Disinfection of Pipelines and Storage Facilities Field Guide



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Disinfection of Pipelines and Storage Facilities Field Guide

by William C. Lauer and Fred J. Sanchez



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Fred J. Sanchez is water quality supervisor for Denver Water. Mr. Sanchez has more than 15 years experience in water quality investigation, and field disinfection and dechlorination of pipelines and storage facilities. He has developed improved field disinfection methods and testing of water pipelines and water storage facilities including the use of ozone for disinfection purposes.

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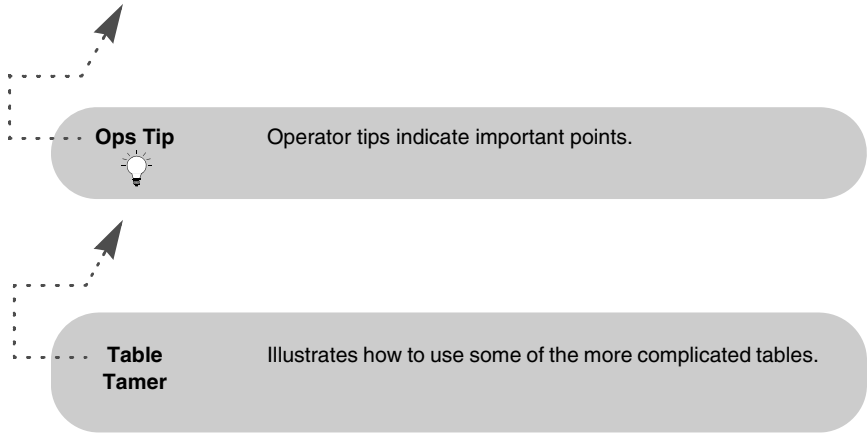
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Foreword

This Disinfection of Pipelines and Storage Facilities Field Guide is one of the "Field Guide" series of books published by the American Water Works Association (AWWA). These books are meant to be small, practical, how-to publications on specific subjects of importance to drinking water system operating personnel. These books omit most of the theory and background that have led to the use of the procedures described in the guides. This fundamental information is found in other AWWA publications and is referenced in the field guides.

The information in this field guide, like the other books in this series, provides what is needed to do the work. Useful tables and easy to follow illustrations help system operators perform the procedures described in the ANSI/AWWA disinfection standards and in other references. The field guides get straight to the point and provide the necessary information to perform the *most common* procedures. This approach leads the operator to the most useful solutions.

There are several special notes included throughout the book. Look for "Ops Tips" and the "Table Tamer" in call-outs and text boxes for help with important points and how to use some of the tables. There are also several "calculators" that help plug in the numbers needed to calculate a value.



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"Calculators" provide easy-to-use, plug-in-the-numbers, equations and examples used to give quick results. The conversion factors and other constants have been combined so that the equation is greatly simplified. The derivation of the formula is not given, just the result. More detail about the source of the constants shown for the calculators is shown in Appendix A.

Calculation result and units of measure	=	Insert known value needed for the calculations	×	constant	(cn-n)

The authors hope this information is useful and is used to supplement hands-on training and, thus, becomes an indispensable companion for both utility and contractor personnel.

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Fred J. Sanchez

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Denver Water has generously provided originals of many of the illustrations used in this book. Several of these were drawn by Nicole Peschel and Fred Sanchez. Other photos are courtesy of Denver Water.

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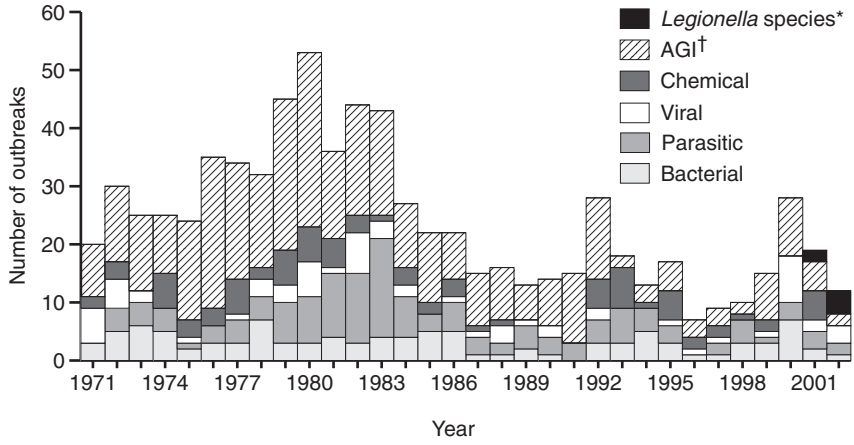
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Chapter 1

The Importance of Distribution System Disinfection

The reports of waterborne disease outbreaks attributed to drinking water have decreased since high numbers in the 1970s and 1980s. However, the annual number remains higher than desirable (Figure 1-1). Acute gastrointestinal illnesses comprise the majority of these identified disease outbreaks in the United States. Most of these outbreaks involve microbiological agents that would respond to proper disinfection.



*Beginning in 2001, Legionnaire's disease was added to the surveillance system, and *Legionella* species were classified separately.
†Acute gastrointestinal illness of unknown etiology.

Reprinted from CDC MMWR Surveillance Summaries, *October 2004.*

Figure 1-1 Number of waterborne-disease outbreaks (n=764) associated with drinking water, by year and etiologic agent—United States, 1971–2002

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According to the Centers for Disease Control and Prevention (CDC), deficiencies in the distribution systems are significant contributing factors leading to waterborne disease outbreaks. Figure 1-2 illustrates the relative contribution of various disease outbreak causes. Distribution system deficiencies account for 32 percent of the total, and these sources are second only to treatment deficiencies at 48 percent. Therefore, careful attention is needed to ensure the integrity of distribution systems, including disinfection of pipelines and storage facilities to reduce the possibility microbiological contamination.

