

San Diego State University
Environmental Health and Safety Department

Water Main and Building Water Disinfection and Testing

I. Water Main Disinfection

A. Introduction

These procedures describes methods of disinfecting 1) newly constructed potable water mains; 2) mains that have been removed from service for planned repairs or for maintenance that exposes them to contamination; 3) mains that have undergone emergency repairs because of physical failure; and 4) mains that, under normal operation, continue to show the presence of coliform organisms. These disinfection procedures are based on the AWWA Standard for Disinfecting Water Mains (C651-05 or the most current). The preparation of the water mains, application of chlorine, and sampling and testing for the presence of coliform and heterotrophic bacteria are described in these procedures. The disinfecting agents discussed in this standard are chlorine solutions that may be derived from liquid chlorine (Cl_2), calcium hypochlorite ($Ca(OCl)_2$), or sodium hypochlorite (NaOCl). Combinations of free chlorine residual and contact time are provided.

B. General Requirements

Installation of all plumbing fittings and valves necessary for full-diameter flushing and chlorination shall be done by the contractor.

Chlorination and final flush shall be done by a commercial disinfecting company which has demonstrated its ability, equipment, and knowledge of chlorination procedures in compliance with AWWA C651-05 or the most current. Contractor shall submit the name of the proposed company for approval. Approvals shall be given by Environmental Health and Safety (EHS) on each specific job. Notify EHS, on the **Attachment 1: Chlorination Notification Form**, at least 5 working days prior to the date of chlorination. Provide EHS the **Attachment 2: Chlorination Report**, indicating the date of chlorination, lines disinfected, method of chlorination, amount and type of disinfection used, concentration applied, chlorine residual attained in system, holding time, chlorine residual after retention period, date of flushing, and chlorine residual concentration after flushing.

Bacteriological analysis shall be done by a state certified testing laboratory for drinking water quality. Disinfecting company shall submit the name of the proposed laboratory as well as the proposed number and location of samples for approval. Approval shall be given by Environmental Health and Safety on each specific job. Notify EHS, on the **Attachment 3: Bacteriological Sampling Notification Form**, at least 3 working days prior to the date of sampling. Provide EHS the **Bacteriological Report**, indicating the date of sampling, sample location, presence or absence of coliform organism (total and

fecal coliform), and heterotrophic plate count. A microbial laboratory analysis report is acceptable as Bacteriological Report. Upon satisfactory completion of all disinfection procedures approved by EH&S and receipt of acceptable bacteriological results, a written approval of the system will be provided to the responsible contractor (**Attachment 4: Chlorination and Bacteriological Testing Verification and Approval**).

C. Nonemergency Water Main Disinfection Procedures

The basic steps in nonemergency disinfection of water mains are the following;

- Preventive Measures: Prevent the introduction of contaminated material into all new mains during storage, construction, installation or repair process. Protect existing distribution system from backflow due to hydrostatic pressure test and disinfection procedures.
- Preliminary Preparation and Flush: All new mains shall be purged of contaminants by means of a full diameter flush.
- Chlorination: All new mains shall be disinfected by means of the tablet, continuous, or slug method and maintain the specified chlorine residual for the minimum required contact time. Document adequate level of chlorine contacted each pipe to provide disinfection.
- Final Flush: All new mains shall be cleared of excess chlorine by flushing the heavily chlorinated water from the main until the normal potable water chlorine residual is observed.
- Bacteriological Testing: Confirm the effectiveness of the disinfection procedure through bacteriological testing, as specified in the American Public Health Association (APHA) "Standard Methods for the Examination of Water and Wastewater".
- Final connection: Final connection of the approved new water main to the active distribution system.

1. Preventive Measures

During construction, the interior as well as all sealing surfaces of pipe, fittings, and other accessories should be kept as clean, dry, and protected from contamination as possible. Inspect the interior of all pipes prior to installation. If dirt enters the pipe, it should be removed and the affected interior of the pipe swabbed with a 1 - 5% chlorine solution. All openings in pipelines should be closed with watertight plugs whenever the trench is unattended.

Sealing, lubricating, or gasket materials used in pipe installation should be stored and handled in a manner that avoids contamination and be suitable for use with potable water and shall not contribute odors. No contaminated material or any material capable of supporting growth of microorganisms shall be used for sealing joints. It shall be delivered to the job site in closed containers and shall be kept clean and applied with dedicated, clean applicator brushes.

Joints of pipe in the trench shall be completed before work is stopped. If water accumulates in the trench, the plugs shall remain in place until the trench is free of standing water and mud that may enter the pipe.

If dirt enters the pipe, it shall be removed and the interior pipe surface swabbed with a 1 to 5 percent hypochlorite disinfecting solution. If the dirt remaining in the pipe will not be removed using the flushing operation, the interior of the pipe shall be cleaned using mechanical means, such as hydraulically propelled foam pig (or other suitable device) in conjunction with the application of a 1 percent hypochlorite disinfecting solution. The cleaning method used shall not force mud or debris into the interior pipe-joint spaces.

If it is not possible to keep the pipe and fittings dry during installation, the water that may enter the pipe-joint spaces shall contain an available chlorine concentration of approximately 25 mg/L. This may be accomplished by adding calcium hypochlorite granules or tablets to each length of pipe before it is lowered into a wet trench or by treating the trench water with hypochlorite tablets.

If the main is flooded during construction, it shall be cleared of the floodwater by draining and flushing with potable water until the main is clean. The section exposed to the floodwater shall then be filled with chlorinated potable water that, at the end of a 24 hr. holding period, will have a free chlorine residual of not less than 25 mg/L. The chlorinated water may then be drained or flushed from the main. After construction is completed, the main shall be disinfected using the continuous-feed or slug method.

