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Disinfection of Water System Components

by

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Course 406
4PDH (4 Hours)

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Disinfection of Water System Components

Course Outline:

Disinfection of Water System Components

Purpose of Surface Disinfection

The purpose of surface disinfection of water system components is to inactivate microorganisms that may be present on interior surfaces and thereby protect the potable water system from biological contamination. Surface disinfection involves the application of a disinfectant chemical to all interior (or wetted) surfaces before placing the components into service.

Without proper surface disinfection, there is a risk that drinking water may become contaminated and people may become sick from a waterborne disease. There have been several waterborne disease outbreaks traced back to a lack of cleaning and disinfection of components such as pipes, pumps, fire hydrants, and storage tanks. It is important to realize that microorganisms naturally grow on virtually every surface and most of the time they cannot be seen or felt. See Figure 1 for an example.

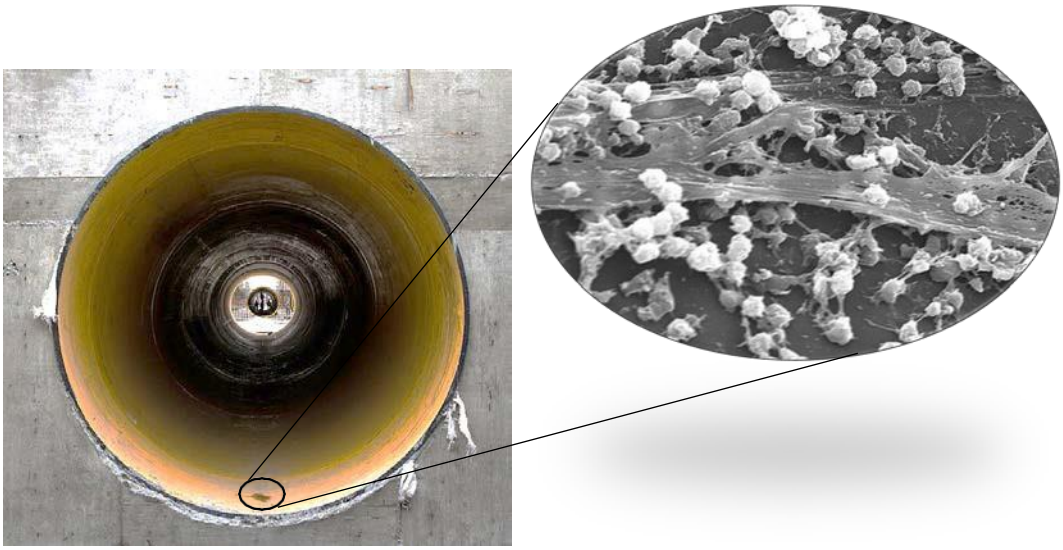


Figure 1: On left, a newly installed pipe with an interior surface that appears clean. On right, a non-visible biofilm viewed under a microscope, which reveals spherical-shaped bacteria called staphylococcus aureus, a dangerous pathogen.
Source (right): Tomas Castelazo, www.tomascastelazo.com / Wikimedia Commons / CC BY-SA 4.0

Disinfection of Water System Components

Although water supply systems normally have a disinfectant residual in the water, such as free chlorine or chloramines, the residual level alone cannot be relied on to ensure the deactivation of microorganisms from components introduced without having been disinfected. The risk is even greater if the wetted surfaces have not been cleaned and/or flushed, as the layer of organics will reduce the chlorine residual, which is the last defense to eliminate any newly introduced pathogens before the water is consumed.

Wetted Surfaces

The term *wetted surface* is often used to describe any interior surface which is in contact with the service water (potable water or water being treated to become potable water). For example, for a new water main installation, the interior of the pipe and the joints up to and including any gaskets would be considered wetted surfaces. Also, the interior of the fire hydrant and the inside of the outlet cap are wetted surfaces. The exterior surfaces of the piping and fire hydrants are not considered wetted surfaces. However, if a pipe is installed submerged inside a water storage tank, wet well, or treatment process, then the pipe exterior would be considered a wetted surface.

The goal of surface disinfection is to apply a disinfectant to all wetted surfaces for a sufficient time to inactivate microorganisms.

Regulations and Standards

Surface disinfection is a regulatory requirement to protect public health. If public water system (PWS) components are placed into service without surface disinfection, a fine, penalty, or other legal action may be taken on the contractor, engineer, and/or utility. Surface disinfection requirements are specified and enforced by state and local environmental or health agencies. The vast majority require adherence to the following AWWA standards:

- C651 - Disinfection of Water Mains
- C652 - Disinfection of Water Storage Facilities
- C653 - Disinfection of Water Treatment Plants
- C654 - Disinfection of Wells

Often, local regulations require following these standards in addition to several more stringent requirements. For example, specific procedures for bacteriological testing and clearance for service are often specified in state regulations. The water utility may also have specific standard procedures to help ensure consistency and quality in disinfection practices. The applicable regulations and standards should be reviewed as part of the planning process for surface disinfection.

This course will cover the disinfection methods found in the above-listed AWWA standards.

Disinfection of Water System Components

Disinfection Chemicals

Many chemicals can disinfection surfaces by inactivating microorganisms. Examples include alcohol, hydrogen peroxide, chlorine, many acids, and most cleaning chemicals. However, most of these chemicals are not appropriate for the disinfection of PWS components because they can have a negative impact on human health. Chemicals used for disinfection need to be NSF 60 approved or FDA approved as safe for adding to drinking water. Also, several potential chemicals are very dangerous to handle. And some acids are so strong they will damage the gaskets in pipe joints.

Given the options, chlorine is the chemical of choice for surface disinfection of PWS components. Chlorine has been used for disinfection in drinking water for over 100 years. The AWWA standards only list the following chlorine chemicals as options for disinfection of PWS components:

1. Liquid chlorine (gas)
2. Sodium hypochlorite
3. Calcium hypochlorite

Although each chemical has very different properties, they produce the same result once dissolved in water. The chemical dissolves and chlorine molecules become available to interact with ammonia, organics, and organisms. Chlorine breaks down the outer membranes of gram-negative bacteria, including those that cause typhoid fever, dysentery, cholera, and Legionnaires' disease. Chlorine is also effective in eliminating gram-positive bacteria, viruses, and most protozoa. However, the effectiveness depends on the chlorine concentration and the contact time.

The AWWA standards specify a combination of chlorine concentration and contact time that is proven to remove more than 99.99% (4-log) of bacteria and viruses. A report by AWWARF entitled *Development of Disinfection Guidelines for the Installation and Replacement of Water Mains* documents the results of actual field evaluations to test and confirm the adequacy of AWWA Standards for disinfection with chlorine. The report confirms the 4-log removal and concludes that heterotrophic plate count (HPC) bacteria are reduced to less than 100 colony-forming units per milliliter (CFU/mL).

Disinfection of Water System Components

Liquid Chlorine (gas)

Liquid chlorine comes in high-pressure cylinders. The chemical has 100% available chlorine since it is pure chlorine. Although stored in the liquid form, it is common to refer to it as chlorine gas since when the valve is opened, the chlorine releases in the gaseous form. It is the least expensive form of chlorine. However, it has safety risks and requires experienced operators and special injection equipment.

A chlorine gas cylinder can be connected to a water main with a flow regulator and injector assembly. See Figure 2 for an example. Another approach is to inject the gas into a water line that fills a storage tank of chlorine solution, and then use the solution for disinfection purposes.

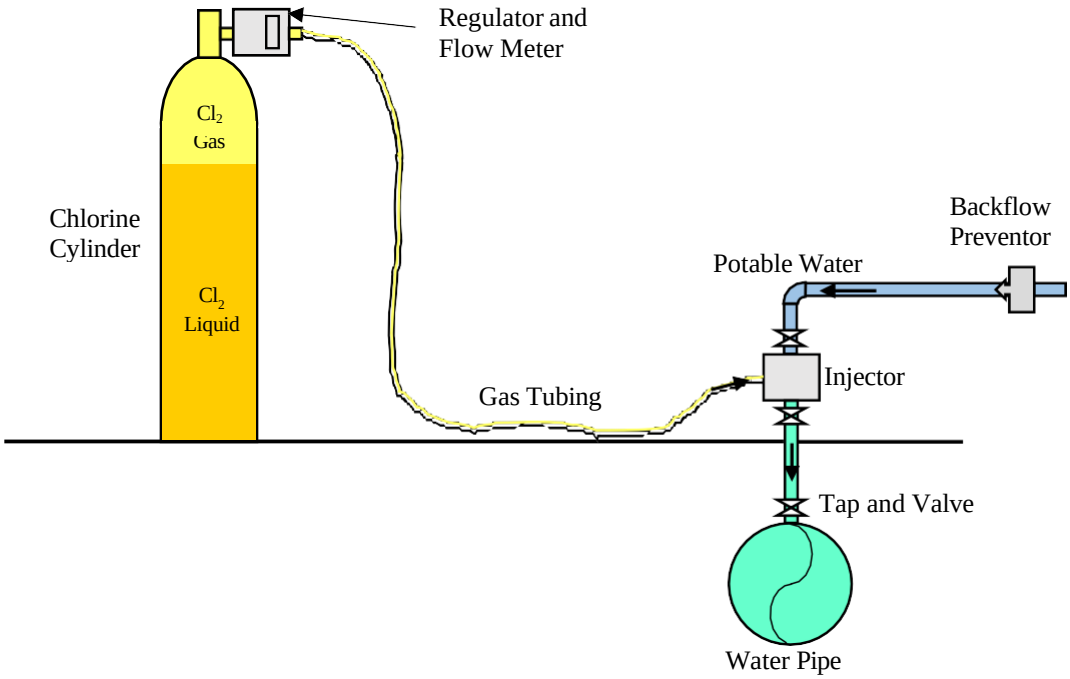


Figure 2: Arrangement for injecting chlorine gas into water piping.

When injected into water, the gaseous bubbles quickly dissolve into the water according to the following reaction:

$$Cl_2 + H_2O \rightarrow HOCl + H^+ + OCl^-$$

Because hydrogen ions are produced, the water will become more acidic (the pH of the water will decrease). Together, the hypochlorous acid (HOCl) and the hypochlorite ions (OCl^-) are referred to as free chlorine. Both forms act to inactivate microorganisms.

Disinfection of Water System Components

Sodium Hypochlorite

Sodium hypochlorite is readily available in the liquid form. Most water treatment plants have storage tanks with sodium hypochlorite available for disinfection purposes. The most common concentration is 12.5% by weight (15% by volume). Sodium hypochlorite is commonly called bleach, although bleach available in the store, and bleach used for swimming pools, should not be used since they contain other additives and are typically not NSF 60 approved.

The sodium hypochlorite solution is often diluted before use because at concentrations over 1% it is very corrosive and can quickly damage gaskets, linings, coatings, and some metallic surfaces. The solution can be pumped into pipes, tanks, or spray containers for disinfection purposes. See Figure 3 for an example.