Pathogens can enter the distribution system through openings in storage facilities, and during water main installation and repair procedures. Pathogens present in water or soil in proximity to water mains and storage facilities (contaminated by sewage, farmland runoff, or other polluted sources) may also enter

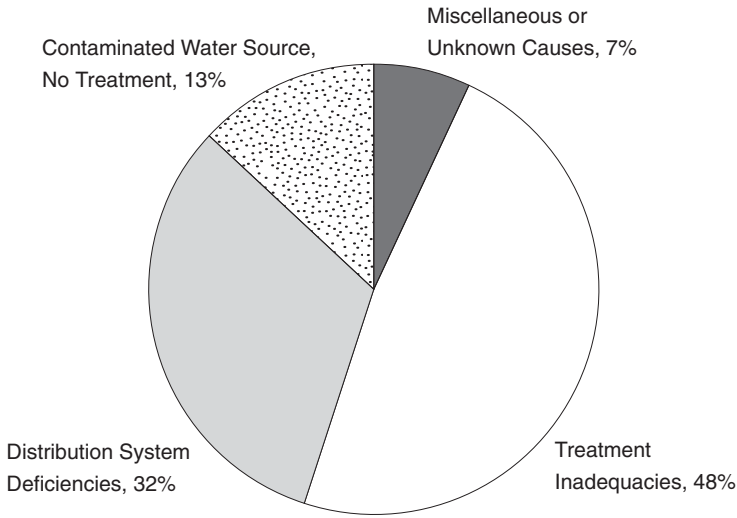


Figure 1-2 Drinking water associated waterborne disease outbreak causes, Community Water Survey, 1971–2002

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pipelines or storage facilities. Figure 1-3 illustrates the findings from tests performed on undisturbed soil and water near pipe installations (Kirmeyer et al. 2001).

Soil containing pathogens and other microbes is the most common source of microbiological contamination associated with water main installation and repair. Wet soil often contains more of these contaminants than dry soil. Microbiological contamination of pipelines comes from:

- Accumulation of soil, sediment, and other foreign material on the interior of new pipes, and appurtenance surfaces during storage and installation.
- Accumulation of soil on the interior of existing exposed pipes.

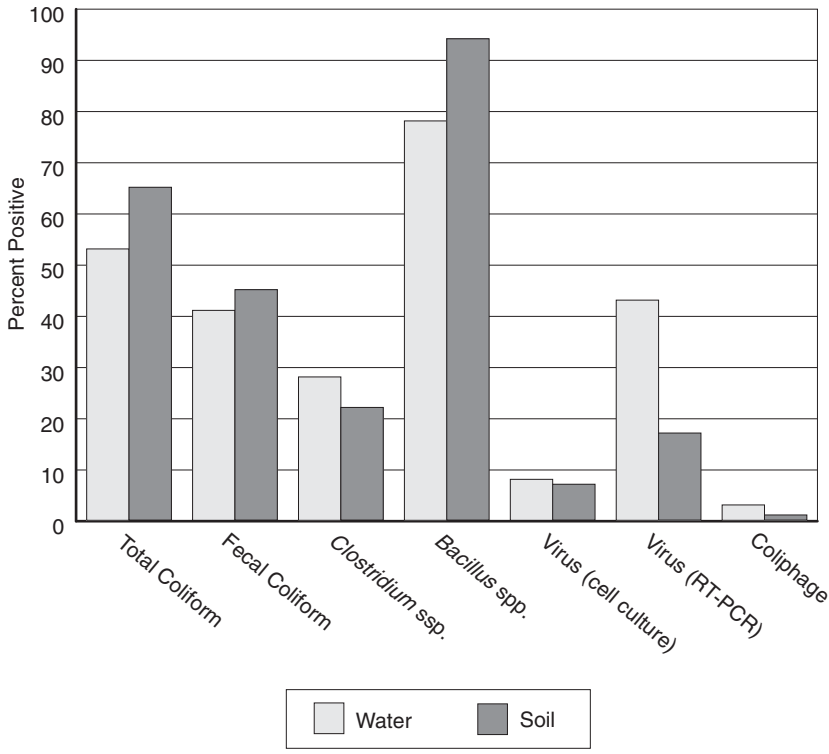


Figure 1-3 Percent positive (for various microbes) water and soil samples

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- Contact with or intrusion of foreign water during storage and installation activities, and sometimes following emergency repairs, most often because of premature main shutdown and depressurization. Foreign water includes trench water, stormwater, and other sources of runoff. For main breaks, potable water that enters the trench from the broken pipe and therefore contacts contaminated soil, is a common source of foreign water.

Distribution system storage facilities consist primarily of: elevated tanks, standpipes, covered above- (or partially above-) ground reservoirs, and underground reservoirs. The sources of contamination for water storage facilities are similar to those for water mains with the addition of contact or intrusion of foreign water or matter that can occur during periodic inspections. Typical contamination routes are through missing or open vents, hatches, doors, or roof openings.

Incorporating adequate disinfection practices for water mains and storage facilities can reduce the risk from these potential contamination pathways. Disinfection requirements are described in these ANSI/AWWA standards:

AWWA Standard for Disinfecting Water Mains. ANSI/AWWA C651. Denver, Colo.: American Water Works Association.

AWWA Standard for Disinfection of Water-Storage Facilities. ANSI/AWWA C652. Denver, Colo.: American Water Works Association.

Plumbing codes address the disinfection of service lines, valves on service lines, and customer meters. Several prominent codes are:

International Plumbing Code, International Code Council (formerly BOCA, ICBO, and SBCCI).

Uniform Plumbing Code, International Association of Plumbing and Mechanical Officials (IAPMO).

National Plumbing Code, Plumbing, Heating and Cooling Contractors Association (PHCC).

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Implementing these standard requirements and using good operating practices can greatly reduce the risk of waterborne disease caused by distribution system contamination.

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Chapter 2

Chlorination Chemicals

Disinfection of water mains and storage facilities is most often performed using one of several forms of chlorine: liquid chlorine, sodium hypochlorite solution, or calcium hypochlorite granules or tablets. All chemicals used for the disinfection of water mains and storage facilities should be certified to NSF/ANSI Standard 60: Drinking Water Treatment Chemicals–Health Effects and should satisfy the requirements of applicable ANSI/AWWA standards. There are other possible disinfectants; however, this field guide is limited exclusively to a discussion of chlorination methods.