The new water main shall be kept isolated from the active distribution system using a physical separation (see figure 1 of AWWA C651) until satisfactory bacteriological testing has been completed and the disinfectant water flushed out.

Water required to fill the new main for hydrostatic pressure testing, disinfection, and flushing shall be supplied through a temporary connection between the distribution system and the new main. The temporary connection shall include an appropriate cross-connection control device consistent with the degree of hazard and shall be disconnected from the new main during the hydrostatic pressure test. It will be necessary to reestablish the temporary connection after completion of the hydrostatic pressure test to flush out the disinfectant water prior to final connection of the new main to the distribution system.

Note: Exposure to high levels of chlorine or high pH can cause severe irritation to customers. Also the chlorinated water can be high in disinfection by-products.

2. Preliminary Preparation and Flushing of Mains

Before being chlorinated, the main should be completely filled with water to eliminate air pockets and then flushed to purge the line of dirt and debris that might have entered the main during the course of the installation or that might have been present in existing piping. This is typically conducted after the completion of the leakage and pressure tests.

Hydrostatic pressure testing shall be done in accordance with the latest revision of ANSI/AWWA C605 "Underground Installation of Polyvinyl Chloride (PVC) Pressure Pipe and Fittings for Water".

Upon completion of the installation of the water main all piping shall be hydrostatically tested, by the Contractor, by pumping water into the main up to a pressure of 120 psi. The 120 psi pressure must be maintained for a period of two (2) hours minimum. The Engineer or Inspector of Record must be present to observe the hydrostatic pressure test of the water main before the water main will be accepted by the university.

If the Contractor is unable to maintain a pressure of 120 psi for two hours, the Contractor shall locate and repair any defects and re-test the water main until it meets the requirements of the pressure test.

The source of potable water used for disinfection and pressure testing shall be flushed prior to its use to ensure that contaminants or debris are not introduced into the new pipe. Adequate drainage must be provided during flushing. Drainage should take place away from the construction area. During the contact period, it is recommended that the valve isolating the new main from this system (if applicable) be tagged to prevent unintentional release of the elevated chlorine residual water into the system.

Ineffective removal of dirt and debris from lines prior to disinfection often leads to failed bacterial tests, requiring repeated disinfection. Minimum flushing rate should be accomplished at a minimum flushing velocity of at least 2.5 ft/sec and no more than 5 ft/sec. for non- fire protection lines. Where the main supplies a fire protection system the velocity shall meet NFPA 24 requirement of 10 ft/s.

Note that flushing is no substitute for preventive measures during construction. Certain contaminants, such as caked deposits, resist flushing at any feasible velocity and pigging of the main may be required. For 24 in. or larger diameter mains, an acceptable alternative to flushing is to broom-sweep the main, carefully removing sweepings prior to chlorinating the main.

All valves and hydrants shall be fully opened and closed under water pressure to ensure proper operations during flushing and to dislodge foreign material. During flushing operations, all valves or connections to existing systems shall be closed and backflow preventors or other approved equipment installed at the source to prevent contamination of existing systems.

Fittings and valves should be thoroughly cleaned before applying chlorine to a main. Special attention should be given to mechanical joints, fittings, and valves that may contain spaces that are difficult to chlorinate once they become filled with water.

Table 1 shows the required flow rate to obtain a velocity of 2.5 ft/sec in commonly used sizes of pipe. Flushing can be enhanced by the use of soft pigs to remove dirt, debris, and air from the main prior to disinfection. The use of pigs can also conserve water and is particularly useful when there is insufficient water supply to attain a 2.5 ft/sec minimum flushing velocity.

Table 1: Flow Required (GPM) for Given Velocity

Pipe Size (in.)	Pipe Area (sq. ft.)	1 ft/sec	2.5 ft/sec	5 ft/sec	10 ft/sec
2	0.02	10	25	50	-
4	0.09	40	100	200	390
6	0.20	90	200	440	880
8	0.35	155	400	780	1560
10	0.55	245	600	1220	2240
12	0.79	350	900	1760	3520
14	1.07	480	1200	2400	-
16	1.40	625	1600	3140	-

Preliminary flushing, however, should not be conducted if tablets or granules of calcium hypochlorite have been placed in the pipe during construction. In this case, special care must be exercised in ensuring that the main does not become contaminated with dirt or other materials during construction.

Flushing of water mains shall not be allowed after ambient temperature has exceeded 85°F without the prior approval of the building engineer.

3. Disinfecting Agent and Method of Chlorination

The forms of chlorine that may be used in the disinfection operations are liquid chlorine (AWWA B301), sodium hypochlorite solution (AWWA B300), or calcium hypochlorite granules or tablets (AWWA B300). Contact with organic material or high temperatures must be avoided due to the danger of fire or explosion.

AWWA Standard C651 describes three methods of chlorination for water mains: tablet, continuous feed and “slug”. The tablet method gives an average chlorine dose of approximately 25 mg/L; continuous-feed method gives a 24-hr chlorine residual of not less than 10 mg/L; and the slug method gives a 3 hr exposure of not less than 50 mg/L free chlorine.

Refer to AWWA C651 for detailed procedures and specifications of the chosen chlorination method. The chlorine dose and minimum contact time for each AWWA method are summarized in Table 2. Recommendations for disinfection of small section of mains under emergency repair are also included in Table 2. Before any disinfection method is utilized, valves must be positioned so that the highly chlorinated water in the main being treated does not flow into water mains in active service.

Table 2: Chlorination Methods for Disinfecting Water Mains

Chlorination Method Used	Initial Chlorine Dose (mg/l)	Minimum Contact Time (hours)	Minimum Chlorine Residual Conc. (mg/l)
• Tablet	25	24	10
• Continuous	25	24	10
• slug	100	3	50

Factors to consider when choosing a method of chlorination include length and diameter of the main, type of joints present, equipment and materials necessary for disinfection, skills, and training of personnel, safety concerns, and whether the main must be put into service on a rapid basis.