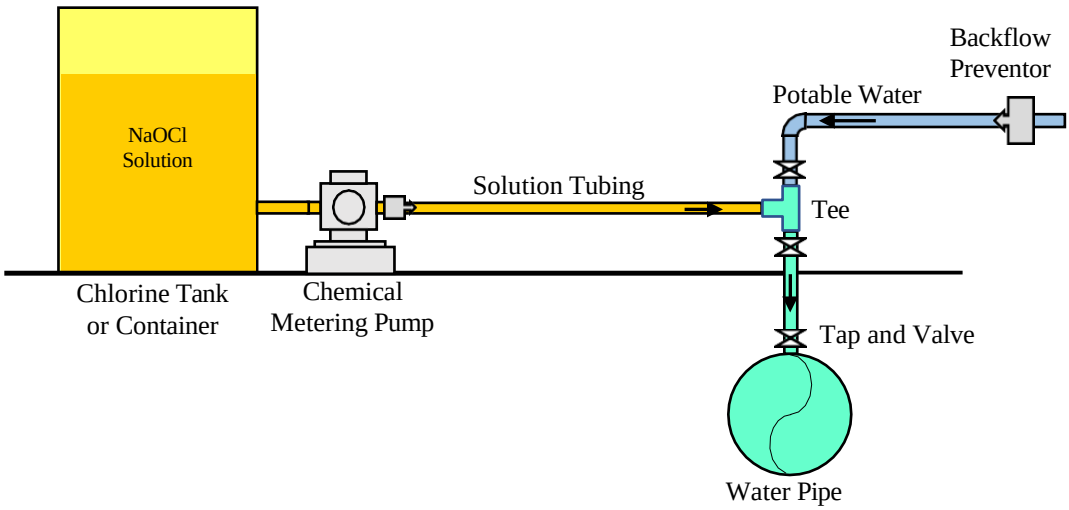


Figure 3: Arrangement for injecting sodium hypochlorite into water piping.

The sodium hypochlorite solution contains hypochlorite ions (OCl^-), which is the disinfectant. Here is the basic dissolution reaction:

$$NaOCl \rightarrow Na^+ + OCl^-$$

Disinfection of Water System Components

Calcium Hypochlorite

Calcium hypochlorite is readily available in solid form as granules and tablets. This is commonly called HTH (high test hypochlorite). See Figure 4 for examples of available products. The AWWA standards specify for granules and tablets to contain approximately 65 percent available chlorine. Products for swimming pools should not be used since they contain other additives and are typically not NSF 60 approved.

Figure 4: Calcium hypochlorite tablets (left) and granules (right).

Once exposed to water, hypochlorite ions (OCl^-) are produced, which is the disinfectant. Here is the dissolution reaction:

$$Ca(OCl)_2 \rightarrow Ca^{+2} + 2OCl^-$$

Chlorine Testing

For testing the free chlorine concentration, it is common to use the following methods:

- DPD (N,N-diethyl-p-phenylenediamine) drop dilution method (see Figure 5),
- Colorimetric chlorine test kit,
- Chlorine test strips (after dilution), and
- Chlorine analyzer.

See the Appendices of AWWA C652 and the Helpful References section for additional information on chlorine testing.

Disinfection of Water System Components

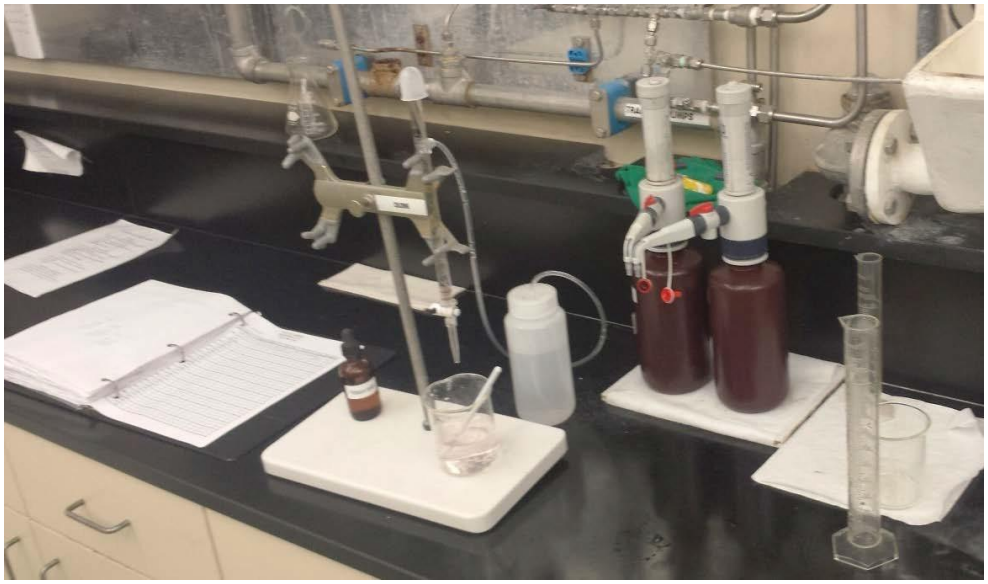


Figure 5: Lab setup for DPD drop dilution method test for chlorine.

Dangers of Chlorine Exposure

All chlorine handling should be done by experienced professionals. Mishandling chlorine can result in serious injury. When a high concentration of chlorine (gas or liquid) encounters the human body, an acid is produced that damages the tissue. Chlorine gases can damage the eyes, throat, and lungs. If someone is exposed to a high concentration of chlorine, seek medical assistance immediately.

Chemical Calculations

AWWA C651 contains several tables that help determine the amount of chlorine to add to achieve the minimum concentration. Common formulas for calculating chlorine dosing can be found in the *Water Distribution System Operation and Maintenance: A Field Study Training Program*.

Chlorine concentrations can be expressed in units of mg/L or ppm (parts per million), which are considered equivalent when chlorine is mixed with potable water under normal conditions. A 1% solution (by weight) is approximately 10,000 mg/L.

The chlorine dose is the *total chlorine*, which equals the sum of the *free chlorine* (also called residual chlorine) and the *combined chlorine*.

Total Chlorine = Free Chlorine + Combined Chlorine

Disinfection of Water System Components

For surface disinfection, the free chlorine component is relied upon to inactivate organisms. For this reason, field tests are focused on confirming the free chlorine concentration (instead of total chlorine). The combined chlorine concentration is typically around 2 to 8 mg/L (depending on the potable water quality). Therefore, if a free chlorine concentration of 100 mg/L is desired, a minimum total chlorine dosage of 102 to 108 mg/L would be required (2 to 8% extra chlorine).

Example 1: Engineer Sally is planning for the disinfection of a new water main that is 8" diameter and 1,000 feet long. She has determined that the pipe needs to be filled with a chlorine solution with a minimum free chlorine concentration of 25 mg/L. How many gallons of 12.5% sodium hypochlorite is required?

Solution: First, Sally calculates the volume of the pipe:

$$VVVVll_{pppppppp} = \frac{\pi\pi}{4} dddaa^2 * lllllllllh = \frac{\pi\pi}{4}\left(\frac{8}{12} ffll\right)^2 1{,}000 ffll = 350 ffll^3 \left(\frac{7.48 llaall}{1\ ffll^3}\right)$$

$$= 2{,}611 llaall$$

Next, Sally converts the sodium hypochlorite concentration to mg/L:

$$CCll_{hyyppyy} = \%ssVVll * 10{,}000\ \frac{mmll}{LL} = 12.5 * 10{,}000\ \frac{mmll}{LL} = 125{,}000\ \frac{mmll}{LL}$$

Sally determines the required total chlorine concentration by adding the free chlorine concentration of 25 mg/L, plus an assumed combined chlorine concentration of 8 mg/L, for a total of 33 mg/L. Finally, Sally uses the dilution equation to calculate the required volume of sodium hypochlorite, which can be rounded up to 0.7 gallons:

$$VVVVll_{hyyppyy} = \frac{VVVVll_{pppppppp} * CCll_{pppppppp}}{CCll_{hyyppyy}} = \frac{2{,}611 llaall * 33\ \frac{mmll}{LL}}{125{,}000\ \frac{mmll}{LL}} = 00.6666\ ggggggg\ oooo\ hhyyppoo$$

Example 2: Continuing with Example 1, the installation foreman informs Sally he is only experienced with using HTH. How many pounds of granules are required?

Solution: Sally uses the following chemical dosage formula to calculate the minimum pounds of HTH granules. Note that standard granules contain 65% chlorine.

$$lll_{HHHHHH} = 2{,}611 llaall * \frac{1\ MMMM}{10^6\ ggggggg} * 8.34\ \frac{gll}{ggggggg} * 33\ \frac{mmgg}{LL} * \frac{100\%}{65\%} = 11.11\ ggll\ oooo\ HHHHHH$$

Disinfection of Water System Components

Water Mains

The disinfection of water mains (and other water pipes) is a common practice occurring regularly in communities across the world. Every time a water pipe is installed, replaced, or repaired; disinfection practices must be followed to prevent contamination of the PWS. AWWA C651 lists the following methods as options:

1. Tablet/Granule
2. Continuous
3. Slug
4. Spray
5. Swab

Each of these methods is described as follows.

Tablet/Granule Method

This method involves placing calcium hypochlorite granules or tablets inside the pipe during installation and then filling the pipe with water to form the chlorine solution for disinfection. The steps in this method are as follows:

1. Cleaning: Pipes must be kept clean and dry during installation. Pipe ends may need to be capped during rain events and overnight. Each pipe section should be inspected after installation to confirm cleanliness. High-velocity flushing of the pipe is not required for this method.
2. Placing granules/tablets: Calcium hypochlorite granules or tablets are to be placed at the beginning of the pipeline, the beginning of each branch, and at regular intervals in all pipelines. The goal is to place enough granules/tablets to produce at least 25 mg/L of available chlorine (it is not required to test the free chlorine concentration for this step). The intervals and quantities differ for granules versus tablets:
    a. Granules (see Figure 6):
        i. Place piles of granules at 500-foot intervals.
        ii. Piles with 65% chlorine shall have a minimum weight (W):
            - $W_{oz} = 15.1 \times D^2$ (in ounces)
            - $W_g = 428 \times D^2$ (in grams)

              where D is inside pipe diameter in feet

b. Tablets (see Figure 7):
    i. Attach tablets with adhesive (NSF 61 Approved) to the top of the inside of the pipe at each pipe section.
    ii. Attach the following quantity of 5-gram tablets in each pipe section:
        - Quantity = $0.0012 \times d^2 \times L$
          where d is inside pipe diameter in inches
          and L is the length of the pipe sections

3. Filling with Water: After the installation of the pipeline is complete, connect a water supply, and slowly fill it with water. Flow rate should not exceed the equivalent of a full pipe velocity of 1 ft/s. If a direct connection is made to a fire hydrant or other PWS device, a backflow preventer or other approved cross-connection control device is required.
4. Hold Time: The chlorinated water shall be held in the pipe for at least 24 hours. If the water temperature is below 41 deg F (5 deg C), the hold time shall be 48 hours.
5. Check Chlorine Concentration: At the end of the hold time, the concentration of free chlorine shall be tested and confirmed to be equal or greater than 0.2 mg/L at each sample location. Typically, the chlorine sample locations are the same as for bacteriological sample locations:
    a. At the beginning of the pipeline,
    b. At a maximum of 1,200-foot intervals,
    c. At the end of the pipeline,
    d. At the end of each branch greater than a pipe section long.
6. Flushing: Flush out the chlorinated water with potable water such that the free chlorine concentration is between 0.4 mg/L and 4 mg/L (or as otherwise required by local regulations). The discharged water may require dechlorination before disposal, per AWWA C655 entitled “Field Dechlorination”.
7. Bacteriological Testing: Test for the presence of total coliform, or fecal coliform, at each sample location. Tests should be repeated a minimum of 16 hours later (some agencies require the two sets of tests on back-to-back days). If results are negative, a submittal is made to the agency having jurisdiction for clearance to place the water main into service.
8. Place into Service: The piping can be connected (use spray or swab method for disinfection of connections) and placed into service by the opening of isolation valves, once clearance has been obtained. Typically, there is a time limit of 60 days after clearance to place items into service, after which disinfection and testing procedures must be repeated.