Chlorine reacts with water to form hypochlorous acid, among other products, shown in the equations below (Eq. 2-1, 2-2, 2-3). This acid can dissociate in water resulting in hypochlorite ion (Eq. 2-4). Hypochlorous acid and hypochlorite ion together are known as free chlorine residual. Hypochlorous acid is 100 times more effective as a disinfectant than hypochlorite ion. The relative amounts of these two compounds in water are largely determined by the pH (Figure 2-1). Low pH (acid) conditions favor the formation of the preferred hypochlorous acid.

Liquid chlorine reaction with water

$$\underset{\text{chlorine}}{Cl_2} + \underset{\text{water}}{H_2O} \rightarrow \underset{\text{hypoclorous acid}}{HOCl} + \underset{\text{hydrocloric acid}}{HCl} \qquad \text{(Eq. 2-1)}$$

Sodium hypochlorite reaction with water

$$\underset{\text{sodium hypochlorite}}{NaOCl} + \underset{\text{water}}{H_2O} \rightarrow \underset{\text{hypochlorous acid}}{HOCl} + \underset{\text{sodium hydroxide}}{NaOH} \qquad \text{(Eq. 2-2)}$$

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Calcium hypochlorite reaction with water

$$\underset{\text{calcium hypochlorite}}{Ca(OCl)_2} + \underset{\text{water}}{H_2O} \rightarrow \underset{\text{hypochlorous acid}}{2HOCl} + \underset{\text{calcium hydroxide}}{Ca(OH)_2} \qquad \text{(Eq. 2-3)}$$

Hypochlorous acid dissociation reaction

$$\underset{\text{hypochlorous acid}}{HOCl} \leftrightarrow H^+ + \underset{\text{hypochlorite ion}}{OCl^-} \qquad \text{(Eq. 2-4)}$$

Low pH High pH

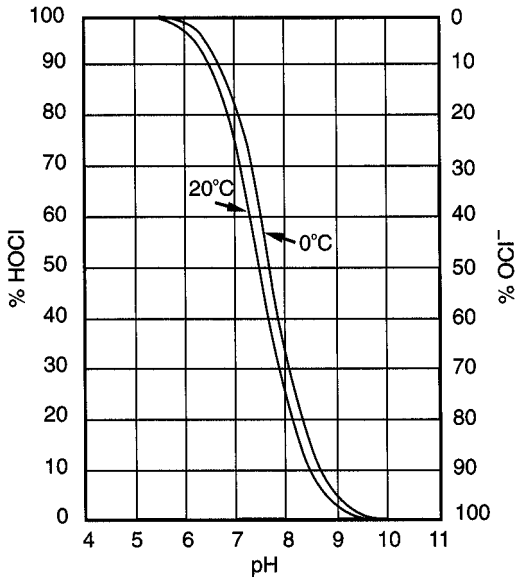


Figure 2-1 pH effect on chlorine species

An important observation is that liquid chlorine (gas under pressure in cylinders) produces an acid in its reaction with water. This results in a lower pH that favors the more effective form of

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free chlorine residual (hypochlorous acid). Both sodium and calcium hypochlorite form hydroxides in water that raise the pH. This, consequently, favors the hypochlorite ion form of the free chlorine residual. At a pH of 10, all of the free available chlorine residual is in the hypochlorite ion form. This greatly reduces the disinfection effectiveness.

Ops Tip



High concentrations of calcium and sodium hypochlorite raise the pH. This lowers the effectiveness of disinfection, so pH adjustment may be necessary.

The three chemicals commonly used for disinfection of pipelines and storage facilities are: liquid chlorine, sodium hypochlorite, and calcium hypochlorite. Some of the more important properties and concerns of these chemicals are discussed in the following sections.

Liquid Chlorine

Chlorine (ANSI/AWWA B301) is a liquefied gas under pressure and is normally packaged in steel cylinders, usually 100 lb, 150 lb, or 1 ton (45.4 kg, 68.0 kg, or 907.2 kg). It is also available in bulk tankers or rail cars.

At room temperature, about 80 percent of the volume of a cylinder is liquid chlorine. Liquid chlorine will change to gas very rapidly when removed from the pressurized cylinder and exposed to atmospheric conditions. One part of liquid chlorine will expand 459 times when it changes to a gas.

Chlorine is a hazardous substance. For detailed safety information, refer to publications of the Chlorine Institute, Washington D.C., and OSHA and DOT regulations that apply to chlorine handling and transportation. Safety precautions and special training are required to comply with all applicable regulations and to ensure safe handling and use. Chlorine use requires:

- Appropriate gas-flow chlorinators and ejectors to provide a controlled high-concentration solution feed.
- Direct supervision of trained personnel who are equipped to handle any emergency.

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- Application of appropriate and required safety practices to protect workers and the public.
- Comprehensive knowledge, training, and certification (where required) of all applicable personnel.

Sodium Hypochlorite

This is a solution of sodium hydroxide and chlorine (NaOCl). It can be purchased in several strengths, generally from 3 to 15 percent by weight (ANSI/AWWA B300). Household bleach is 3 to 4 percent sodium hypochlorite. Commercially, it is available in a variety of containers from 1 qt (1 L) to 30 gal (113.6 L). Bulk tanks or rail cars are available in some areas. On-site generation equipment is available; therefore this chemical can be produced as needed by utility personnel or contractors.

Recommendations of the Chlorine Institute regarding safe handling specifics should be followed. Sodium hypochlorite is not as hazardous as liquid chlorine, but precautions are still recommended.

- Store in a cool, dark place to minimize the rate of decomposition.
- Store in shipping container or container made of compatible material (plastic).
- Keep container closed to prevent corrosive fumes from escaping.
- Wear personal protective equipment, such as gloves, apron, and eye protection.