Disinfection by Continuous-feed Method

The continuous-feed method consists of placing calcium hypochlorite granules in the main during construction (optional), completely filling the main to remove air pockets, flushing the completed main to remove particulates, and filling the main with potable water. The potable water shall be chlorinated so that after a 24-hr holding period in the main there will be a free chlorine residual of not less than 10 mg/L.

Water supplied from a temporary, backflow-protected connection to the existing distribution system or other approved supply source shall flow at a constant measured rate into the newly installed water main. The main should undergo hydrostatic testing prior to disinfection. At a point not more than 10 ft downstream from the beginning of the new main, water entering the new main shall receive a dose of chlorine fed at a constant rate such that the water will have not less than 25 mg/L free chlorine. Table 4 of AWWA C651 gives the amount of chlorine required for each 100 ft of pipe of various diameters.

Water used to fill the new main during the application of chlorine shall be supplied through a temporary connection. This temporary connection shall be installed with an appropriate cross-connection control device, consistent with the degree of hazard for backflow protection of the active distribution system. Chlorine application shall not cease until the entire main is filled with heavily chlorinated water. The chlorinated water shall be retained in the main for at least 24 hr, during which time valves and hydrants in the treated section shall be operated to ensure disinfection of the appurtenances. At the end of this 24 hr period, the treated water in all portions of the main shall have a residual of not less than 10 mg/l of free chlorine.

Inject chlorinated water with a free chlorine concentration no less than 25 mg/L into the water line no more than 10 feet from the beginning of the new main. Provisions shall be taken to eliminate air pockets. Chlorinated water shall remain in the pipe for a minimum of 24 hours.

Disinfection by Slug Method

The slug method consists of placing calcium hypochlorite granules in the main during construction; completely filling the main to eliminate air pockets; flushing the main to remove particulates; and slowly flowing through the main a slug of water dosed with chlorine to a concentration of 100 mg/L. The slow rate of flow ensures that all parts of the main and its appurtenances will be exposed to the highly chlorinated water for a period of not less than 3 hr.

The continuous and slug methods require the use of appropriate chlorine feed equipment and the determination of the necessary chlorine feed rate for the chlorine solution. In long, large-diameter mains, the slug method has the potential for reduction in water and chemicals as compared to the continuous method.

Refer to AWWA C651 for Slug Method disinfection using calcium hypochlorite granules.

Disinfection by Tablet Method

The tablet method consists of placing calcium hypochlorite granules or tablets in the water main as it is being installed and then filling the main with potable water when installation is completed. This method may be used only if the pipes and appurtenances are kept clean and dry during construction. The tablet method is convenient to use for mains with diameters less than 24 inches and does not require special chlorine feed equipment. There are, however important limitations with this method: 1) The use of the tablet method precludes preliminary flushing. Flushing of the lines is often necessary to remove dirt and debris and assists in the removal of air from the lines. 2) Calcium hypochlorite granules or tablets may be dislodged from the lines upon filling and accumulate at points of restriction. 3) The tablet method should not be used in large-diameter mains where a worker must enter the main for inspection due to the potential of toxic fumes.

Refer to AWWA C651 for Tablet Method disinfection using calcium hypochlorite granules or calcium hypochlorite tablets.

4. Final Flushing of Mains

After the applicable minimum retention period, in order to prevent damage to the pipe lining or to prevent corrosion damage to the pipe itself, highly chlorinated water should be flushed from the main until chlorine residual measurements show that the concentration in the water leaving the main is no higher than that generally prevailing in the distribution system. Care must be exercised when flushing water with high free chlorine residuals. Chlorine is toxic to fish and other aquatic life. Disposal of highly chlorinated water to storm drains must be avoided since storm drains discharge directly to a creek, river, or lake. Obtain EHS approval prior to flushing highly chlorinated water. Highly chlorinated water may need to be neutralized prior to releasing to the ground or sanitary sewer.

Flushing of water mains shall not be allowed after the ambient temperature reaches 85°F without the prior approval of the building engineer.

5. Bacteriological Testing

- a) Standard Condition – After final flushing and before the new water main is connected to the distribution system, two consecutive sets of acceptable samples, taken at least 24 hr apart, shall be collected from the new main. At least one set of samples shall be collected from every 1,200 ft of the new water main, plus one set from the end of the line and at least one set from each branch. Samples shall be tested for bacteriological quality in accordance with Standard Methods for the Examination of Water and Wastewater; and shall show the absence of coliform organisms. A standard heterotrophic plate count (HPC) test is also required because new material does not typically contain coliforms but does typically contain heterotrophic bacteria.
- b) Special Condition – If trench water has entered the new main during construction or if, excessive quantities of dirt or debris have entered the new main, bacteriological samples shall be taken at intervals of approximately 200 ft, and the location shall be identified. Samples shall be taken of water that has stood in the new main for at least 16 hr after final flushing has been completed.
- c) Sampling Procedure – Samples for bacteriological analysis shall be collected in sterile bottles treated with sodium thiosulfate, as required by Standard Methods of the Examination of Water and Wastewater. No hose or fire hydrant shall be used in the collection of samples. There should be no water in the trench up to the connection for sampling. The sampling pipe must be dedicated and clean and disinfected and flushed prior to sampling. A corporation cock may be installed in the main with a copper-tube gooseneck assembly. After samples have been collected, the gooseneck assembly may be removed and retained for future use.
- d) Sample Results – If sample results from the lab indicate a measured HPC greater than 500 colony-forming units (cfu) per ml, flushing should be resumed and another coliform and HPC set of samples should be taken until no coliforms are present and the HPC is less than 500 cfu/ml.
- e) Record of Compliance – The record of compliance shall be bacteriological test results certifying that the water sampled from the new water main is free of coliform bacteria contamination and is equal to or better than the bacteriologic water quality in the distribution system.

