Procedures for Emergency Disinfection of Mains

by R. Scott Yoo

A common emergency faced by water utility operators is a main break. When dealing with a main break, each utility has its own plan of action, including procedures for emergency call-out, leak detection, shutdown, excavation, repair, disinfection, flushing, and customer notification. The primary objectives of the plan are to restore water service and prevent contamination of the water supply.

In many situations, chemical disinfection is a key element in preventing contamination of the water supply following a main break. However, the use of a disinfectant alone cannot compensate for improper shutdown procedures, inadequate flushing, or the failure of the operator to use good judgment in restoring water service. The proper procedures to follow for main disinfection relate to the overall repair operation.

1. Minimize the entry of contaminants into the pipe.
2. Remove any contaminants that may have entered the pipe.
3. Disinfect any contamination that remains.
4. Flush the disinfectant from the pipe.
5. Determine the bacterial quality after disinfection.

Minimize Entry of Contaminants

Contaminants can range in size from a tiny virus seeping through a pipe fracture to a large animal wandering into an unattended open pipe.

Minimizing the entry of contaminants is the most important step in maintaining the sanitary quality of the water during main repairs. If no contaminants enter the main, there is no need for disinfection.

The only way to be certain that contamination has not occurred is to repair the break without depressuring the main. This is possible when repairs are made with full-circle clamps, sleeves, or nipples. As long as the main is pressurized and water is observed to flow continuously from the rupture, it is unlikely that the main has become contaminated.

If the main is shut down and depressurized during repair, contamination is likely, and the main should be thoroughly flushed and disinfected before it is returned to service. The following precautions will minimize contamination of the pipe.

1. Excavate to provide at least 18 in. (0.5 m) of clearance all around the pipe.
2. Carefully observe the excavation site and look for signs of broken sewer lines, such as odor or sewer-pipe pieces. If sewage is present, disinfection of the main is necessary.
3. Keep water pumped out of the trench to prevent dirty water from contacting the pipe.
4. When the pipe is cut, carefully observe the water that flows out of the pipe. If the water is dirty, the main may have been shut down too soon. Backflush until the water flows clear.
5. Always examine the inside of the pipe for dirt, pieces of pipe, rocks, and animals (a flashlight can be used). Almost anything can find its way inside an opened pipe.

Plug open end of pipe not being flushed.
**Remove Contaminants**

If contamination of the pipeline is suspected, it is important to physically remove contaminants before attempting disinfection. Particulate matter is generally removed by flushing. Following any shutdown, always backflush in both directions. Achieve as much flushing velocity as is practical without causing damage to property. The minimum flushing velocity should be 2.5 ft/s (0.76 m/s).

If the pipe is cut and a section is removed, always backflush into the trench to remove pieces of pipe, scale, or anything that may have broken loose or entered the pipe. Provide adequate pumping to keep the water level below the open pipe. In a small excavation, it may be necessary to dig a sump. When backflushing the pipe, plug the open end of the side not being flushed. Use a cap, plastic bag with straps, or a redwood plug. As a general rule, flush with enough water to replace all of the pipe volume at least once. Always flush until the water runs clear.

**Disinfect the Pipe**

Always carefully examine the pipe and excavation before deciding on the disinfection procedure to be used. The procedure chosen may vary with the availability of chemicals and equipment as well as the nature of the main break. The two procedures described below, swabbing and hypochlorite injection, are applicable to a wide range of main-break situations.

**Swabbing.** This method is applicable to main breaks where significant contamination of the pipe (for example, by sewage) has not occurred. With this method, all new pieces of pipe, couplings, clamps, or sleeves are swabbed with a concentrated solution of hypochlorite to disinfect the interior surfaces. Following swabbing, the repair is completed and the main flushed without allowing further contamination of the pipe and fittings. The procedure is

1. Backflush the existing pipe in both directions.
2. In a bucket, prepare a concentrated hypochlorite solution (1 percent available chlorine). Add approximately 2 oz (58 g) of dry calcium hypochlorite (65 percent available chlorine) to 1 gal (3.8 L) of water to produce a concentrated hypochlorite solution. This is equivalent to about 26 fl oz (0.76 L) of household bleach (5 percent available chlorine) in 1 gal (3.8 L) of water.
3. Using clean rags dipped in the hypochlorite solution, swab the inside of both ends of the open pipe as far as can be reached. Next, disassemble and swab the interior of all new pieces of pipe, couplings, clamps, and sleeves that will be used in the repair. Disinfect longer pieces of pipe using a mop. If an extra-long replacement pipe is used, disinfect by plugging and filling it with hypochlorite solution.