Calcium Hypochlorite

Calcium hypochlorite is a dry, white or yellow-white, granular material produced from the reaction of lime and chlorine (ANSI/AWWA B300). Calcium hypochlorite is commonly 65 percent available chlorine. It is commercially available in granular, powdered, or tablet forms.

Tablet size is about 5 g and can take 7 hr or longer to dissolve in water. Colder temperatures may increase dissolving time, so adequate time is needed when using this form of the chemical. Calcium hypochlorite intended for swimming pool disinfection

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should not be used, because binders and other compounds may be included, making it very difficult to remove from pipelines or other facilities being disinfected.

The recommendations of the Chlorine Institute regarding safe handling specifics should be followed. Some precautions needed for the safe handling and storage of this material include:

- Store in the original container and avoid moisture.
- Decomposition may occur if stored for a lengthy period.
- It can ignite or explode on contact with organic materials (oil, rags, or alcohol) and should not be exposed to fire or elevated temperatures.
- Personal protective equipment should include: protective apron, rubber gloves, eye protection, and a dust-protection respirator.

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Chapter 3

Disinfection of Pipelines

Operators should follow these important steps to provide the maximum public health protection when installing new or replacement drinking water mains and other pipelines intended for potable water service. Each of these steps is discussed in more detail in the following sections.

1. Inspection
2. Sanitary Construction Methods
3. Flushing or Cleaning
4. Preventing Backflow During Installation
5. Providing Temporary Service
6. Chlorination (Chemical Disinfection)
7. Final Flushing
8. Bacteriological Testing
9. Connection to Distribution System
10. Documentation

Inspection

The pipes and appurtenances should be examined for any damage with close attention to joints. Any damage to the pipe ends or gasket areas may result in leakage. Any damaged sections should be rejected. The pipe sections should be clean and free of blemishes on the pipe interior. The coatings and linings should be fully cured before completing installation. Before placing pipe in a trench, it should be thoroughly inspected for contamination and interference.

Sanitary Construction Methods

The installation methods for water mains should include the adoption of sanitary procedures that can improve disinfection. These procedures are critical to achieve satisfactory bacteriological

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quality. Although it may seem time consuming or unnecessary to perform each sanitary practice, experience has shown that the steps actually save time because they reduce the failure rate of bacteriological tests. Failed tests can necessitate rechlorination or sometimes require reinstallation.

Keep Pipe Clean and Dry

The interior of pipes and pipeline fittings must be protected from contamination during installation. The openings must be sealed with watertight plugs or other suitable plugs when the construction is halted and personnel are not present to ensure that animals or debris do not enter the pipe.

Ops Tip

Keeping the pipe clean during installation is the single most important factor that results in successful disinfection.

As pipe is delivered to the site and if it is strung along the trench, precautions should be taken to prevent material from entering the pipe. Any delay in the installation of delivered pipe can lead to possible contamination (Figure 3-1). One precaution is to cover the ends of the pipe if it is not installed on the delivery day (Figure 3-2). Pipe may be purchased and delivered with covered ends; this practice prevents foreign material from entering the pipe.

Joints

The joints should be connected in the trench before stopping work. Plugs should remain in place to prevent water or mud from entering the pipe.

Packing Materials

Packing material made of molded or tubular rubber rings, rope of treated paper, or other approved materials (ANSI/NSF Standard 61) should be used. Jute or hemp materials are not approved for this purpose.

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Courtesy Denver Water

Figure 3-1 Unprotected pipe exposed to possible contamination



Courtesy Denver Water

Figure 3-2 Protected pipeline along trench

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Sealing Materials

Only sealing materials, gaskets, and lubricants certified according to ANSI/NSF Standard 61 should be used. Lubricants should be kept in clean, closed containers and applied with clean applicator brushes.

Wet-Trench Construction

Sometimes it is not possible to prevent water from entering the pipe as it is installed. Water entering the pipe should contain approximately 25 mg/L chlorine. This can be accomplished by adding chlorine granules or tablets to each length of pipe as it is lowered into the wet trench or by treating the trench water itself.

Ops Tip  Removing water from the trench will improve disinfection.

Flooding by Storm or Accident During Construction

If the new main is flooded during construction, the pipe should be drained and flushed (if possible) with potable water until the flood water is removed. The flooded section should be chlorinated so that a 25 mg/L residual remains for at least 24 hr. The chlorinated water should be drained from the main (following acceptable disposal procedures for high chlorine water). When construction is completed, the main should be disinfected using the continuous-feed or slug method described in this chapter.

Flushing and Cleaning

This may be the single most important step to ensure that the pipe passes the bacteriological tests needed before the main can be used for potable water service. Extra time and care taken with this process will result in less rework, retesting, and a quicker return to service.

Ops Tip  Carefully cleaning the pipe before beginning disinfection will improve success.

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Fire hydrants are usually used for flushing. In some cases, a blowoff connection is used if one has been installed. A velocity of at least 2.5 ft/sec (0.8 m/sec) is needed to remove dirt or other debris from the pipe. A low velocity flush (1 ft/sec) is adequate to "rinse" a clean pipe or to refresh the water within a main. Use Table 3-1 to determine the flushing flow rate needed to achieve 2.5 ft/sec or 1 ft/sec velocity within pipelines of various diameters.

Regardless of the velocity, flush long enough to result in two or three complete changes of the water within the pipeline. Table 3-2 is useful to determine the volume needed to achieve three

Table 3-1 Approximate pipeline flushing rates*

Pipe Diameter		Flow for 1 ft/sec velocity		Flow for 2.5 ft/sec velocity	
in.	*mm*	*gpm*	*L/sec*†	*gpm*	*L/sec*
2	50	10	0.6	25	1.6
4	100	40	2.5	100	6
6	150	1,190	6.0	200	13.0
8	200	150	10	400	25
10	250	250	16	600	38
12	300	350	22	900	57
16	400	625	39	1,600	100
18	450	800	50	2,000	126
20	500	1,000	63	2,500	158
24	600	1,400	88	3,500	220

* Flushing flow rates are approximate because precise values are not needed for these operations. Time to flush 100 ft (30.48 m) at 1 ft/sec is about 1.7 min and 40 sec at 2.5 ft/sec.

