on shock chlorination process no recommendations regarding follow up microbial validation testing are included. You should consult with applicable agencies having jurisdictional authority and your contracted professionals in designing an appropriate microbial testing structure.

Resources

1. https://engineering.purdue.edu/PlumbingSafety/covid19/index_html
2. https://legionellae.org/wp-content/uploads/European-Society-of-Clinical-Microbiology-and-Infectious-Diseases-Guidance-for-Managing-Legionella-During-the-Coronavirus-Pandemic.pdf
3. https://esprinstitute.org/wp-content/uploads/2020/04/FINAL_Coronavirus-Building-Flushing-Guidance-20200403-rev-1.pdf

For more information

More emergency resources are available on our Drinking Water Emergencies webpage.

Our publications are online at doh.wa.gov/drinkingwater.

Contact our nearest regional office from 8 AM to 5 PM, Monday through Friday. If you have an after-hours emergency, call 877-481-4901.

Eastern Region, Spokane Valley 509-329-2100.

Northwest Region, Kent 253-395-6750.

Southwest Region, Tumwater 360-236-3030.