6. Redisinfection

If the initial disinfection fails to produce satisfactory bacteriological results or if other water quality is affected, the new main may be reflashed and shall be resampled. If check samples also fail to produce acceptable results, the main shall be rechlorinated by the continuous-feed or slug method until satisfactory results are obtained – that being two consecutive sets of acceptable samples taken 24 hr apart.

D. Final Connections to Existing Mains

Water mains and appurtenances must be completely installed, flushed, disinfected, and satisfactory bacteriological sample results received prior to permanent connections being made to the active distribution system. Sanitary construction practices must be followed during installation of the final connection so that there is no contamination of the new or existing water main with foreign material or groundwater.

1. *Connections equal to or less than one pipe length (~18ft [5.5 m]).* The new pipe, fittings, and valve(s) required for the connection may be spray-disinfected or swabbed with a minimum 1-5 percent solution of chlorine just prior to being installed, if the total length of the connection from the end of a new main to the existing main is equal to or less than 18ft (5.5 m).
2. *Connections greater than one pipe length (>18ft [5.5 m]).* The pipe required for the connection must be set up aboveground, disinfected, and bacteriological samples taken, as describe, if the total length of the connection from the end of a new main to the existing main is greater than 18 ft (5.5 m). After satisfactory bacteriological sample results have been received for the predisinfected pipe, the pipe can be used in connecting the new main to the active distribution system. Between the time the satisfactory bacteriological sample results are received and the time that the connection piping is installed, the ends of the piping must be sealed with plastic wraps, watertight plugs, or caps.

E. Disinfection Procedures When Cutting Into or Repairing Existing Mains

The following procedures apply primarily when existing mains are wholly or partially dewatered. After the appropriate procedures have been completed, the existing main may be returned to service prior to completion of bacteriological testing in order to minimize the time customers are without water. Leaks or breaks that are repaired with clamping devices while the mains remain full of pressurized water may present little danger of contamination and therefore may not require disinfection.

1. *Trench treatment.* When an existing main is opened, either by accident or by design, the excavation will likely be wet and may be badly contaminated from nearby sewers. Liberal quantities of hypochlorite applied to open trench areas will lessen the danger from this pollution. Tablets have the advantage in this situation, because they dissolve slowly and continue to release hypochlorite as water is pumped from the excavation
2. *Swabbing with hypochlorite solution.* The interior of pipe and fittings (particularly couplings and sleeves) used in making the repair shall be swabbed or sprayed with a 1 percent hypochlorite solution before they are installed.
3. *Flushing.* Thorough flushing is the most practical means of removing contamination introduced during repairs. If valve and hydrant locations permit, flushing toward the work location from both directions is recommended. Flushing shall be started as soon

as the repairs are completed and shall be continued until discolored water is eliminated.

4. *Slug chlorination.* Where practical, in addition to the procedures previously described, the section of the main in which the break is located shall be isolated, all service connections shut off, and the section flushed and chlorinated. The dose may be increased to as much as 300 mg/L and the contact time reduced to as little as 15 min. After chlorination, flushing shall be resumed and continued until discolored water is eliminated and the chlorine concentration in the water exiting the main is no higher than the prevailing water in the distribution system or that which is acceptable for domestic use.
5. *Bacteriological samples.* Bacteriological samples shall be taken after repairs are completed to provide a record for determining the procedure's effectiveness. If the direction of flow is unknown, then samples shall be taken on each side of the main break. If positive bacteriological samples are recorded, then the situation shall be evaluated to determine corrective action. Daily sampling shall be continued until two consecutive negative samples are recorded.

Table 3: Disinfection Procedures when Cutting into or Repairing Existing Mains

Chlorination Method Used	Initial Chlorine Dose (mg/l)	Minimum Contact Time (hours)	Minimum Chlorine Residual Conc. (mg/l)
• Trench Treatment	N/A	N/A	N/A
• Swabbing	1% Solution	N/A	N/A
• Flushing	N/A	N/A	N/A
• Slug	300	15 minutes	100

F. Special Procedure for Caulked Tapping Sleeves

Before a tapping sleeve is installed, the exterior of the main to be tapped shall be thoroughly cleaned, and the interior surface of the sleeve shall be lightly dusted with calcium hypochlorite powder.

Tapping sleeves are used to avoid shutting down the main. After the tap is made, it is impossible to disinfect the annulus without shutting down the main and removing the sleeve. The space between the tapping sleeve and the tapped pipe is approximately 1/2 in. (13 mm), so that as little as 100 mg/ft² of calcium hypochlorite powder will provide a chlorine concentration of more than 50 mg/L.

II. Domestic/Building Water System Disinfection

A. Introduction

All new, remodeled or repaired potable water systems (including those that have been removed from service for planned repairs or for maintenance and were exposed to contamination, those that have undergone emergency repairs because of physical failure, and those that under normal operation continue to show presence of coliform) must be disinfected prior to use. Existing water systems that are being altered by adding additional plumbing fixtures or appurtenances such as a new water service, a complete or partial repipe, a relocated water heater, a new restroom, etc. shall be deemed disinfected by flushing of the water system until only potable, non-malodorous water appears at the point of outlets. This method is a normal plumbing practice and should only be written as a correction if upon inspection non-potable (discolored or malodorous) water is detected. New potable water systems partnered with all new construction will be required to be disinfected with water – chlorine solutions. The entire new system is to be disinfected from the Reduced Pressure Principle Backflow device all the way upstream to be furthest water outlet on the new system. All disinfection procedures must be conducted under the direction of the SDSU Environmental Health and Safety Department.