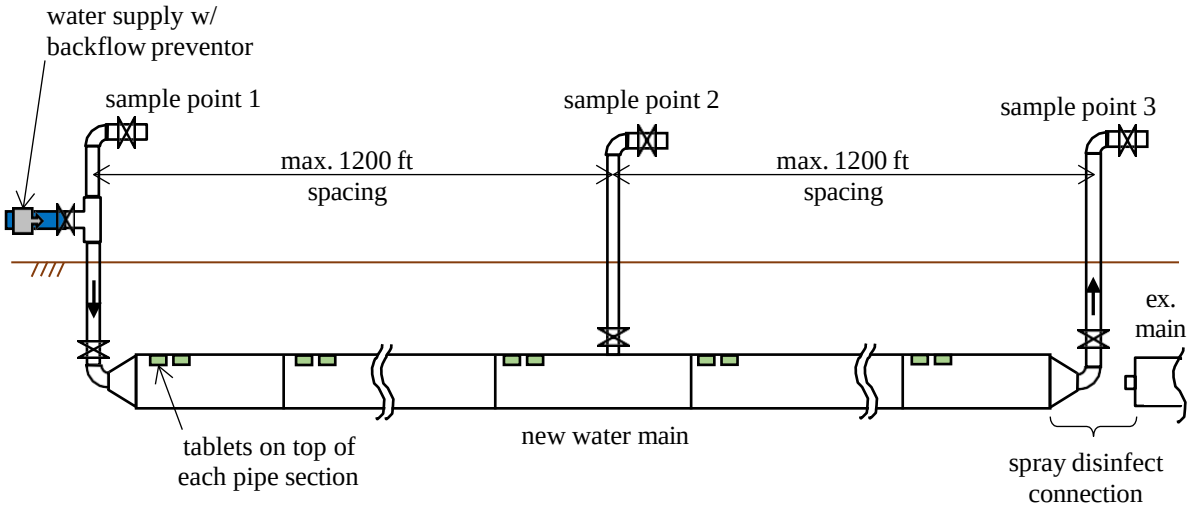


Figure 6: Tablet method for disinfecting a new water main. Once the water supply valve is opened, the pipe will fill with water and the chlorine tablets dissolve.

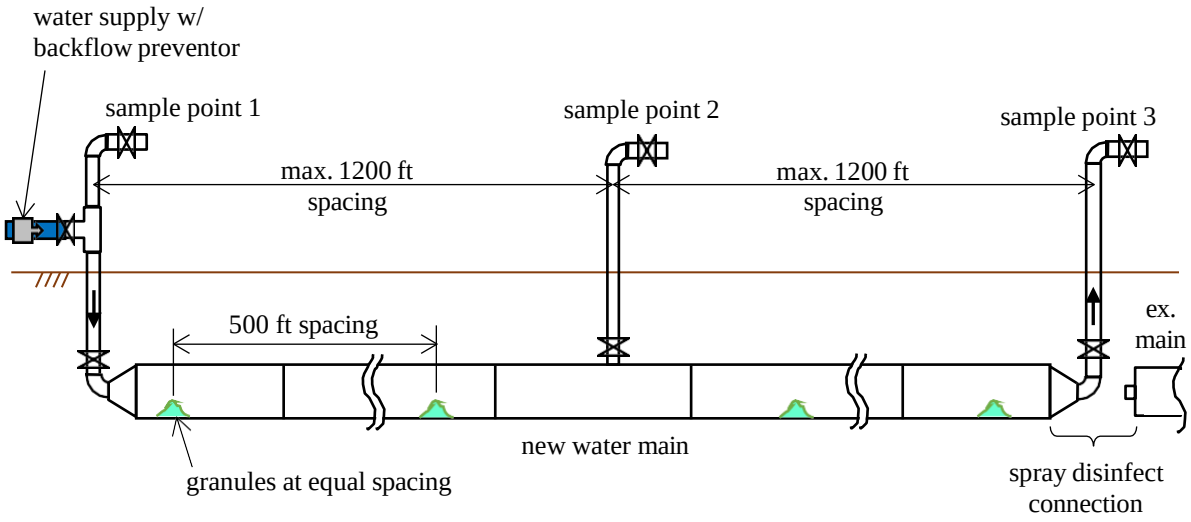


Figure 7: Granule method for disinfecting a new water main. Once the water supply valve is opened, the pipe will fill with water and the chlorine granules dissolve.

See Figure 8 for an example test report for the tablet/granule method. Note that with the tablet/granule method, disinfection must be done during or after disinfection.

DISINFECTION REPORT
TABLET/GRANULE METHOD

Project Name:	Example project
Project Number:	XX-XXX
Location:	Example, XX
Contractor:	ABCD Corp.
Inspector:	John Doe, Sr
Engineer:	John Doe, Jr, P.E.
Pipes Disinfected:	New XX" water main, XXX ft long
AWWA Method:	AWWA C651 Tablet/Granular Method

Placement of Calcium Hypochlorite

Calcium Hypochlorite Product:	DryTec 23203, Calcium Hypochlorite Granular, 68% concentration, NSF Approved, meets AWWA C651, 4.1.3.
Description of Approach:	Pipe sections washed clean prior to installation. Pipe kept dry by plugging open ends overnight. X.X oz of granules placed inside the first section of pipe and at 500 ft intervals.

Disinfection

Description of Approach:	Potable water slowly introduced into the pipe at location A until the entire pipe section was filled and water was coming out the tap at location B. The valves were closed and the solution held in the pipe. After the required waiting period, the chlorine level was checked to confirm compliance. Finally, potable water was introduced to flush out the chlorine solution.			
Start of Holding Time:	12/14/20 11:00 AM	date & time		
End of Holding Time:	12/15/20 12:00 PM	date & time	Note: 48 hrs req if water temp <41 deg F	
Time Elapsed:	25.00	hours		
Min. Time Required:	24.00	hours	In Compliance?	Yes
Ending Chlorine Conc.	3.0	mg/L (free)		
Min. Ending Chlorine Conc.:	0.2	mg/L (free)	In Compliance?	Yes

Bacteriological Testing

Max. Chlorine Conc. Allowed:	4.0	mg/L (free)		
Day 1 Sample Point 1:	12/15/20 1:00 PM	date & time		
Chlorine Conc.:	1.8	mg/L (free)	In Compliance?	Yes
Day 1 Sample Point 2:	12/15/20 1:30 PM	date & time		
Chlorine Conc.:	1.2	mg/L (free)	In Compliance?	Yes
Day 2 Sample Point 1:	12/16/20 1:00 PM	date & time		
Chlorine Conc.:	1.3	mg/L (free)	In Compliance?	Yes
Day 2 Sample Point 2:	12/16/20 1:30 PM	date & time		
Chlorine Conc.:	0.6	mg/L (free)	In Compliance?	Yes

Compliance

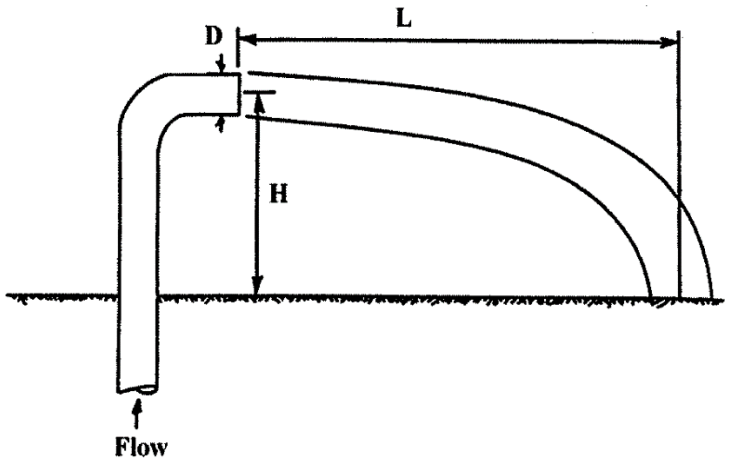
X	This test DOES comply with AWWA standards and project specifications
	This test DOES NOT comply with AWWA standards and project specifications

Figure 8: Example disinfection report for the tablet/granule method.

Continuous Method

This method involves flushing the pipeline, then filling it with a solution of a minimum of 25 mg/L free chlorine and holding it for 24 hours. AWWA C651 uses the term continuous-feed method, however, chlorine does not need to be fed continuously. The steps in this method are as follows:

1. Flushing: Fill the piping with water to remove air pockets and flush with pressurized water such that the velocity is at least 3.0 ft/s. If a flow meter is not available, the flow rate can be estimated by measuring the distance the water discharges, as depicted in Figure 9. For pipes larger than 24-inch diameter, it is acceptable to broom sweep the pipe instead of flushing.



$$\text{Flow}_{\text{gpm}} = \frac{2.83\ (DD_{iiii})^2(LL_{iiii})}{\sqrt{HH_{iii}}}$$

Figure 9: Formula for estimating flow rate by measuring the average distance traveled by the discharged water.

2. Adding Chlorine Solution: The piping is to be filled with a chlorine solution that results in a free chlorine concentration of at least 25 mg/L. See Figure 10 for an example arrangement. Note that chlorine interacts with any ammonia, organics, and organisms in the water and on pipe surfaces, such that the free chlorine will be less than the total chlorine added. Thus, it is common to add double the required chlorine. A maximum chlorine concentration is not specified in AWWA C651, however, any concentration over 1% (10,000 mg/L) has the potential to damage components such as gaskets. Also, the higher the chlorine concentration, the more flushing is needed before bacteriological testing.

Common methods for adding chlorine are as follows:

a. Chlorine gas: A chlorine cylinder can be connected to a water supply that fills the pipe with the chlorine solution, as shown in Figure 2. If a direct connection is made to a fire hydrant, an approved cross-connection control device is required. Another approach is to inject the gas into a water line that fills a storage tank with a chlorine solution, and then the pipe is filled with the solution.
b. Granules/Tablets: Add granules or tablets to a storage tank and fill the tank with water to create a chlorine solution. Fill the pipe with the solution.
c. Sodium Hypochlorite: A storage tank with a diluted sodium hypochlorite solution is used to fill the pipe, as shown in Figure 3.

3. Check Chlorine Concentration: The concentration of free chlorine shall be tested and confirmed to be equal to or greater than 25 mg/L. Typically, the chlorine sample locations are the same as for bacteriological sample locations. See Step 5 of the Tablet/Granule method for the sample intervals for long pipelines.
4. Hold Time: The chlorinated water shall be held in the pipe for at least 24 hours. During the hold time, it is acceptable to let a continuous flow of chlorine solution enter the pipe and discharge out the end (at a low flow rate) to ensure the free chlorine concentration does not drop below 10 mg/L.
5. Check Chlorine Concentration: At the end of the hold time, the concentration of free chlorine shall be tested and confirmed to be equal or greater than 10 mg/L at each sample location.
6. Flushing: Flush out the chlorinated water with potable water such that the free chlorine concentration is between 0.4 mg/L and 4 mg/L (or as otherwise required by local regulations). The discharged water may require dechlorination before disposal, per AWWA C655 entitled “Field Dechlorination”.
7. Bacteriological Testing: Test for the presence of total coliform, or fecal coliform, at each sample location. Tests should be repeated a minimum of 16 hours later (some agencies require the two sets of tests on back-to-back days). If results are negative, a submittal is made to the agency having jurisdiction for clearance to place the water main into service.
8. Place into Service: The piping can be connected (use spray or swab method for disinfection of connections) and placed into service by the opening of isolation valves, once clearance has been obtained. Typically, there is a time limit of 60 days after clearance to place items into service, after which disinfection and testing procedures must be repeated.