To prevent recontamination, disinfect each piece of pipe just prior to installation. Avoid unnecessary handling of the pipe, which could lead to contamination by human hands or dirt. Do not place disinfected materials directly on the ground. Use bricks or blocks to support them.

4. As a safety precaution, wear proper eye and respiratory protection when working with hypochlorite. To prevent damage to skin and personal clothing, wear rubber gloves and protective clothing. Hypochlorite will irritate skin and bleach clothing, so avoid splashing the solution on yourself or co-workers.

5. Following completion of the repair, flush the main to remove high concentrations of hypochlorite and any materials dislodged from the pipe wall during the repair.

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One variation of the swabbing method is to apply the hypochlorite solution using a sprayer instead of cloth rags. A convenient type of sprayer is a 2.5-gal (9.5-L) pressurized-water fire extinguisher. The extinguisher is filled with hypochlorite solution and pressurized through the air valve with compressed air. The disinfectant is then sprayed onto the interior surfaces of pipe and fittings.

The swabbing method and variations thereof are quick and effective for main breaks where repairs are made without the threat of significant contamination by sewage. Most main breaks are disinfected using this technique. However, if there is a potential for more serious contamination (e.g., when sewage is detected in the trench during repairs and the main has been shut down) the main should be disinfected more thoroughly. This is accomplished by filling the main with heavily chlorinated water. The method of choice is hypochlorite injection.

**Hypochlorite injection.** Using this method, hypochlorite solution is injected into a flowing main to achieve a high chlorine residual throughout the pipe section. Hypochlorite solution can be injected using a gasoline or electrically powered chemical-feed pump designed for feeding chlorine solutions (hypochlorinator). After sufficient contact time, the main is flushed to remove the heavily chlorinated water.

Ideally, disinfection is accomplished by maintaining a high chlorine residual (100 mg/L) throughout the pipe for at least 3 hours. However, this much time is not practical if customers are out of water, and disinfection is usually accomplished by using shorter contact times and higher chlorine dosages.

The following steps are necessary to ensure adequate disinfection and safety for the consumer.

1. Shut off all service connections prior to attempting disinfection. This will prevent the entry of highly chlorinated water to the consumer’s premises.
2. In cases where flushing through the consumer’s service line is not possible, remove the meter and install a standpipe at the meter connection. Extend the standpipe at least 12 in. (0.3 m) aboveground to prevent the backflow of dirty water from the meter box during flushing.
3. Install the hypochlorinator not more than 10 ft (3 m) from the downstream side of the valve that will supply water to the shutdown area. The hypochlorinator may be adapted to pump through a hydrant or meter connection. However, if there is no such connection close to the supply valve, it may be necessary to tap the main in order to introduce hypochlorite.
4. Always flush the main to remove dirty water and air before attempting disinfection.
5. Following the flush, adjust the flow to a constant, measured rate. The flow rate and the pipe size (diameter and length) will determine the time required to dispense the hypochlorite solution throughout the pipe.

In the absence of a meter, approximate the flow rate by using a Pitot tube or by measuring the time required to fill a container of known volume. Another method is to measure the trajectory of the blowoff discharge and estimate flow (discharge).

6. Begin disinfection by pumping hypochlorite solution into the repaired main. The minimum chlorine dosage should be 100 mg/L.

Liquid sodium hypochlorite can be purchased in concentrations ranging from 5 percent to 15 percent available chlorine. The quantity of liquid hypochlorite and the pumping rate depend on the solution concentration, the chlorine dosage desired, the flow (flushing) rate, and the total volume of the pipe to be chlorinated. A sample calculation is provided for 300 ft of 6-in. main, which will be disinfected with sodium hypochlorite (12.5 percent available chlorine) to a chlorine dose of 100 mg/L while flushing at a rate of 200 gpm.