† The values in this table are calculated for US units and then converted to SI units. The L/sec values are calculated by converting the approximate gpm values. The resultant values, therefore, multiply the rounding errors.

Table Tamer

Use this table to determine the flushing rates for either a 1 ft/sec or 2.5 ft/sec velocity. Example: A 6-in. (152-mm) pipe needs to be flushed at about 200 gpm (13 L/sec) to achieve a 2.5 ft/sec velocity.

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water changes within a pipeline. This volume is also the amount that will need to be dechlorinated, if that is required. A useful field estimate is to flush for about 2 minutes for each 100 ft of pipeline if your flow rate is achieving a 2.5 ft/sec velocity.

The flow may be measured by a flowmeter or estimated using the trajectory discharge method. Use Figure 3-3 to estimate the flow using this method. Table 3-3 provides some calculated values using

Table 3-2 Approximate flush volume for three water changes*

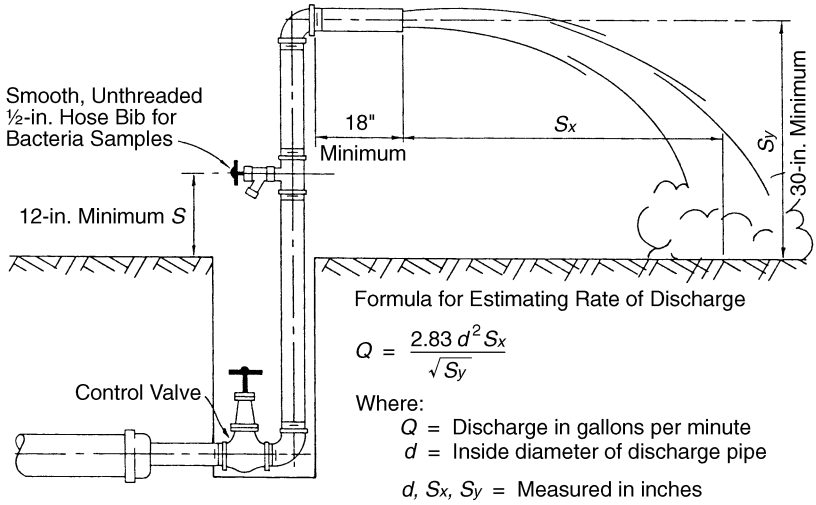
Pipe Diameter		Volume in 100 ft of pipe		Volume for Three Water Changes in 100 ft of pipe	
in.	*mm*	*gal*	*L*	*gal*	*L*
2	50	16	62	11,49	,185
4	100	65	247	1,196	,740
6	150	148	555	1,440	1,660
8	200	261	988	,780	2,960
10	250	408	1,540	1,220	4,630
12	300	587	2,220	1,760	6,660
16	400	1,040	3,950	3,130	11,850
18	450	1,320	5,000	3,960	15,000
20	500	1,630	6,170	4,890	18,520
24	600	2,350	8,800	7,040	26,660

* Time to flush three water changes of 100 ft (30.48 m) at 1 ft/sec is about 5 min and 2 min at 2.5 ft/sec. The values in this table are calculated for US units and then converted to SI units. Approximate volumes are acceptable for field applications.

Table Tamer This information is used to calculate the volume of water within a pipeline and the amount needed for three water changes. Example: 500 ft of 6-in. (152-mm) pipe needs 440 gal for 100 ft (from the table), so for 500 ft, 2,200 gallons are needed.

Ops Tip For each 100 ft (30.5 m) of pipe length flush for about 2 min.

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Note: This figure applies to pipes up to and including 8-in. (200-mm) diameter.

Figure 3-3 Trajectory discharge method of flow estimation and illustration of combination blowoff and sampling tap

this method for common size pipelines and other standard conditions. Using this table, a flow can be easily estimated from field measurements.

Large diameter pipelines may require excessive water to flush adequately. In these cases, it may be necessary to employ poly pigs or swabs (powerwashers and hydraulic jet sprayers are sometimes used) to clean the pipe without using great volumes of water (Figures 3-4, 3-5, 3-6).

If dirt enters the pipe, it should be removed by flushing the pipe with potable water, and the interior surface of the pipe swabbed with 1 to 5 percent chlorine solution (sodium or calcium hypochlorite). Small quantities of 1 percent solution should be prepared as shown in Table 3-4. If there is material adhering to the interior of the pipe that cannot be flushed out, a more aggressive cleaning may be necessary. Hydraulically propelled swabs, poly pigs, or other suitable devices including mechanical scrapers may be used to remove the attached material. This cleaning

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Table 3-3 Trajectory needed to achieve flushing velocity

Diameter of Main		Diameter, *d*, of Discharge		Trajectory (*Sx*) for 1 *ft/sec*		Trajectory (*Sx*) for 2.5 *ft/sec*	
in.	*mm*	*in.*	*mm*	*ft*	*m*	*ft*	*m*
6	152	2	51	4	1.2	8.8	2.7
6	152	2.5	64	2.5	0.8	5.7	1.7
6	152	4	102	1	0.3	2.2	0.7
8	203	2	51	6.6	2	17.7	5.4
8	203	2.5	64	4.2	1.3	11.3	3.5
8	203	3	76	3	0.9	7.9	2.4
8	203	4	102	1.7	0.5	4.4	1.3

NOTE: 36 in. (914 mm) distance from discharge to ground (*Sy* in Figure 3-3)

Table Tamer

This table lists some typical results when using the trajectory discharge method and the equation shown in Figure 3-3. The table assumes that the distance from discharge to the ground (*Sy*) is 36 in. The calculation is provided so that *only* the trajectory distance from the discharge pipe is needed. Example: A 6-in. main is flushed using a 2.5-in. diameter discharge pipe. To achieve a 2.5 ft/sec velocity in the main, the trajectory must be 5.7 ft.

should be followed with an application of chlorine solution as previously described.