Disinfection of Water System Components

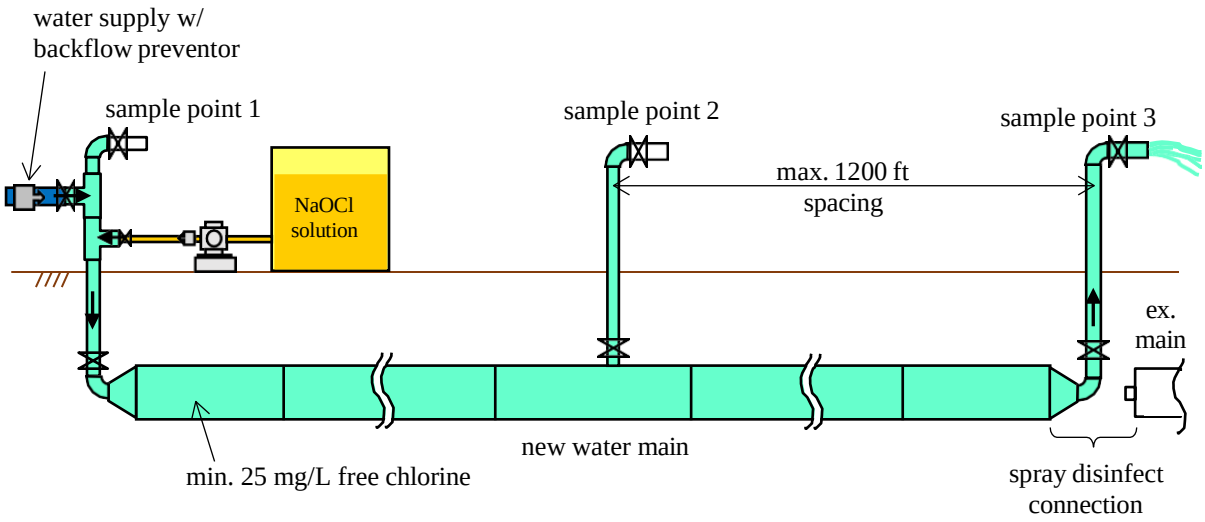


Figure 10: Continuous method for disinfecting a new water main. The pipe is being filled with water and the chlorine solution.

See Figure 11 for an example test report for the continuous method.

DISINFECTION REPORT
CONTINUOUS FEED METHOD

Project Name:	Example project
Project Number:	XX-XXX
Location:	Example, XX
Contractor:	ABCD Corp.
Inspector:	John Doe, Sr
Engineer:	John Doe, Jr, P.E.
Pipes Disinfected:	New XX" water main, XXX ft long
AWWA Method:	AWWA C651 Continuous Feed Method

Flushing

Description of Approach:	Potable water was pumped into the pipe at location A. Flushing water discharged out the X" tap at location B. Air pockets were removed and flushing was continued for 30 minutes.			
Pipe Flushing Complete:	12/14/20 8:00 AM	date & time		
Flushing Velocity (Approx):	3.0	fps		
Min. Flushing Velocity Req.:	3.0	fps	In Compliance?	Yes

Disinfection

Chlorine Chemical:	Mixture of 12.5% sodium hypochlorite (NSF Approved) and potable water to produce a 1% chlorine solution, meets AWWA C651, 4.4.3.			
Description of Approach:	The chlorine solution was pumped into the pipe at location A until the entire pipe section was filled and the chlorine solution was coming out the tap at location B. The valves were closed and the solution held in the pipe. After the required waiting period, the chlorine level was checked to confirm compliance. Finally, potable water was introduced to flush out the chlorine solution.			
Start of Holding Time:	12/14/20 11:00 AM	date & time		
End of Holding Time:	12/15/20 12:00 PM	date & time		
Time Elapsed:	25.00	hours		
Min. Time Required:	24.00	hours	In Compliance?	Yes
Starting Chlorine Conc.	52	mg/L (free)		
Min. Starting Chlorine Conc.:	25	mg/L (free)	In Compliance?	Yes
Ending Chlorine Conc.	13	mg/L (free)		
Min. Ending Chlorine Conc.:	10	mg/L (free)	In Compliance?	Yes

Bacteriological Testing

Max. Chlorine Conc. Allowed:	4.0	mg/L (free)		
Day 1 Sample Point 1:	12/15/20 1:00 PM	date & time		
Chlorine Conc.:	1.8	mg/L (free)	In Compliance?	Yes
Day 1 Sample Point 2:	12/15/20 1:30 PM	date & time		
Chlorine Conc.:	1.2	mg/L (free)	In Compliance?	Yes
Day 2 Sample Point 1:	12/16/20 1:00 PM	date & time		
Chlorine Conc.:	1.3	mg/L (free)	In Compliance?	Yes
Day 2 Sample Point 2:	12/16/20 1:30 PM	date & time		
Chlorine Conc.:	0.6	mg/L (free)	In Compliance?	Yes

Compliance

X	This test DOES comply with AWWA standards and project specifications
	This test DOES NOT comply with AWWA standards and project specifications

Figure 11: Example disinfection report for the continuous method.

Slug Method

This method involves flushing the pipeline, then filling it with a solution of a minimum of 100 mg/L free chlorine that stays in contact with surfaces for a minimum of 3 hours. The "slug" of chlorine solution can be moved through a long pipeline instead of filling the entire pipeline, provided all pipe components stay in contact with the slug for at least 3 hours. The steps in this method are as follows:

1. Flushing: Fill the piping with water to remove air pockets and flush with pressurized water such that the velocity is at least 3.0 ft/s. If a flow meter is not available, the flow rate can be estimated by measuring the distance the water discharges, as depicted in Figure 9. For pipes larger than 24-inch diameter, it is acceptable to broom sweep the pipe instead of flushing.
2. Add Chlorine, Hold, and Check Chlorine Concentration: With the pipe full of water, add a chlorine solution that results in a free chlorine concentration of at least 100 mg/L. The solution can be made with chlorine gas, granules, tablets, or sodium hypochlorite (similar to the Continuous Method, Step 2).
   Common approaches are as follows:
   a. Short pipelines:
      i. Add the chlorine solution at the beginning of the pipeline and continue until the chlorine solution is coming out of the sample tap at the end of the pipeline. Open and close all valves and fire hydrants to ensure complete exposure to the chlorine solution.
      ii. Confirm the free chlorine concentration is equal or greater than 100 mg/L at beginning and end sample points.
      iii. Hold for at least 3 hours. Additional chlorine can be added during this time to maintain the chlorine concentration.
      iv. At the end of the hold time, the concentration of free chlorine shall be tested and confirmed to be equal or greater than 50 mg/L at each sample location.
   b. Long pipelines (see Figure 12):
      i. Divide the pipeline into segments (typically 1200 feet long) and ensure there is a sample tap near the beginning and end of each segment with an isolation valve between. Ideally, the first segment should have the largest volume to minimize adding chlorine into each pipe segment.
      ii. Add the chlorine solution at the beginning of the first segment and continue until the chlorine solution is coming out of the sample tap at the end of the segment. Open and close all valves and fire

hydrants in the segment to ensure complete exposure to the chlorine solution.

iii. Isolate the first segment by closing the valve downstream of the sample tap.
iv. Check the concentration of free chlorine at the two sample locations, to confirm it is equal to or greater than 100 mg/L.
v. Hold for at least 3 hours. Additional chlorine can be added during this time to maintain the chlorine concentration.
vi. At the end of the hold time, the concentration of free chlorine shall be tested and confirmed to be equal or greater than 50 mg/L at each sample location.
vii. Open the isolation valve and introduce water at the beginning of the pipeline to move the “slug” of chlorine to the next segment. Once the chlorine solution is coming out of the sample tap at the end of the second segment, close the downstream and upstream valves to isolate the pipe segment.
viii. Repeat the above steps for each pipe segment to ensure all wetted surfaces are disinfected for at least three hours with the slug of chlorine.

c. Repairs to uncontrolled pipe breaks:
   i. The section of the pipe shall be isolated and cleaned.
   ii. Disinfection procedures for short pipelines apply, except it is acceptable to use a chlorine concentration of 300 mg/L and a contact time of 15 minutes. Other disinfection methods may be used as explained in the Spray and Swab Methods subsection.

3. Flushing: Flush out the chlorinated water with potable water such that the free chlorine concentration is between 0.4 mg/L and 4 mg/L (or as otherwise required by local regulations). The discharged water may require dechlorination before disposal, per AWWA C655 entitled “Field Dechlorination”.
4. Bacteriological Testing: Test for the presence of total coliform, or fecal coliform, at each sample location. Tests should be repeated a minimum of 16 hours later (some agencies require the two sets of tests on back-to-back days). If results are negative, a submittal is made to the agency having jurisdiction for clearance to place the water main into service.
5. Place into Service: The piping can be connected (use spray or swab method for disinfection of connections) and placed into service by the opening of isolation valves, once clearance has been obtained. Typically, there is a time limit of 60

days after clearance to place items into service, after which disinfection and testing procedures must be repeated.

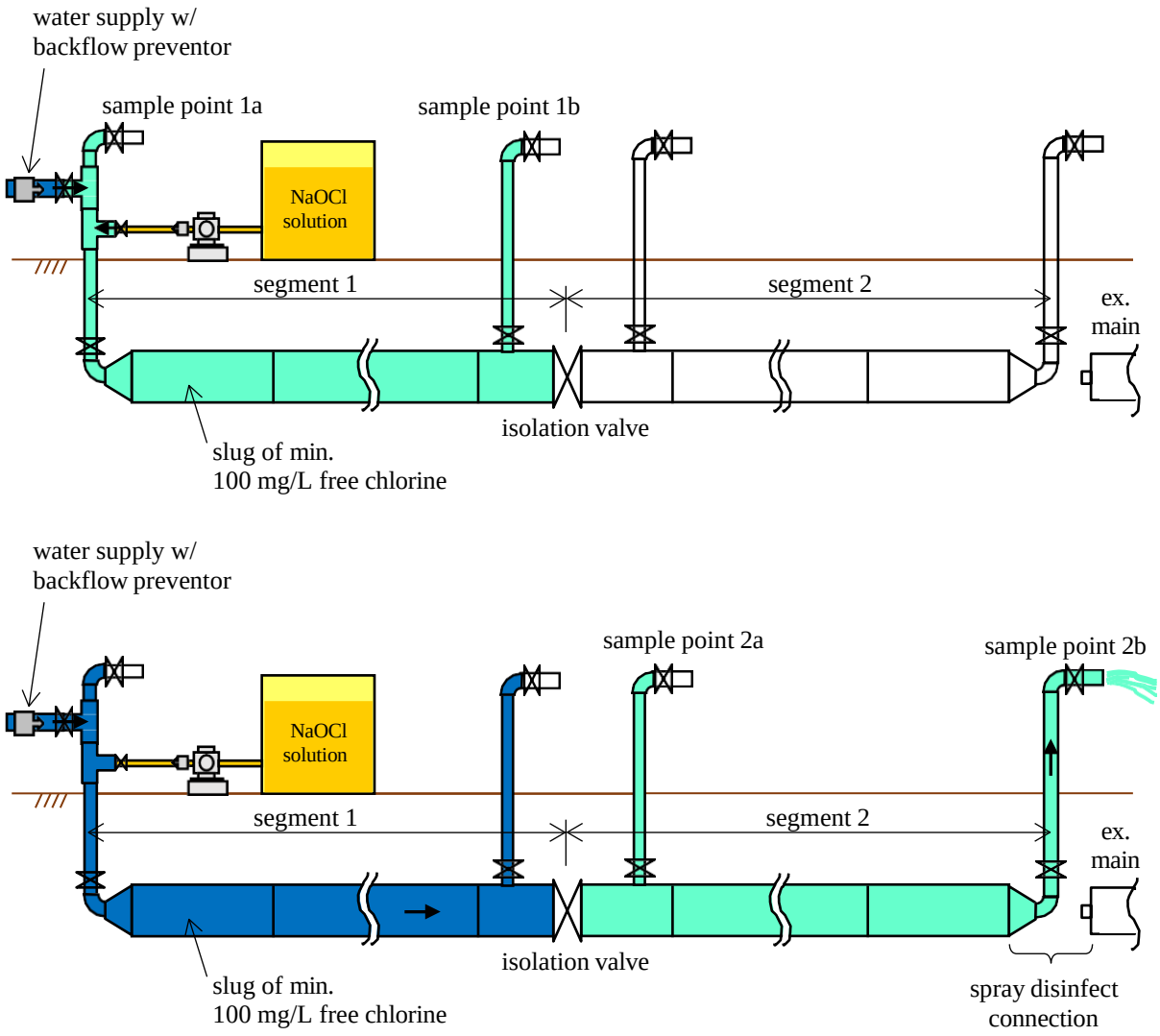


Figure 12: Slug method for disinfecting a new water main. The first segment of the pipe is filled with the “slug” of chlorinated water (top). After holding for 3 hours, valves are opened to allow the slug to move to the second segment (bottom).