B. General Requirements

Prior to utilization of newly constructed or altered potable water piping systems, all affected potable water piping shall be disinfected using procedures prescribed in the California Plumbing Code Sections 609.9.1 through 609.9.4. The method to be followed shall be that prescribed by the Environmental Health and Safety Department.

Installation of all plumbing fittings and valves necessary for flushing and chlorination shall be done by the plumbing contractor or plumber.

Chlorination and final flush shall be done by a commercial disinfecting company which has demonstrated its ability, equipment, and knowledge of chlorination procedures in compliance with the 2010 California Plumbing Code, Sec. 609.9.1 to 609.9.4 or the most current.

Submit to EHS **Attachment 1: Chlorination Notification Form**, at least 5 working days prior to the date of chlorination. Contractor or plumber shall provide the name and contact information of the disinfecting company, the water system to be chlorinated, the proposed date of chlorination, method of chlorination, chlorine concentration and hold time. EHS will review and authorize to proceed with the chlorination on the specified date. Approvals shall be given by Environmental Health and Safety (EHS) on each specific job.

Submit to EHS **Attachment 2: Chlorination Report** immediately following final flush (3 days prior to proposed bacterial sampling date). Disinfecting company shall indicate the date of chlorination, method of chlorination, lines disinfected, amount and type of disinfection used, concentration applied, chlorine residual attained in system, holding

time, chlorine residual after retention period, date of flushing, and chlorine residual concentration after flushing. EHS will review and approve the Chlorination Report and authorize to proceed with the 3 day water hold in preparation for the water sampling for bacteriological analysis. Approval shall be given by Environmental Health and Safety on each specific job.

Submit to EHS **Attachment 3: Bacteriological Sampling Notification Form**, at least 3 working days prior to the proposed bacteriological sampling date. Bacteriological analysis shall be done by a state certified testing laboratory for drinking water quality. Disinfecting company shall submit the name of the proposed laboratory and sampling date, proposed number and sample collection sites for approval. EHS will review and approve the proposed number and sample collection sites indicated in Attachment 3 and authorize to proceed with the water sampling for bacteriological analysis. Approval shall be given by Environmental Health and Safety on each specific job.

Submit to EHS the **Bacteriological Report** prior to utilizing the new or altered potable water piping system. The report would indicate the sample date, sample location, presence or absence of coliform organism (total and fecal coliform), and the heterotrophic plate count. A microbial laboratory analysis report is acceptable as Bacteriological Report. Upon satisfactory completion of all disinfection procedures approved by EHS and receipt of acceptable bacteriological results, a written approval of the system will be provided to the responsible contractor (**Attachment 4: Chlorination and Bacteriological Testing Verification and Approval**).

C. Summary of Disinfection Procedures

The basic steps in nonemergency disinfection of domestic/building water systems are the following:

1. Preventive Measures: Prevent the introduction of contaminated material into all new pipe fittings, and other accessories during the installation process. Protect the existing distribution system from backflow due to hydrostatic pressure test and disinfection procedures.
2. Preliminary Preparation and Flush: All new domestic/building water systems shall be purged of contaminants by means of a full diameter flush.
3. Chlorination: All new domestic/building water systems shall be disinfected and maintain the specified chlorine residual for the minimum required contact time. Document adequate level of chlorine contacted each pipe to provide disinfection.
4. Final Flush: All new domestic/building water systems shall be cleared of excess chlorine by flushing the heavily chlorinated water from the domestic/building water system until the normal potable water chlorine residual is observed.
5. Bacteriological Testing: Confirm the effectiveness of the disinfection procedure through bacteriological testing, as specified in the American Public Health Association (APHA) "Standard Methods for the Examination of Water and Wastewater".
6. Final Connection: Final connection of the approved new water system to the active distribution system.

D. Preventive Measures

During construction, the interior as well as all sealing surfaces of pipe, fittings, and other accessories should be kept as clean as possible. Inspect the interior of all pipes prior to installation. If dirt enters the pipe, it should be removed and the affected interior of the pipe swabbed with a 1% chlorine solution. All openings in pipelines should be closed with watertight plugs whenever the trench is unattended. Sealing, lubricating, or gasket materials used in pipe installations should be stored and handled in a manner that avoids contamination and be suitable for use with potable water.

E. Preliminary Preparation of the System

1. All fixtures to be served by the potable water system shall be in place at the time of chlorination.
2. Provide and install, within 3 feet of the supply main, an injection port for introducing the chlorine solution. An upstream gate valve or other means to control water flow, while connecting chlorination equipment is required.
3. There shall be no dead end sections in the system exceeding 3 feet in length. All branches within the system shall lead to an outlet for bleeding and flushing.
4. Prior to injection, it is necessary to place signs on each fixture being treated in order to prevent persons from using heavily chlorinated water. Sign shall read “Heavily chlorinated water – Do not use”.

F. Preliminary Flushing of Domestic/Building Water Systems

Before being chlorinated, the domestic/building water system should be completely filled with water to eliminate air pockets and then flushed to purge the line of dirt and debris. This is typically conducted after the completion of the leakage and pressure tests.

Hydrostatic pressure testing shall be done in accordance with the latest revision of ANSI/AWWA C605 “Underground Installation of Polyvinyl Chloride (PVC) Pressure Pipe and Fittings for Water”.

Upon completion of the installation of the water main all piping shall be hydrostatically tested, by the Contractor, by pumping water into the main up to a pressure of 120 psi. The 120 psi pressure must be maintained for a period of two (2) hours minimum. The Engineer or Inspector of Record must be present to observe the hydrostatic pressure test of the water main before the water main will be accepted by the university.

The source of potable water used for disinfection and pressure testing shall be flushed prior to its use to ensure that contaminants or debris are not introduced into the new pipe.