More aggressive methods of cleaning larger diameter pipelines include using powerwashers or hydraulic spray jets. The equipment, used commonly for cleaning sewer collection system piping, is suitable for this purpose (Figure 3-7, 3-8). These devices may be self-propelled and can do a superior job cleaning the pipe interior. Some high pressure powerwashers can clean an entire pipe section from one end.

Preventing Backflow During Installation

High chlorine levels used for disinfection of new pipelines or other nonpotable conditions may contaminate the potable

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Courtesy Denver Water

Figure 3-4 Powerwashing pipe section

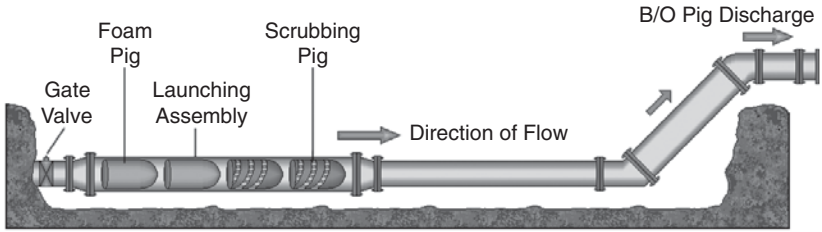


Courtesy Denver Water

Figure 3-5 Powerwashing close-up

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Courtesy Nicole Peschel

Figure 3-6 Pipeline pigging illustration

Table 3-4 Making small amounts of 1% or 5% chlorine solution with 65% available chlorine calcium hypochlorite*

US Units			SI Units		
Water Volume (*gal*)	1% Solution (*lb* needed)	5% Solution (*lb* needed)	Water Volume (*L*)	1% Solution (*g* needed)	5% Solution (*g* needed)
0.25 or 1 qt	0.03125 or about 3 teaspoons	0.15625	1	15.4	77
1	0.125 or ⅛ lb	0.625	4	61.6	308
2	0.25 or ¼ lb	1.25	5	77	385
3	0.375 or about ⅓ lb	1.875	8	123.2	616
4	0.5 or ½ lb	2.5	10	154	770
5	0.625	3.125	20	308	1,540
10	1.25	6.25	40	616	3,080

* The values in this table are rounded and approximated for field use.

Table Tamer For one gallon of 1% chlorine solution, ⅛ lb or about 60 g of calcium hypochlorite should be used. See shaded cells above.

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Courtesy Denver Water

Figure 3-7 Hydraulic jet cleaning



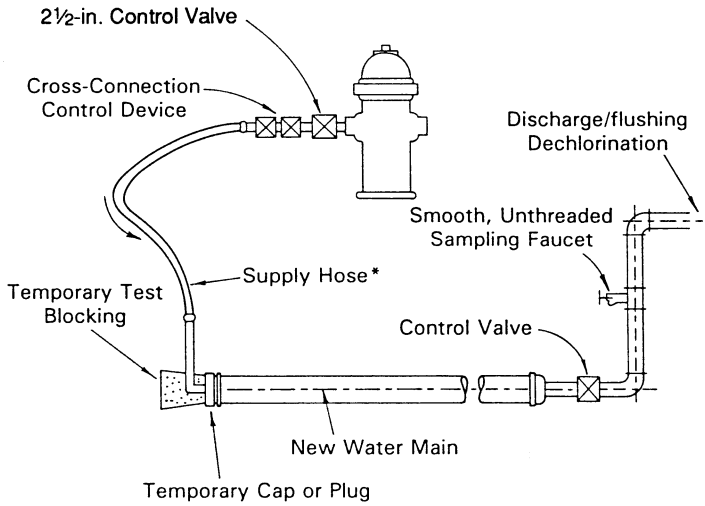
Courtesy Denver Water

Figure 3-8 Washing during pipeline repair

distribution system. Therefore, prevent backflow from newly installed (but untested) pipelines to the active distribution system. This can be accomplished with a physical separation (Figure 3-9) between the systems or by the use of an approved backflow prevention device. Hydrostatic pressure testing of new pipelines is another situation when backflow is a possibility.

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*Clean potable-water hose only. This hose must be removed during the hydrostatic pressure test.

NOTE: Applies to pipes with diameters 4 in. (100 mm) through 12 in. (300 mm). Larger sizes must be handled on a case-by-case basis.

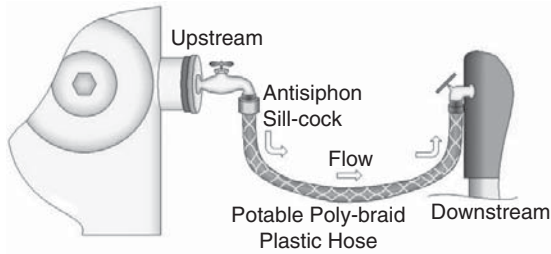
Figure 3-9 Suggested temporary flushing connection (AWWA Standard 651 *Disinfecting Water Mains*)

Providing Temporary Service

When new pipelines are installed as replacements, interruptions in water service may occur. It is common practice in the US to install temporary piping to provide continuous service when the supply is disrupted for more than several hours. Temporary supply lines are typically installed aboveground (Figure 3-10), and residences and businesses are connected by flexible hose to outside spigots or in meter pits.

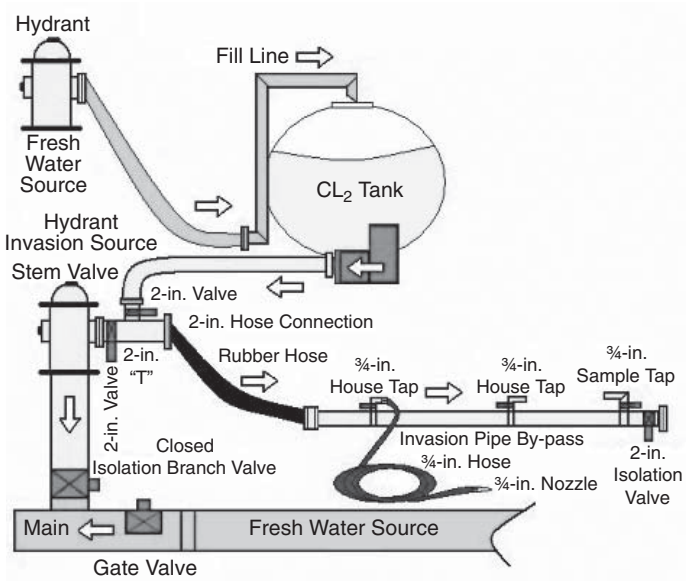
The use of temporary water lines can significantly increase the project time and cost. This is because the temporary network must be disinfected (Figure 3-11), and the water must pass bacteriological testing before customers can be connected. Additionally, the public can view the temporary lines as an unsightly

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Courtesy Nicole Peschel

Figure 3-10 Temporary hydrant connection



Courtesy Nicole Peschel

Figure 3-11 Temporary service line chlorination example

nuisance that may impede vehicular traffic and cause hazards for pedestrians.