See Figure 13 for an example test report for the slug method with a short pipeline.

DISINFECTION REPORT
SLUG METHOD

Project Name:	Example project
Project Number:	XX-XXX
Location:	Example, XX
Contractor:	ABCD Corp.
Inspector:	John Doe, Sr
Engineer:	John Doe, Jr, P.E.
Pipes Disinfected:	New XX" water main, XXX ft long
AWWA Method:	AWWA C651 Slug Method

Flushing

Description of Approach:	Potable water was pumped into the pipe at location A. Flushing water discharged out the X" tap at location B. Air pockets were removed and flushing was continued for 30 minutes.			
Pipe Flushing Complete:	12/14/20 8:00 AM	date & time		
Flushing Velocity (Approx):	3.0	fps		
Min. Flushing Velocity Req.:	3.0	fps	In Compliance?	Yes

Disinfection

Chlorine Chemical:	Mixture of 12.5% sodium hypochlorite (NSF Approved) and potable water to produce a 200 mg/L chlorine solution, meets AWWA C651, 4.1.2.			
Description of Approach:	The chlorine solution was pumped into the pipe at location A at a slow constant rate so all pipe interior surfaces were exposed to a slug of chlorine for more than 3 hours. Chlorine concentration of the slug was measured at the beginning (location A) and end (location B) to confirm compliance. Finally, potable water was introduced to flush out the chlorine solution.			
Solution Introduced:	12/14/20 9:00 AM	date & time		
Solution Stopped:	12/14/20 12:30 PM	date & time		
Slug Reached Location B:	12/14/20 10:00 AM	date & time		
Slug Ended at Location B:	12/14/20 2:00 PM	date & time	Note: 15 min at >300 mg/L allowed for repair work	
Slug Time:	4.00	hours		
Min. Time Required:	3.00	hours	In Compliance?	Yes
Location A Chlorine Conc.	200	mg/L (free)		
Min. Chlorine Conc.:	100	mg/L (free)	In Compliance?	Yes
Location B Chlorine Conc.	150	mg/L (free)		
Min. Ending Chlorine Conc.:	100	mg/L (free)	In Compliance?	Yes

Bacteriological Testing

Max. Chlorine Conc. Allowed:	4.0	mg/L (free)		
Day 1 Sample Point 1:	12/15/20 1:00 PM	date & time		
Chlorine Conc.:	1.8	mg/L (free)	In Compliance?	Yes
Day 1 Sample Point 2:	12/15/20 1:30 PM	date & time		
Chlorine Conc.:	1.2	mg/L (free)	In Compliance?	Yes
Day 2 Sample Point 1:	12/16/20 1:00 PM	date & time		
Chlorine Conc.:	1.3	mg/L (free)	In Compliance?	Yes
Day 2 Sample Point 2:	12/16/20 1:30 PM	date & time		
Chlorine Conc.:	0.6	mg/L (free)	In Compliance?	Yes

Compliance

X	This test DOES comply with AWWA standards and project specifications
	This test DOES NOT comply with AWWA standards and project specifications

Figure 13: Example disinfection report for the slug method.

Disinfection of Water System Components

Spray and Swab Methods

These methods involve cleaning interior surfaces, spraying or swabbing surfaces with a high concentration chlorine solution, and then spraying or flushing with potable water. This method is essentially the same as Method 2 in AWWA C652 for the disinfection of water storage facilities. For swabbing, a brush or sponge dipped in the chlorine solution is commonly used to swab (wipe) the surfaces. See previous procedures for preparing the chlorine solution. The concentration of chlorine and the required hold time depend on the application:

1. Large transmission mains:
    a. After the pipe is cleaned, spray a chlorine solution containing a minimum of 200 mg/L on all wetted surfaces.
    b. After 30 minutes, spray all surfaces with potable water or flush the pipe with potable water.
    c. See the previous methods for procedures for bacteriological testing and placing into service.
2. Short connections (≤20 feet) to existing water pipes (see Figure 14):
    a. After the pipe is cleaned, spray or swab wetted surfaces with a chlorine solution containing a minimum of 1% chlorine (10,000 mg/L), just before installation.
    b. There is no hold time required. However, such a high concentration can cause corrosion if allowed to stay for more than 30 minutes, so it is advisable to spray all surfaces with potable water or flush the pipe with potable water within 30 minutes.
    c. Bacteriological testing is typically not required to place the connection into service.
3. Repairs and cutting into existing water pipes:
    a. After the pipe opening is cleaned, spray or swab wetted surfaces with a chlorine solution containing a minimum of 1% chlorine (10,000 mg/L), just before completing the final pipework.
    b. There is no hold time required. However, such a high concentration can cause corrosion if allowed to stay for more than 30 minutes, so it is advisable to spray all surfaces with potable water or flush the pipe with potable water within 30 minutes.
    c. Flush the pipe (using a nearby fire hydrant, flushing tap, or other connection) to obtain three volumes of turnover. Check that the discharged water is clear.

   d. Bacteriological testing is typically not required to place the connection into service.
4. Repairs to water pipes exposed to the environment: This applies if trench soils, rainwater, or other elements entered the pipe during the repair.
   a. After the pipe opening is cleaned, spray wetted surfaces with a chlorine solution containing a minimum of 1% chlorine (10,000 mg/L), just before completing final repairs. Spray all accessible upstream and downstream surfaces.
   b. There is no hold time required. However, such a high concentration can cause corrosion if allowed to stay for more than 30 minutes, so it is advisable to spray all surfaces with potable water or flush the pipe with potable water within 30 minutes.
   c. Flush the pipe (using a nearby fire hydrant, flushing tap, or other connection) to obtain three volumes of turnover. Check that the discharged water is clear.
   d. Bacteriological testing is recommended before placing the connection into service.
5. Uncontrolled and contaminated pipe breaks: This applies to a pipe break in which there are obvious signs of contamination, such as muddy trench water flowing into the pipe, a leaking sewer pipe in the trench, or the pipe being open for a long time. Disinfection options are as follows:
   a. The spray method is only allowed if the pipe is large enough to allow entrance for spraying all surfaces (see procedures for Large Transmission Mains).
   b. Otherwise, disinfect the isolated pipe segment using the tablet/granular, continuous, or slug methods, as described earlier.
   c. For the slug method, it is acceptable to use a chlorine concentration of 300 mg/L and a contact time of 15 minutes.
   d. In place of high-velocity flushing, it is acceptable to flush the pipe to obtain three volumes of turnover and check that the discharged water is clear.

Figure 14: Examples of spray disinfection for pipe components being replaced on an existing finished water pump station. After being sprayed, the wetted surfaces should not be handled, and workers should wear rubber gloves.

See Figures 15 and 16 for example test reports for the spray and swab methods.

DISINFECTION REPORT
SPRAY METHOD

Project Name: Example project
Project Number: XX-XXX
Location: Example, XX
Contractor: ABCD Corp.
Inspector: John Doe, Sr
Engineer: John Doe, Jr, P.E.
Facilities Disinfected: XX" Large Pipe
AWWA Method: AWWA C652 Chlorination Method 2 (as referenced in AWWA C653, 4.4)

Cleaning

Description of Approach:	Surfaces were wiped and rinsed clean with potable water.		
Surfaces Cleaned & Washed:	12/14/20 9:00 AM	Date & Time	

Disinfection

Chlorine Chemical:	Mixture of 12.5% sodium hypochlorite (NSF Approved) and potable water, meets AWWA C652, 4.2.2.		
Description of Approach:	The chlorine solution was sprayed on all wetted surfaces with a pressurized hand held sprayer. After the required waiting period, the surfaces were rinsed with potable water.		
Surfaces Sprayed:	12/15/20 8:00 AM	date & time	
Rinsed with Potable Water:	12/15/20 8:35 AM	date & time	
Time Elapsed:	0.58	hours	
Min. Time Required:	0.50	hours	In Compliance? Yes
Chlorine Conc. of Solution	320	mg/L (free)	
Min. Chlorine Conc. Req'd:	200	mg/L (free)	In Compliance? Yes

Bacteriological Testing (if required)

Max. Chlorine Conc. Allowed:	4.0	mg/L (free)	
Day 1 Sample Point 1:	12/15/20 1:00 PM	date & time	
Chlorine Conc.:	1.8	mg/L (free)	In Compliance? Yes
Day 1 Sample Point 2:	12/15/20 1:30 PM	date & time	
Chlorine Conc.:	1.2	mg/L (free)	In Compliance? Yes
Day 2 Sample Point 1:	12/16/20 1:00 PM	date & time	
Chlorine Conc.:	1.3	mg/L (free)	In Compliance? Yes
Day 2 Sample Point 2:	12/16/20 1:30 PM	date & time	
Chlorine Conc.:	0.6	mg/L (free)	In Compliance? Yes

Compliance

X	This test DOES comply with AWWA standards and project specifications
	This test DOES NOT comply with AWWA standards and project specifications

Figure 15: Example disinfection report for the spray method.

DISINFECTION REPORT
SWAB METHOD

Project Name: Example project
Project Number: XX-XXX
Location: Example, XX
Contractor: ABCD Corp.
Inspector: John Doe, Sr
Engineer: John Doe, Jr, P.E.
Facilities Disinfected: XX" Pipe Opening and Repair Clamp
AWWA Method: AWWA C651 Swab Method (for Cutting Into or Repairing Existing Pipes)

Cleaning

Description of Approach: Surfaces were wiped and rinsed clean with potable water.
Surfaces Cleaned & Washed: 12/14/20 9:00 AM Date & Time

Disinfection

Chlorine Chemical: Mixture of 12.5% sodium hypochlorite (NSF Approved) and potable water to produce a 11,000 mg/L chlorine solution, meets AWWA C651, 4.1.2.
Description of Approach: The chlorine solution was wiped on all wetted surfaces around the pipe opening and the new clamp with a new sponge. After being returned to service, the water main was flushed to obtain three volumes of turnover.

Surfaces Swabbed: 12/15/20 8:00 AM date & time
Water Main Flushed: 12/15/20 1:35 AM date & time
Chlorine Conc. of Solution 11000 mg/L (free)
Min. Chlorine Conc. Req'd: 10000 mg/L (free) In Compliance? Yes

Bacteriological Testing (if required)

Max. Chlorine Conc. Allowed: 4.0 mg/L (free)

Day 1 Sample: 12/15/20 1:00 PM date & time
Chlorine Conc.: 1.8 mg/L (free) In Compliance? Yes

Day 2 Sample: 12/16/20 1:00 PM date & time
Chlorine Conc.: 1.3 mg/L (free) In Compliance? Yes

Compliance

X This test DOES comply with AWWA standards and project specifications
_____ This test DOES NOT comply with AWWA standards and project specifications

Figure 16: Example disinfection report for the swab method.

Disinfection of Water System Components

Water Storage Facilities

Disinfecting a potable water storage tank is required at the initial installation and each time the tank is emptied and entered for repairs, coating work, or other invasive activities. AWWA C652 lists the following disinfection options:

- Method 1 - 100% Fill
- Method 2 - Spray
- Method 3 - 5% Fill

Each of these methods is described as follows.