Adequate drainage must be provided during flushing. Drainage should take place away from the construction area.

Ineffective removal of dirt and debris from lines prior to disinfection often leads to failed bacterial tests, requiring repeated disinfection. Preliminary flushing should be accomplished at a velocity of at least 2.5 ft/sec and no more than 5 ft/sec.

All valves shall be fully opened and closed under water pressure to ensure proper operations during flushing and to dislodge foreign material. During flushing operations, all valves or connections to existing systems shall be closed and backflow preventors or other approved equipment installed at the source to prevent contamination of existing systems.

Fittings and valves should be thoroughly cleaned before applying chlorine to a domestic/building water system. Special attention should be given to mechanical joints, fittings, and valves that may contain spaces that are difficult to chlorinate once they become filled with water.

Table 1 shows the required flow rate to obtain a velocity of 2.5 ft/sec in commonly used sizes of pipe. Flushing can be enhanced by the used of soft pigs to remove dirt, debris, and air from the domestic/building water system prior to disinfection. The use of pigs can also conserve water and is particularly useful when there is insufficient water supply to attain a 2.5 ft/sec minimum flushing velocity.

Table 1: Flow Required (GPM) for Given Velocity

Pipe Size (in.)	Pipe Area (sq. ft.)	1 ft/sec	2.5 ft/sec	5 ft/sec
2	0.02	10	25	50
4	0.09	40	100	200
6	0.20	90	200	440
8	0.35	155	400	780
10	0.55	245	600	1220
12	0.79	350	900	1760
14	1.07	480	1200	2400
16	1.40	625	1600	3140

G. Chlorination Procedures

The pipe system shall be flushed with clean, potable water until only potable water appears at the points of outlet.

The system or parts thereof shall be filled with a water-chlorine solution containing not less than fifty (50) parts per million of chlorine, and the system or part thereof shall be valved-off and allowed to stand for twenty-four (24) hours; or, the system or part thereof shall be filled with a water-chlorine solution containing not less than two-hundred (200) parts per million of chlorine and allowed to stand for three (3) hours.

Following the allowed standing time, the system shall be flushed with clean, potable water until the chlorine residual in the water coming from the system does not exceed the chlorine residual in the flushing water. A disinfection declaration shall be required to be filled out by the person or persons performing the disinfection of the system. The declaration shall include the date and starting time of disinfection, person or persons

names and company who performed the disinfection, the mixture method used and the length of time the system was flushed. This declaration may be hand written or typed but must be wet signed by the person(s) who performed the disinfection. This declaration must be provided for acceptance of final plumbing inspection.

The procedure shall be repeated if microbiological analysis of water sampling and testing indicates that contamination persists in the system.

Table 2: Disinfection Procedures for Domestic Water Lines/Systems

Chlorination Method Used	Initial Chlorine Dose (mg/l)	Minimum Contact Time (hours)	Minimum Chlorine Residual Conc. (mg/l)
• 24-Hour Hold	50	24 hours	40
• 3-Hour Scrub	200	3 hours	160

H. Disinfecting Agent and Method of Chlorination

There are two options available to companies performing the chlorination, the “24 hour hold” method and the “3 hour scrub” method. In general, the “24 hour hold” is the method of choice, but the “3 hour scrub” can be used on small jobs where time is crucial and the chlorinators’ skills are highly satisfactory. The following is a description of the two procedures:

1. “24 Hour Hold Method”

- a. The chlorine shall be introduced at such a rate into the supply stream to provide a uniform concentration of chlorine in the entire system. The concentration is to be sufficient to maintain a 50 ppm chlorine level at each fixture after a hold period of 24 hours.
- b. During injection, the chlorine shall be drawn through each outlet and fixture in the system. In order to expedite the chlorination of hot water systems, it is usually best to drain the water heater prior to beginning the chlorine injection. When chlorine of proper concentration is found at each outlet, all valves shall be closed, including the service cock and supply valve. In order to prevent tampering with the system during the 24 hour hold period, it is recommended that signs be placed, fixtures be taped, and/or valve handles be removed.
- c. Testing for the residual concentration in the system at the end of the 24 hours will be performed or witnessed by EHS or the Inspector of Record. No water shall be released from the system until these samples are taken. A minimum concentration of 45 ppm of chlorine must be found at all chosen sampling points.
- d. After satisfactory compliance with the 45 ppm for the 24 hour residual requirement, the system shall be flushed at a relatively high velocity to remove the injected chlorine. Evidence of proper flushing will be

reduction of chlorine concentration in the system to no more than 0.5 ppm above that in the normal supply.

- e. When EHS has approved the flushing process, the entire system shall be resecured for a holding period of not less than 3 days prior to taking samples for bacteriological analysis. During this holding period, it is again recommended that all valves be closed, taped, and handles removed to maintain chlorination integrity and prevent repetition of the entire process.

2. "3 Hour Scrub Method"

- f. The chlorine shall be introduced at such a rate into the supply stream to provide a uniform 200 ppm concentration during an entire 3 hour time period with all fixtures flowing. A substantial flow is required at all fixtures; dripping is not acceptable.
- g. In order to expedite the chlorination of hot water systems, it is usually best to drain the water heater prior to beginning the chlorine injection.
- h. Testing for chlorine concentration shall be frequently done by the personnel performing the chlorination and tested or witnessed at least once by EHS.
- i. After completion of the "3 hour scrub", the system shall be flushed at a relatively high velocity to remove the injected chlorine. Evidence of proper flushing will be reduction of chlorine concentration in the system to no more than 0.5 ppm above that in the normal supply.
- j. When EHS has approved the flushing process, the entire system shall be secured for a holding period of not less than 3 days prior to the taking samples for bacteriological analysis. During this holding period, it is recommended that all valves be closed, taped, and handles removed to maintain chlorination integrity and prevent repetition of the entire process.