Many other industrialized countries do not provide temporary service lines. Instead they select alternatives such as supplying bottled water or locating water trucks in the area. Some suppliers

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consider lengthy interruptions in water service as acceptable. A decision to install temporary service lines or other alternative water sources requires careful consideration of a number of factors including: site conditions, fire flow requirements, expected duration of the service interruption, cold temperatures, backflow prevention devices, internal plumbing, number of customers affected, and the type of customer (e.g., hospitals, schools, or individual residences).

Temporary pipelines are made of a variety of materials, including steel, polyvinyl chloride (PVC), and high density polyethylene (HDPE). The use of fire hoses or rubber hoses should be avoided. Components must be certified to NSF Standard 61 and approved for potable water service. Generally, installation follows the same procedures as for permanent pipelines.

- Flush and disinfect all hydrants used as supply
- Carefully select pipeline location and placement
- Select appropriate pipeline material
- Install pipeline, with ramps as necessary and buried where required
- Install backflow prevention device where required
- Connect pipeline to hydrant
- Fill line, chlorinate, flush, sample, and test for chlorine residual and bacteria
- Transfer customers to temporary service following satisfactory test results
- Remove temporary service

Ops Tip 

Store short, predisinfected coils of approved pipe so they are ready for emergency use.

Disinfection procedures are the same as for permanent pipelines (ANSI/AWWA C651). Temporary pipelines must be flushed (usually at 2.5 ft/sec) to remove any dirt or debris. Chlorination is conducted according to C651 and as described in the following

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section. Bacteriological testing is then conducted before the temporary service is placed into use.

Chlorination

Three methods of chlorination are described in this field guide: tablet or granules, continuous feed, and slug. Factors to consider when selecting one of these methods are the length and diameter of the main, the type of joints, availability of materials, equipment required, training of the personnel, and safety concerns.

Each method has advantages and disadvantages that need to be considered. The calculation of the amount and the application procedures for each method are discussed in detail later in this chapter (summary shown in Table 3-5).

Tablets (granules)

- Pipe must be clean and dry
- Convenient for use in mains up to 24 in. diameter
- Need adequate time to dissolve in water
- Water flow may move granules to one end of a pipeline
- Disinfection may not be uniform

Continuous feed

- Suitable for general application
- Gas chlorinator needed
- Chlorine gas safety issues

Slug

- Suitable for large-diameter mains
- Chlorine gas feed and safety issues
- May save chemicals
- Reduces volume of high-chlorine water for disposal

When employing any of the chlorination methods, there are several measurements that are always needed. Some of these are defined by the pipeline measurements and some are the result of the chlorination method selected. Filling out the chlorination chemical amount calculation checklist ensures that the procedure

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Table 3-5 Pipeline disinfection methods summary

Method	Chlorine Dosage	Holding Time	Minimum Chlorine Residual	Notes
Tablet or granules	25 mg/L	24 hr, 48 hr if temperature <5°C	Detectable	Add enough to fill entire pipeline segment
Continuous feed	25 mg/L	24 hr	10 mg/L	Add enough to fill entire pipeline segment
Slug	100 mg/L	3 hr	50 mg/L at any point	Fill % of pipeline with slug and move the slug slowly to give 3 hr contact

is completed satisfactorily. This checklist is used for all of the examples shown in this field guide.

Chlorination Chemical Amount Calculation Checklist

- ❑ The pipeline diameter and length.
- ❑ Valves, hydrants, tees, and other appurtenances.
- ❑ Volume of chlorination (Table 3-6) water to disinfect pipeline (this is the volume for disposal; chlorine residual is needed to determine dechlorination chemical amount needed).
- ❑ Amount of chlorine chemical needed to complete the disinfection procedure.

Final Flushing

Heavily chlorinated water should be flushed from the main following the required holding period (usually at least 24 hr). All main fittings, valves, and branches must be flushed. Chlorine

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Ops Tip



This table may be one of the most useful. Just multiply the length of pipe by the volume per foot. This equals the total volume.

Table 3-6 Approximate pipeline volume for various diameters

US Units		SI Units	
Pipe Diameter *in.*	*gal/ft*	Pipe Diameter *mm*	*L/m*
2	0.16	50	1.96
4	0.65	100	7.85
6	1.47	150	17.66
8	2.61	200	31.40
10	4.08	250	49.06
12	5.87	300	70.65
16	10.44	400	125.60
18	13.21	450	158.96
20	16.31	500	196.25
24	23.49	600	282.60
30	36.70	800	502.40
36	52.85	900	635.85
42	71.93	1,000	785.00
48	93.95	1,200	1,130.40
54	118.90	1,400	1,538.60
60	146.80	1,500	1,766.25
64	167.02	1,600	2,009.60

Table Tamer

This is two tables. The left table is in US units and the right table is in SI units. Multiply the length of the pipeline by the volume for each unit length to get the total volume of the pipeline. Example: 100 m of 150-mm pipeline contains 1,766 L.

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residual of the flush water exiting the chlorinated main should be measured until the residual is no greater than the feed water.