Method 1 – 100% Fill

This method involves cleaning the tank and filled it to the point of overflow with potable water and chlorine. After a hold time of 6 hours or 24 hours, the free chlorine should be confirmed to be a minimum of 10 mg/L. The steps in this method are as follows:

1. Cleaning: Removed any construction debris. The floor and inside walls of the tank should be cleaned with a high-pressure water jet, sweeping, scrubbing, or similar means. Remove debris and water from cleaning operations. Any drains should be flushed out. Screened openings should also be washed and inspected.
2. Fill with Water and Chlorine: The tank is to be filled with a chlorine solution that results in a free chlorine concentration of at least 10 mg/L. See Figure 17 for an example arrangement. Note that chlorine interacts with any ammonia, organics, and organisms in the water and on the tank surfaces, such that the free chlorine will be less than the total chlorine added. Also, chlorine evaporates into the air on top of the tank such that the concentration decreases over time. Thus, it is common to add double the required chlorine and/or continue feeding chlorine into the tank during the hold time. Common methods for feeding chlorine are as follows:
    a. Chlorine gas:
        i. A chlorine cylinder can be connected to a water supply that connects to the inlet pipe to the tank, as generally shown in Figure 2. If a direct connection is made to a fire hydrant, an approved cross-connection control device is required. The tank is filled through the inlet pipe at the same time as the chlorine gas is injected into the pipe. This provides superior mixing.

ii. Another approach is to inject the gas into a water line that fills a chemical tank to create a chlorine solution. Then the solution is pumped into the water storage tank during or after filling with water.

b. Granules/Tablets: Spread granules or tablets (broken into sizes not larger than ¼-inch) on the floor of the storage tank and fill the tank with water to create a chlorine solution.

c. Sodium Hypochlorite:

i. A chemical tank with sodium hypochlorite is connected to a water supply that connects to the inlet pipe to the tank, as generally shown in Figure 3. If a direct connection is made to a fire hydrant, an approved cross-connection control device is required. The tank is filled through the inlet pipe at the same time as the chlorine solution is injected into the pipe. This provides superior mixing.

ii. A sodium hypochlorite solution is pumped into the water storage tank (through a side or roof penetration) during or after filling with water.

3. Hold Time: The hold time depends on the chlorine feed method:
   a. Hold 6 hours if chlorine gas or sodium hypochlorite was added to the inlet pipe during filling (options 2.a.i. and 2.c.i. above).
   b. Hold 24 hours for other chlorine feed methods.
   c. During the hold time, it is acceptable to let a continuous flow of chlorine solution enter the tank to ensure the free chlorine concentration does not drop below 10 mg/L. A sample port can be opened to prevent water from coming out of the overflow.
4. Check Chlorine Concentration: At the end of the hold time, the concentration of free chlorine shall be tested and confirmed to be equal or greater than 10 mg/L at each sample location. Often two samples will be taken: 1) from the top of the tank, and 2) from a side port.
5. Add Water: Add potable water until the free chlorine concentration is between 0.4 mg/L and 4 mg/L (or as otherwise required by local regulations). The discharged water may require dechlorination before disposal, per AWWA C655 entitled “Field Dechlorination”.
6. Bacteriological Testing: Test for the presence of total coliform, or fecal coliform, at each sample location. Tests should be repeated a minimum of 16 hours later (some agencies require the two sets of tests on back-to-back days). If results are negative, a submittal is made to the agency having jurisdiction for clearance to place the tank into service.

7. Place into Service: The tank can be placed into service by the opening of isolation valves, once clearance has been obtained. Typically, there is a time limit of 60 days after clearance to place items into service, after which disinfection and testing procedures must be repeated.

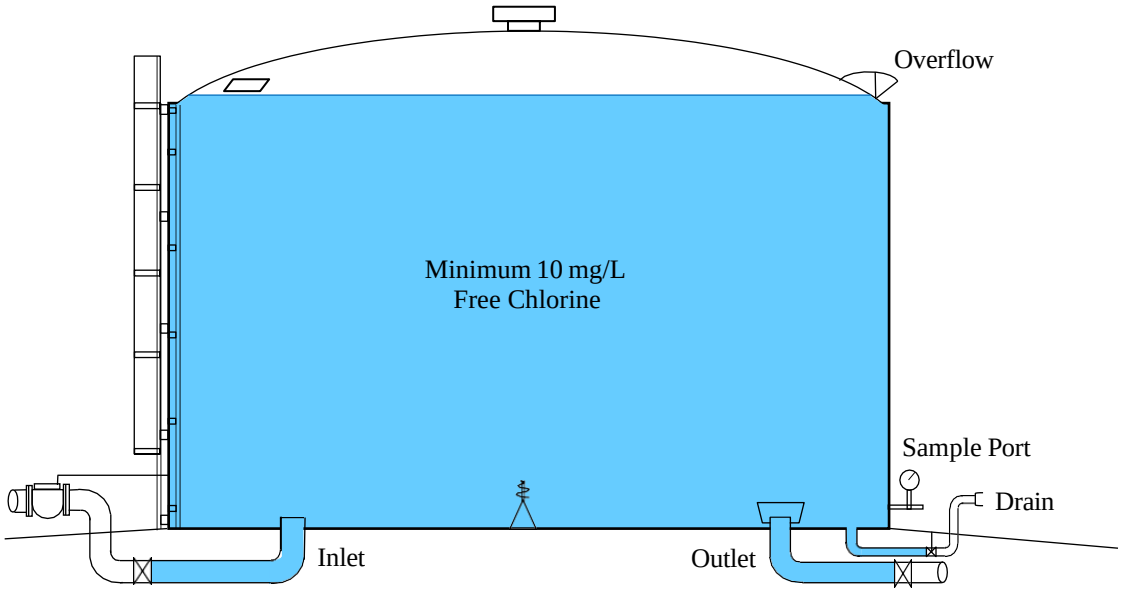


Figure 17: Example of the 100% fill method for a ground storage tank.

See Figure 18 for an example test report for the 100% fill method.

Disinfection of Water System Components

DISINFECTION REPORT
100 PERCENT FILL METHOD

Project Name: Example project
Project Number: XX-XXX
Location: Example, XX
Contractor: ABCD Corp.
Inspector: John Doe, Sr
Engineer: John Doe, Jr, P.E.
Facilities Disinfected: Wet Well No X
AWWA Method: AWWA C652 Chlorination Method 1

Cleaning

Description of Approach: Debris inside well was removed, floor was swept, floor and walls pressure washed, and the interior was inspected.
Interior Cleaned & Washed: 12/14/20 9:00 AM Date & Time

Disinfection

Chlorine Chemical: 68% granulated calcium hypochlorite (NSF Approved) per AWWA C653, 4.3.3.
Description of Approach: Spread calcium hypochlorite on the floor and filled with potable water to the overflow level. The total chlorine level was measured for compliance, and the full wet well was held for the 24 hour time required. Afterwards, potable water was introduced to reduce the chlorine level below 4 mg/L for Bac-T testing.

Tank Filled to Overflow:	12/15/20 8:00 AM	date & time	
End of Holding Time:	12/16/20 8:00 AM	date & time	
Time Elapsed:	24.00	hours	
Min. Time Required:	24.00	hours	In Compliance? Yes
Chlorine Conc. at Full Tank:	10.5	mg/L (free)	
Min. Chlorine Conc. Req'd:	10.0	mg/L (free)	In Compliance? Yes

Bacteriological Testing

Max. Chlorine Conc. Allowed:	4.0	mg/L (free)	
Day 1 Sample Point 1:	12/16/20 1:00 PM	date & time	
Chlorine Conc.:	1.8	mg/L (free)	In Compliance? Yes
Day 1 Sample Point 2:	12/16/20 1:30 PM	date & time	
Chlorine Conc.:	1.2	mg/L (free)	In Compliance? Yes
Day 2 Sample Point 1:	12/17/20 1:00 PM	date & time	
Chlorine Conc.:	1.3	mg/L (free)	In Compliance? Yes
Day 2 Sample Point 2:	12/17/20 1:30 PM	date & time	
Chlorine Conc.:	0.6	mg/L (free)	In Compliance? Yes

Compliance

X This test DOES comply with AWWA standards and project specifications
_____ This test DOES NOT comply with AWWA standards and project specifications

Figure 18: Example disinfection report for the 100% fill method.

Method 2 – Spray

This method involves cleaning interior surfaces, spraying wetted surfaces with a high concentration chlorine solution, filling any interior pipes with a chlorine solution, holding for 30 minutes, and then filling the tank with potable water. The steps in this method are as follows:

1. Cleaning: Removed any construction debris. The floor and inside walls of the tank should be cleaned with a high-pressure water jet, sweeping, scrubbing, or similar means. Remove debris and water from cleaning operations. Any drains should be flushed out. Screened openings should also be washed and inspected.
2. Spraying: Spray a chlorine solution containing a minimum of 200 mg/L on all wetted surfaces, including the tank floor, interior walls, and submerged piping.
3. Fill Pipes: The drain pipe and other connected pipes are to be filled with a chlorine solution so the free chlorine will be a minimum of 10 mg/L. See Figure 19 for an example. Typically, the spray solution will be added so the pipe is 10% full, and then the pipe is filled with water (a 10 to 1 dilution).
4. Hold Time: The chlorine solution should remain on the surfaces for at least 30 minutes.
5. Fill Tank: The tank is to be filled to the overflow level with potable water.
6. Bacteriological Testing: Test for the presence of total coliform, or fecal coliform, at each sample location. Often two samples will be taken: 1) from the top of the tank, and 2) from a side port. Tests should be repeated a minimum of 16 hours later (some agencies require the two sets of tests on back-to-back days). If results are negative, a submittal is made to the agency having jurisdiction for clearance to place the tank into service.
7. Place into Service: The tank can be placed into service by the opening of isolation valves, once clearance has been obtained. Typically, there is a time limit of 60 days after clearance to place items into service, after which disinfection and testing procedures must be repeated.

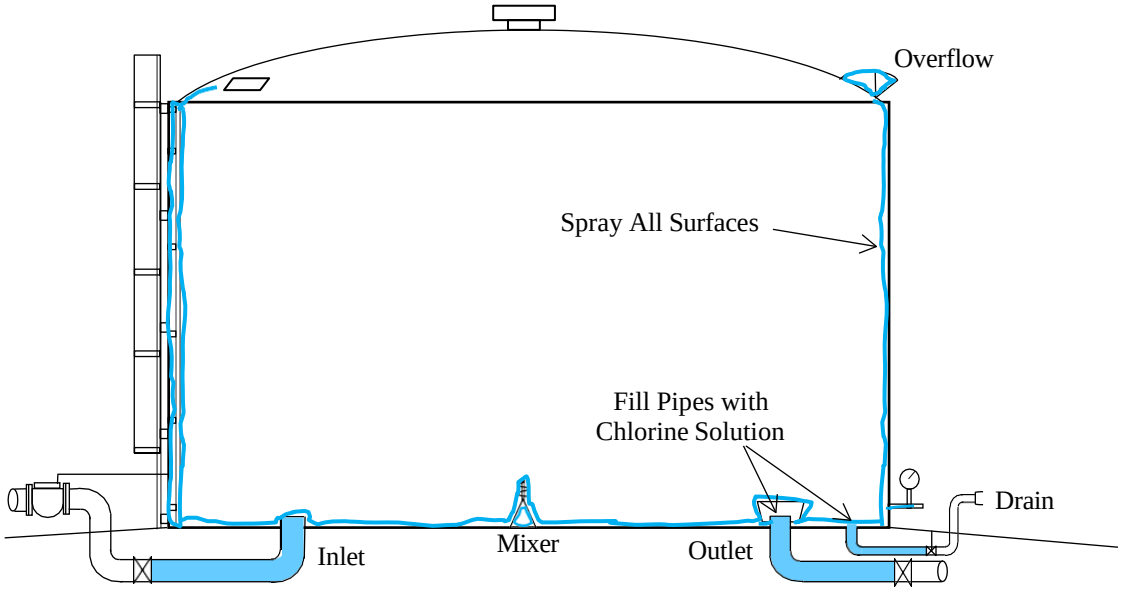


Figure 19: Example of the spray method for a ground storage tank. All wetted surfaces are sprayed with a minimum 200 mg/L chlorine solution, as represented by the cyan lines. Pipes are filled with a minimum 10 mg/L chlorine solution. Hold for at least 30 minutes before rinsing or filling the tank.