The hypochlorite pumping rate $R$ is calculated by the following formula:

$$R = \frac{D}{C} \times Q$$

Where:
- $D = \text{chlorine dose} = 100 \text{ mg/L}$
- $C = \text{hypochlorite solution concentration} = 12.5\%$
- $Q = \text{flow (flushing) rate} = 200 \text{ gpm}$

Thus,

$$R = \frac{100 \text{ mg/L}}{125,000 \text{ mg/L}} \times 200 \text{ gpm} = 0.16 \text{ gpm}$$

For this example, therefore, a pumping rate of 0.16 gpm is required.

Hypochlorite is pumped continuously until the desired chlorine residual is distributed throughout the pipe.

Continuing with the above example, the minimum amount of hypochlorite solution $a$, which is required to treat one pipe volume, can be calculated by the following formula:

$$a = \frac{D}{C} \times V$$

Where:
- $D = \text{chlorine dose} = 100 \text{ mg/L}$
- $C = \text{hypochlorite solution concentration} = 12.5\%$
- $V = \text{pipe volume}$

The pipe volume $V$ can be calculated as follows:

$$V = \frac{d^2}{2} \times \pi \times l$$

Swab all new pipe pieces used in repair.
Where:
- \( d = \) pipe diameter = 6 in. = 0.5 ft
- \( l = \) pipe length = 300 ft

Thus,
\[
V = \frac{0.5}{2} \times 3.14 \times 300 = 58.88 \text{ ft}^3
\]

Converting cubic feet to gallons,
\[
V = 58.88 \text{ ft}^3 \times \frac{7.48 \text{ gal}}{1 \text{ ft}^3} = 440.39 \text{ gal}
\]

And,
\[
a = \frac{100 \text{ mg/L}}{125,000 \text{ mg/L}} \times 440.39 \text{ gal} = 0.35 \text{ gal}
\]

For this example, the minimum amount of hypochlorite solution required is 0.35 gal. However, this assumes that only one pipe volume is chlorinated. In practice, several times this amount of hypochlorite must be injected because pumping must continue until the operator can measure chlorine residuals at the blowoffs and shut down the main.

The same calculations used in the above example are used to prepare Table 1, which indicates the gallons of hypochlorite solution (12.5 percent available chlorine) necessary to achieve chlorine dosages of 100 and 300 mg/L in mains of various sizes. The table is useful for estimating the minimum amount of hypochlorite that will be necessary for any main disinfection.

A similar table can be prepared for other hypochlorite solution concentrations. For example, if a 5 percent rather than a 12.5 percent available chlorine solution is used, multiply the values in Table 1 by 12.5/5 (or 2.5) to determine the quantity of solution required.

7. To determine when the hypochlorite solution has reached the end of the repaired main, measure the chlorine residual at the terminal hydrant or blowoff.

8. Once the residual is detected at all blowoffs, shut down the main and allow the heavily chlorinated water to stand in the pipe. For a chlorine dose of 100 mg/L, the recommended minimum contact time is 3 hours.

9. If the main cannot be kept out of service for 3 hours, the chlorine contact time can be reduced by injecting a more concentrated hypochlorite solution. In such cases, apply a chlorine dosage of at least 300 mg/L. Allow the chlorine solution to remain in the pipe for the maximum permissible contact period consistent with the need for service from the repaired main, but in no case should the contact time be less than 15 min. At the end of this period, a chlorine residual of at least 100 mg/L should be present.

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### Flush Disinfectant from Pipe

At the end of the hypochlorite contact period, flush the main until the chlorine residual has been reduced to the level normally present in water supplied to the area. As a general rule, flush until the pipe volume has been replaced at least once. Prior to restoring service, flush each service line to eliminate air and high concentrations of chlorine.

### Determine Bacteriological Quality

Bacteriological samples are taken after repairs to provide a record of the effectiveness of the disinfection procedure. After the residual disinfectant has been removed from the repaired main, collect a sample from at least one point located immediately downstream of the repair. If the direction of flow is unknown, collect samples on each side of the repair.

A combination blowoff and sample tap, similar to the one pictured in Figure 1, is useful for sampling repaired mains. Samples also may be collected from customer services that have been disinfected and thoroughly flushed. Do not collect samples from hoses or fire hydrants.

### Summary

Disinfection often is a key element in preventing contamination of the water supply following repair of a main break. However, in order to minimize the risk of contamination, proper care also must be exercised in the shutdown, repair, and flushing of the main.

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