Flush water containing high chlorine concentrations may require treatment to avoid adverse environmental impact. Consult appropriate regulatory agencies regarding requirements for the disposal of heavily chlorinated water (Tikkanen, 2001). It may be necessary to dechlorinate the water prior to disposal. Chapter 7 includes procedures for dechlorination. Some of these procedures may not be approved by every regulatory agency. Follow regulatory agency directives regarding the approved treatment procedures for your area.

Bacteriological Testing

Perform bacteriological tests on water in the new pipeline after flushing but before it is connected to the distribution system. The tests must satisfy all applicable regulatory requirements. A certified laboratory must perform the analyses. The results must be negative (no coliform present) before connecting the pipeline and releasing the water for use by customers. The following testing protocol is listed in ANSI/AWWA Standard C651.

1. Collect two samples from the new pipeline taken at least 24 hr apart.
2. Collect a sample from at least every 1,200 ft (366 m) of new main.
3. Collect a sample from the end of the line and at least one from each branch.
4. Test samples for total coliform bacteria in accordance with *Standard Methods for the Examination of Water and Wastewater*. Additional tests may be required including: chlorine residual, turbidity, pH, and heterotrophic plate count (HPC).
5. *Special Condition*. Collect additional samples at intervals of approximately 200 ft (61 m) if trench water has entered the new main during construction or if excessive quantities of dirt or debris have entered the new main. Take samples of water that has stood in the new main for at least 16 hr after final flushing.

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6. Collect samples in sterile bottles treated with sodium thiosulfate as required by *Standard Methods for the Examination of Water and Wastewater*. Do not use hose or fire hydrants for the collection of samples. A combination blowoff and sampling tap used for 8 in. (200 mm) mains and smaller is shown in Figure 3-3. Ensure that there is no water in the trench up to the connection for sampling. Use a clean and disinfected sampling pipe that has been flushed prior to sampling. A corporation cock may be installed in the main with a copper tube gooseneck assembly. This assembly can be removed after sampling and used again.
7. If the HPC test results are greater than 500 colony-forming units (cfu) per mL, flush and collect a repeat sample until no coliforms are present and HPC is below 500 cfu/mL.
8. Coliform bacteria must be absent from the samples and the bacteriological quality of the water equal to or better than that of the distribution system.
9. If unsatisfactory test results are obtained, flush the main again and resample. If check samples also fail to produce acceptable results, rechlorinate the main by the continuous-feed or slug method until two consecutive sets of acceptable tests are taken at least 24 hr apart. In some cases, it may be necessary to pig or pressure wash the pipe prior to rechlorinating the main. It is advisable to check the quality of the water entering the new main because high velocities used for flushing may have disturbed sediment in the supply piping and resulted in poor quality feed water.

Connection to Distribution System

When all bacteriological tests are satisfactory the new main may be connected to the distribution system and placed in service. If the final connection is one pipe length (18 ft or 5.5 m) or less, the new pipe, fittings, and valve(s) required for the final connection may be spray-disinfected or swabbed with a 1–5 percent chlorine solution (Table 3-4) just prior to being installed. If the final connection is greater than one pipe length (greater than 18 ft

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or 5.5 m), the connection pipe is disinfected and bacteriological samples tested as previously described. The pipe should be connected to the distribution system after obtaining satisfactory test results. The ends of the predisinfected connection pipe should be covered during the testing and before the connection is complete.

Note: The bacteriological test is the final step in a sanitary installation process that includes inspection, use of proper materials and protection of pipes during installation, cleaning and flushing, and employing adequate disinfection procedures.

Documentation

Accurate records should be kept to document the installation conditions and test results (including water quality testing). The records should identify persons that conducted tests and that released the pipeline for service. The as-built plans should be completed identifying the types and locations of valve boxes, hydrants, and other appurtenances. The valve opening direction and any flow test results for hydrants should be recorded.

Pipeline Chlorination Method Specifics

Specific procedures for implementing each of the three pipeline chlorination methods are described in the following section. The procedures include tables and calculators for determining the necessary information to efficiently and accurately chlorinate pipelines.

Tablet Method

Calcium hypochlorite tablets (or granules) are placed in the water main as it is being installed. The main is then filled with potable water. This procedure cannot be used on solvent-welded plastic or on screwed-joint steel pipe. Fire or explosion may result from the reaction of calcium hypochlorite and joint compounds. This method also cannot be used if the main must be flushed before it is disinfected, because this process would remove the calcium hypochlorite from the main.

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Use Tables 3-7a & b and 3-8a & b to determine the amount of calcium hypochlorite granules or the number of tablets needed to disinfect the length of pipeline. Table 3-7a lists the amount (by weight) of calcium hypochlorite granules needed to achieve a 25 mg/L dosage for each 500 ft of pipeline. Weights are given in ounces and grams.

Often facilities are not available to weigh out the amount of chemical needed for the job. Kitchen measures are then handy for this purpose. Teaspoons, ¼-cup, ½-cup, and 1-cup measures are readily available and Table 3-7b lists the approximate number of these measures needed. From the table, about 1 cup is needed for each 500-ft length of 8-in. diameter pipe. A plastic one-cup kitchen measure is all you need in the field to make this measurement.

Tables 3-8a & b list the number of 5-gram tablets needed for various pipe lengths, in both US and SI units. So, from Table 3-8a, a single tablet is needed for an 18-ft length of 6-in. diameter pipe. Similarly, from Table 3-8b, two tablets are required for a 6-m length of 200-mm diameter pipe.

If this method is used, great care must be taken to ensure that the pipeline is clean, dry, and free of dirt, debris, and other contamination. Fill the pipeline slowly to ensure that the granules are not moved to one end of the pipeline and to allow time for the tablets to dissolve.

Chlorination Steps and Precautions.

1. Place calcium hypochlorite granules or tablets at the upstream end of the first section of pipe, at the end of each branch main, and at 500-ft intervals (Tables 3-7a, b and 3-8a, b).
2. Use NSF/ANSI Standard 61 certified adhesive to attach tablets inside and at the top of each section of the main (Figure 3-12).

Ops Tip



Tablets aren't generally used if more than five need to be used in one place. Use a combination of tablets and granules in this case.

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