See Figure 15 for an example test report for the spray method.

Method 3 – 5% Fill

This method involves cleaning the tank, filling it to 5 percent full with a minimum 50 mg/L chlorine concentration, waiting 6 hours, filling the tank to the point of overflow with potable water, and then holding for 24 hours. The steps in this method are as follows:

1. Cleaning: Removed any construction debris. The floor and inside walls of the tank should be cleaned with a high-pressure water jet, sweeping, scrubbing, or similar means. Remove debris and water from cleaning operations. Any drains should be flushed out. Screened openings should also be washed and inspected.
2. Fill to 5% with Water and Chlorine: The tank is to be filled to 5% full (5% of the maximum tank volume) with a chlorine solution that results in a free chlorine concentration of least 50 mg/L. See Figure 20 for an example arrangement. Note that chlorine interacts with any ammonia, organics, and organisms in the water and on the tank surfaces, such that the free chlorine will be less than the total chlorine added. It is common to add double the required chlorine.

   Common methods for feeding chlorine are as follows:
   a. Chlorine gas:
      i. A chlorine cylinder can be connected to a water supply that connects to the inlet pipe to the tank, as generally shown in Figure 2. If a direct connection is made to a fire hydrant, an approved cross-connection control device is required. The tank is filled through the inlet pipe at the same time as the chlorine gas is injected into the pipe. This provides superior mixing.
      ii. Another approach is to inject the gas into a water line that fills a chemical tank to create a chlorine solution. Then the solution is pumped into the water storage tank during or after filling to 5% with water.
   b. Granules/Tablets: Spread granules or tablets (broken into sizes not larger than ¼-inch) on the floor of the storage tank and fill the tank to 5% with water to create a chlorine solution.
   c. Sodium Hypochlorite:
      i. A chemical tank with sodium hypochlorite is connected to a water supply that connects to the inlet pipe to the tank, as generally shown in Figure 3. If a direct connection is made to a fire hydrant, an approved cross-connection control device is required. The tank

is filled to 5% through the inlet pipe at the same time as the chlorine solution is injected into the pipe. This provides superior mixing.

ii. A sodium hypochlorite solution is pumped into the water storage tank (through a side or roof penetration) during or after filling to 5% with water.

3. Hold Time: Hold for 6 hours.
8. Fill Tank: The tank is to be filled to the overflow level with potable water.
4. Hold Time: Hold for 24 hours.
5. Add Water: Add potable water until the free chlorine concentration is between 0.4 mg/L and 4 mg/L (or as otherwise required by local regulations). The discharged water may require dechlorination prior to disposal, per AWWA C655 entitled “Field Dechlorination”.
6. Bacteriological Testing: Test for the presence of total coliform, or fecal coliform, at each sample location. Often two samples will be taken: 1) from the top of the tank, and 2) from a side port. Tests should be repeated a minimum of 16 hours later (some agencies require the two sets of tests on back-to-back days). If results are negative, a submittal is made to the agency having jurisdiction for clearance to place the tank into service.
7. Place into Service: The tank can be placed into service by the opening of isolation valves, once clearance has been obtained. Typically, there is a time limit of 60 days after clearance to place items into service, after which disinfection and testing procedures must be repeated.

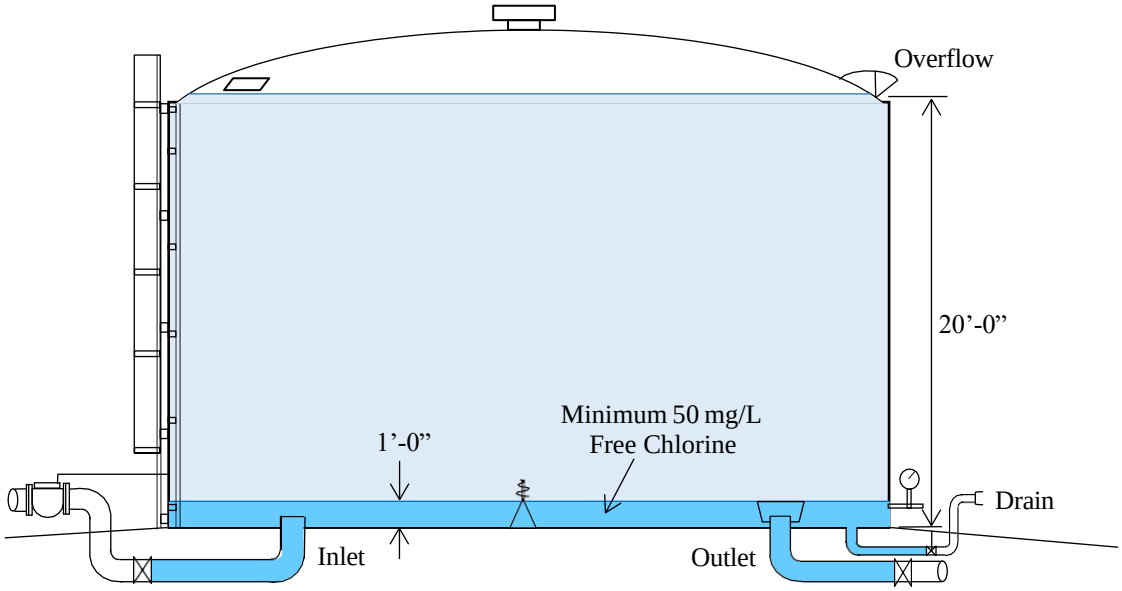


Figure 20: Example of the 5% fill method for a 20-foot tall ground storage tank. The minimum 50 mg/L chlorine solution is to fill approximately 5% of the tank (1’-0” deep), as depicted in turquoise. Hold for 6 hours. Then the tank is filled to the overflow and held for 24 hours.

See Figure 21 for an example test report for the 5% fill then 100% fill method.

DISINFECTION REPORT
5 PERCENT FILL METHOD

Project Name:	Example project
Project Number:	XX-XXX
Location:	Example, XX
Contractor:	ABCD Corp.
Inspector:	John Doe, Sr
Engineer:	John Doe, Jr, P.E.
Facilities Disinfected:	Water Storage Tank No X (X.X MG)
AWWA Method:	AWWA C652 Chlorination Method 3

Cleaning

Description of Approach:	Debris inside tank was removed, floor was swept, floor and walls pressure washed, and the tank interior was inspected.	
Interior Cleaned & Washed:	12/14/20 9:00 AM	Date & Time

Disinfection

Chlorine Chemical:	68% granulated calcium hypochlorite (NSF Approved) per AWWA C653, 4.3.3.			
Description of Approach:	Spread calcium hypochlorite on the floor of the tank and filled the tank to 5% volume with potable water. The total chlorine concentration was measured for compliance and the solution was held for the 6 hour time required. Afterwards, the tank was filled until the solution came out of the overflow. The total chlorine level was measured for compliance, and the full tank was held for the 24 hour time required. Afterwards, potable water was introduced to reduce the chlorine level below 4 mg/L for Bac-T testing.			
Start of 5% Disinfection:	12/15/20 8:00 AM	date & time		
End of 5% Disinfection:	12/15/20 2:00 PM	date & time		
Time Elapsed:	6.00	hours		
Min. Time Required:	6.00	hours	In Compliance?	Yes
Chlorine Conc. at 5% Volume:	60	mg/L (free)		
Min. Chlorine Conc. Req'd:	50	mg/L (free)	In Compliance?	Yes
Tank Filled to Overflow:	12/15/20 8:00 AM	date & time		
End of Holding Time:	12/16/20 8:00 AM	date & time		
Time Elapsed:	24.00	hours		
Min. Time Required:	24.00	hours	In Compliance?	Yes
Chlorine Conc. at Full Tank:	2.2	mg/L (free)		
Min. Chlorine Conc. Req'd:	2.0	mg/L (free)	In Compliance?	Yes

Bacteriological Testing

Max. Chlorine Conc. Allowed:	4.0	mg/L (free)		
Day 1 Sample Point 1:	12/16/20 1:00 PM	date & time		
Chlorine Conc.:	1.8	mg/L (free)	In Compliance?	Yes
Day 1 Sample Point 2:	12/16/20 1:30 PM	date & time		
Chlorine Conc.:	1.2	mg/L (free)	In Compliance?	Yes
Day 2 Sample Point 1:	12/17/20 1:00 PM	date & time		
Chlorine Conc.:	1.3	mg/L (free)	In Compliance?	Yes
Day 2 Sample Point 2:	12/17/20 1:30 PM	date & time		
Chlorine Conc.:	0.6	mg/L (free)	In Compliance?	Yes

Compliance

X	This test DOES comply with AWWA standards and project specifications
	This test DOES NOT comply with AWWA standards and project specifications

Figure 21: Example disinfection report for the 5% fill method.

Disinfection of Water System Components

Water Treatment Plant Components

Disinfection of water treatment plant (WTP) components is covered by AWWA C653. Disinfection is required for all components that are downstream from the filter influent, downstream from the first point of disinfection, or all components if no primary disinfection is provided (for example, some small groundwater systems). Local agencies may require additional WTP components to be disinfected. However, even if some components do not require disinfection and official clearance, it is good practice to perform disinfection to avoid potential positive fecal coliform results in the finished water. In all cases, cleaning of surfaces is required.

AWWA C653 lists the following disinfection options for WTP components:

- Piping and pump stations:
  - C651 Tablet/Granule Method
  - C651 Continuous-Feed Method
  - C651 Slug Method
  - C651 Spray Method
  - C651 Swab Method
- Tanks, basins, wet wells, clear wells, pressure filter vessels (before placing activated carbon media), and similar:
  - C652 Method 1 - 100% Fill
  - C652 Method 2 - Spray
  - C652 Method 3 - 5% Fill then 100% Fill
- Gravity/Sand Filters:
  - Backwash Method
  - Influent Method

The C651 and C652 methods have been described previously. The two Gravity/Sand Filter Methods are described as follows.

Backwash Method

This method involves injecting chlorine into the backwash flow to achieve a free chlorine residual of 25 mg/L throughout the filter, holding for 12 hours, and then confirming a free chlorine residual of at least 15 mg/L. See Figure 22 for an example arrangement.

Disinfection of Water System Components

The steps in the backwash method are as follows:

1. Cleaning: Removed any construction debris. The floor and inside walls of the tank should be cleaned with a high-pressure water jet, sweeping, scrubbing, or similar means. Remove debris and water from cleaning operations.
2. Fill with Water and Chlorine: The tank is to be filled through the backwash pipe with a chlorine solution that results in a free chlorine concentration of at least 25 mg/L throughout the filter basin. Note that chlorine interacts with any ammonia, organics, and organisms, such that the free chlorine will be less than the total chlorine added. Also, chlorine evaporates into the air such that the concentration decreases over time. Thus, it is common to add double the required chlorine and/or continue feeding chlorine into the tank during the hold time. Common methods for feeding chlorine are as follows:
    a. Chlorine gas:
        i. A chlorine cylinder can be connected to a water supply that connects to the pipe, as generally shown in Figure 2. If a direct connection is made to a fire hydrant, an approved cross-connection control device is required. The basin is filled through the backwash pipe at the same time as the chlorine gas is injected into the pipe.
    b. Granules/Tablets: Add granules or tablets to a chemical tank and fill it with water to create a chlorine solution. Pump the chlorine solution into the backwash pipe at the same time as filling the basin.
    c. Sodium Hypochlorite:
        i. A chemical tank with sodium hypochlorite is connected to a water supply that connects to the inlet pipe to the tank, as generally shown in Figure 3. If a direct connection is made to a fire hydrant, an approved cross-connection control device is required. The tank is filled through the inlet pipe at the same time as the chlorine solution is injected into the pipe.
3. Hold Time: Hold for 6 hours.
4. Check Chlorine Concentration: At the end of the hold time, the concentration of free chlorine shall be tested and confirmed to be equal or greater than 15 mg/L at each sample location. Samples shall be taken from the top and bottom of the basin, at a minimum.
5. Add Water: Add potable water until the free chlorine concentration is between 0.4 mg/L and 4 mg/L (or as otherwise required by local regulations). The discharged

water may require dechlorination prior to disposal, per AWWA C655 entitled "Field Dechlorination".