I. Preliminary Approval and Bacteriological Sampling

When EHS has approved the flushing process, the entire system shall be secured for a holding period of not less than 3 days prior to taking samples for bacteriological analysis. During this holding period, it is recommended that all valves be closed, taped, and handles removed to maintain chlorination integrity and prevent repetition of the entire process.

At the completion of the 3 day hold period, bacteriological water samples are taken under the direction of EHS. The number of necessary samples and sampling locations shall be determined by EHS. Sufficient samples shall be taken to represent all portions of the newly installed system particularly drinking water fountains, hand sinks, eyewash stations, etc. A control sample shall also be taken from a building nearby that receives water from the same water main. The domestic water system cannot be used until the effectiveness of the chlorination procedure on the system has been determined by EHS.

If initial bacteriological samples are unsatisfactory, the new building water system should be reflushed and additional samples collected and analyzed. If any of the check samples

are also unsatisfactory, the new building water system must be rechlorinated, reflashed, and resampled until satisfactory results are achieved.

J. Bacteriological Analysis

Water testing must be done by a state certified testing laboratory approved by EHS. Sample bottles must be provided by the laboratory and analysis must be done in accordance with APHA "Standard Methods". The laboratory shall report the presence of any coliform bacteria in a 100 ml sample (this must be negative to be acceptable) and the heterotrophic plate count of bacteria per ml of the sample (this count must be less than 500 or equal to the supply to be acceptable)

K. Final Approval

Upon satisfactory completion of all disinfection procedures designated by EHS and receipt of acceptable bacteriological results, written approval of the system will be provided to the responsible contractor (**Attachment 4: Chlorination and Bacteriological Testing Verification and Approval**). Failure to fully comply with the above procedures may result in a requirement to repeat chlorination of the system until the specified standards are met.

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Attachment 1: Chlorination Proposal and Notification Form

I. Project Manager: Complete this form prior to chlorination process. Submit to EHS (email: mmtran@mail.sdsu.edu or fax: 619-594-2854) the following information 5 days prior to proposed chlorination date.

Disinfectant Company: _____

Contact Person and Phone Number: _____

Proposed Date of Chlorination: _____

Water Line(s)/System(s) to be Chlorinated: _____

Date Line/System Pressure Test Completed: _____ Test Pressure (psi): _____

Date Line/System Flush Completed: _____ Flush Flow Rate (gpm): _____

- Disinfection Procedure:
- Tablet Continuous Slug
 - 24-hr Hold Method 3-hr Scrub Method
 - Premixed Solution or hypochlorite injection
 - Swabbing with Hypochlorite Solution
 - Trench Treatment Flushing

Chlorine Agent to be Used: Calcium hypochlorite Sodium hypochlorite

Proposed Chlorine Concentration (prior to chlorine hold time): _____

Proposed Chlorine Hold Time: 24-hour 3-hour 15-minutes (slug method for existing mains only)

Expected Chlorine Concentration (after chlorine hold time): _____

II. Project Manager:

Signature and Date: _____

Company Name: _____

Phone Number: _____

Email Address: _____

III. EHS: Notification Form Received (sign and date): _____

Proposed chlorination not acceptable. Resubmit updated form.

Proposed chlorination acceptable. Proceed with chlorination.

- Project Manager (name: _____) was notified to proceed with chlorination (EHS sign and date): _____

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Attachment 2: Chlorination Report Form

- I. **Project Manager:** Complete this form during chlorination process. Submit to EHS (email: mmtran@mail.sdsu.edu or fax: 619-594-2854) the following information immediately following final flush (3 days prior to proposed bacterial sampling date.) Submit **Bacteriological Sampling Notification (Attachment 3)** along with this form.

Disinfectant Company: _____

Date of Chlorination: _____

Water Line(s)/System(s) Chlorinated: _____

Was the System Initially Flushed?: Yes No

Did the system pass Pressure Test?: Yes No N/A (Domestic system only)

Chlorination Method: Tablet Continuous Slug
 Premixed Solution or hypochlorite injection
 Swabbing

Chlorine Agent: Calcium hypochlorite Sodium hypochlorite

Complete Before Chlorine Hold

Actual Chlorine Concentration (prior to chlorine hold time): _____

Date measured: _____ Signature: _____

Proposed Chlorine Hold Time: 24-hour 3-hour 15-minutes

Expected Chlorine Concentration (after chlorine hold time): _____

Complete after Chlorine Hold

Actual Chlorine Hold Time: 24-hour 3-hour 15-minutes

Actual Chlorine Concentration After Chlorine Hold Time: _____

Date measured: _____ Signature: _____

Complete after Final Flush

Date of Final Flushing: _____

Chlorine Concentration After Final Flushing: _____

Date measured: _____ Signature: _____

- II. **Project Manager:**

Signature and Date: _____

Company Name: _____

Phone Number: _____

Email Address: _____

- III. **EHS:**

Chlorination Report Form Received (sign and date): _____

Chlorine concentration not acceptable. Re-chlorinate.

Chlorine concentration acceptable. Proceed with required retention period

(Retention Periods: main = 1 day, domestic = 3 days)

- Project Manager (name: _____) was notified to proceed with required retention period (EHS sign and date): _____

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Attachment 3: Bacteriological Sampling Notification Form

I. **Project Manager:** Complete and submit this form to EHS (email: mmtran@mail.sdsu.edu or fax: 619-594-2854) 3 days prior to proposed bacteriological sampling date.