6. Bacteriological Testing: Test for the presence of total coliform, or fecal coliform, at each sample location. Tests should be repeated a minimum of 30 minutes later (some agencies require the two sets of tests on back-to-back days). If results are negative, a submittal is made to the agency having jurisdiction for clearance to place the filter into service.
7. Place into Service: The filter can be placed into service by the opening of isolation valves, once clearance has been obtained. Typically, there is a time limit of 60 days after clearance to place items into service, after which disinfection and testing procedures must be repeated.

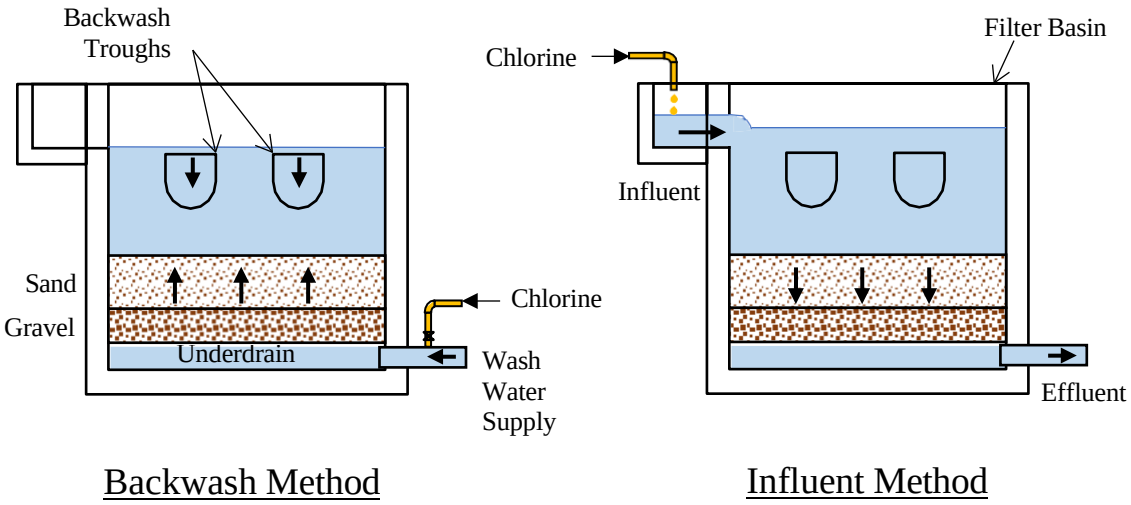


Figure 22: Methods for gravity filter disinfection. For both methods, the basin is to be filled with chlorine and water to produce a free chlorine residual of 25 mg/L throughout the filter. The solution is to be held for 12 hours, and then the free chlorine residual is confirmed to be at least 15 mg/L at the top and bottom of the basin.

Disinfection of Water System Components

Influent Method

This method involves injecting chlorine into the influent flow to achieve a free chlorine residual of 25 mg/L throughout the filter, holding for 12 hours, and then confirming a free chlorine residual of at least 15 mg/L. The steps and requirements for this method are the same as the backwash method, except, in Step 2, the chlorine solution is injected into the influent flow (instead of the backflow) until the chlorine solution passes the underdrain and reaches the filter-to-waste piping. See Figure 22 for an example arrangement.

GAC Media

If granular activated carbon (GAC) is present in the filters, disinfection of the filter basin shall be done with the Backwash or Influent Method before careful installation of the GAC media. Equipment used in placing the media must be cleaned and disinfected with a solution containing a minimum of 200 mg/L of free chlorine.

Disinfection of Water System Components

Raw Water Wells

Disinfection of raw water wells is covered by AWWA C654. Disinfection is required after initial installation and each time the well is serviced such that contamination is possible. Disinfection is done in three steps:

1. Gravel and Annular Casing Disinfection
2. Equipment Disinfection
3. Well Casing Disinfection

Well disinfection methods, per AWWA C654, are summarized as follows and shown in Figure 23.

1. Gravel and Annular Casing Disinfection

The following are options for disinfecting the gravel and annual casing:

- Tablet or Granular: Calcium hypochlorite tablets or granules are mixed with the gravel before placement. There shall be ¼ to ½ pound of calcium hypochlorite per ton of gravel.
- Chlorine in Drilling Fluid: A chlorine solution is added to the drilling fluid before adding gravel. The entire volume of fluid in the well shall have a minimum of 50 mg/L of free chlorine.
- Gravel in Existing Wells: Any replacement gravel shall be soaked in a chlorine solution with a minimum of 50 mg/L of free chlorine, for a minimum of 30 minutes.
- Existing Gravel Pack: Annular space with gravel shall be filled with a chlorine solution with a minimum of 100 mg/L of free chlorine. Chlorine solution is to be fed down the gravel chute with air releasing through the casing vent. The solution shall be fed until the space is full or until at least twice the annular volume has been added.

2. Equipment Disinfection

All permanent equipment and material to be installed, including pumps and flanges, shall have wetted surfaces sprayed with a chlorine solution with a minimum of 200 mg/L of free chlorine.

3. Well Casing Disinfection

The following are procedures for final disinfection of the well:

- With the well full of water, add chlorine into the well to produce a minimum of 50 mg/L of free chlorine in the entire well casing. Calcium hypochlorite tablets or granules may be dropped into the well. Or, a sodium hypochlorite solution may be injected through a tube that is lowered and raised through the well height during the injection.
- Surge the well three times to induce mixing.
- Confirm the free chlorine is at least 50 mg/L.
- Hold for 12 hours.
- Pump well water to waste, plus an additional 15 minutes of pumping.
- Optional: Flow may be recirculated by turning on the pump and using smaller recirculation piping connecting the pump discharge pipe to the well casing vent.

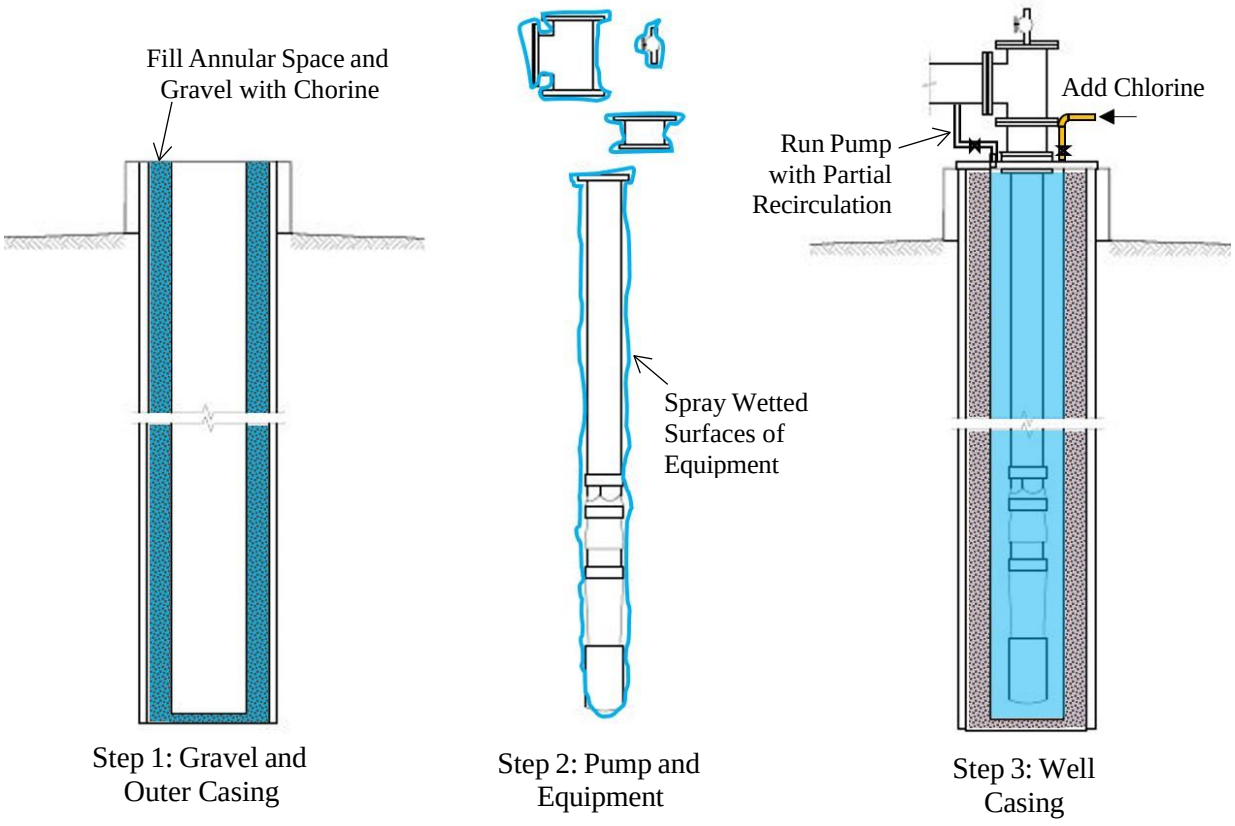


Figure 23: Basic steps for well disinfection.

Summary of Methods

Table 1: Summary of AWWA Methods for Disinfection of PWS Components						
Method	Application	AWWA Std.	Initial Free Chlorine (mg/L)	Hold Time (hours)	Final Free Chlorine (mg/L)	Notes
Tablet/Granule	Piping	C651	25	24	0.2	Hold 48 hrs if temp <41 deg F
Continuous	Piping	C651	25	24	10	
Slug	Piping	C651	100	3	50	
	Pipe Break Repairs	C651	300	0.25	N/A	
Spray or Swab	Large Diameter Piping	C651	200	0.50	N/A	
	Pipe Connections	C651	10,000	N/A	N/A	1% solution
	Pipe Cuts and Repairs	C651	10,000	N/A	N/A	1% solution
	Storage Tanks, Basins, Clearwells, Vessels, etc.	C652 & C653	200	0.50	N/A	
	Well Equipment	C654	200	N/A	N/A	
100% Fill	Storage Tanks	C652	10	6 or 24	10	6 hrs if mixed with inlet flow
5% Fill	Storage Tanks	C652	50	6	N/A	50 mg/L at 5% Full
Backwash	Gravity Filters	C653	25	12	15	
Influent	Gravity Filters	C653	25	12	15	
Well Casing	Raw Water Wells	C654	50	12	50	Gravel disinfected separately

Helpful References

AWWA (2014) “Disinfection of Water Mains”, AWWA Standard C651.

AWWA (2019) “Disinfection of Water Storage Facilities”, AWWA Standard C652.

AWWA (2020) “Disinfection of Water Treatment Plants”, AWWA Standard C653.

AWWA (2013) “Disinfection of Wells”, AWWA Standard C654.

AWWA (2012) “Water Distribution System Operation and Maintenance: A Field Study Training Program”, 6th Ed.

AWWARF (1998) “Development of Disinfection Guidelines for the Installation and Replacement of Water Mains”.

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