Water Line(s)/System(s) Chlorinated: _____

Proposed Retention Period (After Flushing) _____

Proposed Date of Bacteriological Sampling: _____

Proposed Locations of Bacteriological Sampling: 1. _____
2. _____
3. _____
4. _____
5. _____

Name and Title of Collector/Sampler: _____

Name of Certified Testing Laboratory: _____

II. **Project Manager:** Signature and Date: _____

Company Name: _____

Phone Number: _____

Email Address: _____

III. **EHS:** Bacterial Sampling Form Received (sign and date): _____

Proposed sampling location(s) not acceptable. Submit updated form.

Proposed sampling location(s) acceptable.

- Project Manager (name: _____) was notified to proceed with Bacterial Sampling period (EHS sign and date): _____

Note: Provide EHS the **Microbial Laboratory Analysis Report** indicating the **date of sampling, sample locations, presence or absence of coliform organism, and heterotrophic plate count.** A **Microbial Laboratory Analysis Report** is considered the Bacteriological Report. Upon satisfactory completion of all disinfection procedures approved by EHS and receipt of acceptable bacteriological results, a written approval of the system will be provided to the responsible contractor.

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Attachment 4: Chlorination and Bacteriological Testing Verification and Approval

Water Line(s)/System(s) Chlorinated and Tested: _____

I. EHS:

- System Approved: Meets Disinfection and Testing Requirements. Water Line/System approved to be placed in to operation.
- System Not Approved: No Chlorination or Unacceptable Chlorination Method and/or Results
- System Not Approved: No Chlorination Report Submitted
- System Not Approved: Failed Bacteriological Analysis (1st Submission)
- System Not Approved: Failed Bacteriological Analysis (2nd Submission). Need to Repeat Chlorination.

II. EHS Signature and Date: _____

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Appendix A

Bacteriological Sampling and Analysis

AWWA C651 provides that two consecutive sets of samples, taken at least 24 hours apart, shall be collected from the main and analyzed for bacteriological contamination. If initial bacteriological samples are unsatisfactory, the new main should be reflushed and additional samples collected and analyzed. According to AWWA C651, if any of the check samples are also unsatisfactory, the main must be rechlorinated, reflushed, and resampled until satisfactory results are achieved.

Analysis Method

AWWA Standard C651 provides that bacteriological testing of the disinfected main should be conducted in accordance with Standard methods for the Examination of Water and Wastewater and show the absence of coliform organisms. Total coliform is the indicator group of bacteria for the use in monitoring drinking water. The Maximum Contaminant Level for total coliform as determined by the Safe Drinking Water Act is now based on the presence or absence of the indicator bacteria, not on density or direct count. There are four standard laboratory techniques that are approved for coliform analysis:

- 1) MMO-MUG
- 2) Multiple tube fermentation (MTF)
- 3) Presence-absence (PA)
- 4) Membrane filtration (MF)

The MMO-MUG method is a new technique that is able to confirm the presence of total coliforms in a shorter time frame than the other approved methods. This technique is based on a color change that occurs as the result of the reaction of an enzyme produced by the coliform group of bacteria with the MMO-MUG media. There are several formats currently available for this method. They all involve inoculation in the laboratory of the drinking water sample with a specific quantity of MMO-MUG media. The inoculated sample is incubated at 35°C for 24 hours and observed for development of yellow coloration. If the yellow color is equal to or darker than the minimal standard supplied with the product, the sample contained confirmed total coliforms. The confirmed presence of total coliforms should be interpreted as unsatisfactory requiring reflushing of the main and additional bacteriological samples collected and analyzed.

The laboratory that is chosen to perform the analysis will typically provide the sampler with appropriate containers for sample collection.

Number of Samples

AWWA C651 provides that at least one set of samples for bacteriological analysis should be collected from every 1,200 ft of the new water main, one set from the end of the line, and at least one set from each branch. If trench water or excessive quantities of dirt has entered the new main during construction, AWWA Standard C651 specifies that samples should be taken at intervals of approximately 200 ft and shall be identified by location.

Sample Collection Procedures

- 1) Use only sterile bottles furnished by the laboratory. Keep the bottles sealed until used. Each sample bottle should contain a dechlorinating agent (typically, sodium thiosulfate) in sufficient amount to neutralize any residual chlorine in the water sample. Do not rinse the bottle prior to taking the sample as such rinsing will remove the dechlorinating agent and render the subsequent sample invalid.
- 2) Try to avoid collecting the sample from a hose or fire hydrant. Such outlets will often contaminate the sample leading to unsatisfactory results. AWWA Standard C651 recommends the use of a specially installed sampling tap consisting of a smooth, unthreaded, ½ inch hose bib. A corporation stop installed in the main equipped with a copper-tube goose-neck assembly can also function as a sampling tap.
- 3) Be sure that the heavily chlorinated water has been thoroughly flushed from the main before sampling. Run water through the sampling tap at a steady rate 3 to 5 minutes before beginning sampling procedures.
- 4) Wash hands thoroughly. Remove the bottle lid must before filling, holding the lid in your free hand. Do not contaminate the inner surface of the cap of the bottle with your hands. Fill the bottle to the shoulder or fill line. Do not overflow the bottle or splash water on the outside of the bottle. Replace the lid and tighten securely.
- 5) Complete the appropriate sample documentation provided by the laboratory. This will typically include a sample label and chain of custody form.
- 6) Deliver the samples to the laboratory promptly after collection. There are strict time limits on the amount of time that may elapse between sample collection and analysis before the sample is considered too old to analyze. Check with the laboratory on sample holding time requirements. Unless special arrangements are made, avoid having the sample arrive at the laboratory on weekends or holidays.
- 7) Samples should be held at a temperature of 4°C. If practicable, place samples in an iced cooler for storage during transport if transport time will exceed 1 hour. At no time, however, should the sample container be allowed to become immersed or submerged in the ice or melted ice water. Check with the laboratory for specific packaging and transport recommendations.