WATER SYSTEM DISINFECTION

Disinfection is the primary method for destroying or inactivating pathogenic organisms that spread disease in drinking water. A disinfectant, such as chlorine, frequently is added to water to ensure that it is free of harmful bacteria and viruses. Chlorine is the most common disinfectant for small water systems, and the only disinfectant this publication addresses.

People expect safe, wholesome water from hydrants (figure 59). Adding chlorine to the water helps ensure that the water stays safe throughout the distribution system to the point of use.

Public water supplies that add chlorine to the water must meet State requirements for dose, equipment, and monitoring. A chlorine dose too low may allow regrowth of disinfectant-resistant pathogens, excessive biofilm development in distribution systems, or an unpleasant taste in the water. A chlorine dose too high may cause taste and odor problems, distribution pipe degradation, unnecessary disinfection byproducts, and health problems.

All public water systems that use surface water, or ground water under the direct influence of surface water, are required to disinfect the water. Some States require that all public water systems maintain a chlorine residual in the distribution system. A chlorine residual entering the distribution system should be at least 0.2 mg/L. The chlorine residual should be detectable at the farthest tap in the distribution system. Some States require the residual to be at least 0.2 mg/L at the farthest tap. The chlorine dose may need to be increased at the tank to maintain a detectable residual at the farthest tap. The chlorine residual in drinking water should never exceed 4 mg/L. A chlorine test kit, such as the one shown in figure 60, is required to measure the chlorine residual in water systems.

Components

Common disinfection methods for small USDA Forest Service systems are:

- Erosion-feed tablet chlorinators for calcium hypochlorite.
- Metering pumps for hypochlorite solutions.
- Onsite hypochlorite generators.

Hypochlorite reacts with water to form chlorine. Calcium hypochlorite, also called high test hypochlorite, is a solid that contains 65 to 75 percent available chlorine. Sodium hypochlorite, also called bleach, is a liquid that contains 5 to 15 percent available chlorine. Onsite hypochlorite generators make about a 3 percent chlorine solution.
Erosion-Feed Chlorinators
Install erosion-feed chlorinators (figure 61) in areas with or without electric power. A sidestream of water is directed to the chlorinator, where it dissolves the calcium hypochlorite tablet. The solution returns to the main water line or well.

Metered Hypochlorination Systems
Metered hypochlorination systems consist of a solution tank and chemical metering pump. Sodium hypochlorite (liquid) or calcium hypochlorite (solid or powder) make the solution. Chemical pumps inject the chlorine solution into the water. A solution tank holds the diluted hypochlorite (figure 62).

Chemical pumps may be either electric or water powered. Water-powered chemical injectors can work on gravity systems, such as springs, and in areas without electric power.

The injection point (figure 63) contains a check valve to prevent water from flowing back into the chemical tank and injects the chlorine solution into the middle of the water pipe for rapid mixing.
An electric chemical pump must be interconnected to the well pump as a safety factor, so when the well pump does not operate, the chemical pump will not operate, and if the chemical pump does not operate, the well pump will not operate (figure 64).

Onsite Chlorine Generators

Onsite chlorine generators (figure 65) make chlorine by converting a brine solution—sodium chloride and water—into sodium hydroxide and chlorine. Water softener salt is dissolved in a brine tank (figure 66). The saturated brine solution is mixed with fresh water through a two-headed metering pump (figure 67) to the required concentration. The chlorine solution may be stored in a solution tank and injected into the water with a chemical metering pump, or injected directly into the water.
Erosion-feed hypochlorinators are simple devices. A sidestream of water flows through the chlorinator and dissolves a calcium hypochlorite tablet or pellets. The chlorinated water is returned to the main water line or well.

Maintenance check list:
- Check for scale or calcium buildup in the chlorinator. Clean the chlorinator when scale or calcium sediment is visible.
- Check for the chlorine tablets or pellets bridging or binding. If the chlorinator contains hypochlorite tablets, but no chlorine residual is present in the water, the tablets or pellets may be binding in the chlorinator.

Adjust the chlorine dose by increasing the amount of water that flows through the chlorinator. Follow manufacturer’s directions for adjusting the water flow and chlorine dose.

Calcium hypochlorite or high test hypochlorite is a strong oxidizer (figure 68). Wear personal protective equipment when handling this product. Follow guidelines published in the product’s material safety data sheet. Care must be taken when transporting and storing calcium hypochlorite to keep it away from organic materials, petroleum products, fats, and oils. A very hot fire may start if oils come in contact with calcium hypochlorite. Store the tablets in a sealed container in a cool place to prevent moisture from contacting the tablets.
Calcium hypochlorite is available as a fast-dissolving powder or pellets that can be dissolved in a solution tank and metered into the water. Calcium hypochlorite is available as 65 to 75 percent chlorine.

**Hypochlorination Systems**

Figure 69 shows a hypochlorination system. Sodium hypochlorite (figure 70) is diluted in the solution tank, and the metering pump injects the solution into the water system. Small chemical metering pumps are usually sealed and cannot be repaired. They must be replaced if not functioning correctly.

![Figure 69—Hypochlorination system.](image1.jpg)

![Figure 70—Sodium hypochlorite.](image2.jpg)

**Maintenance checklist:**

- Change the oil and lubricate the moving parts per the manufacturer’s recommendation.
- Check for sediment and scale buildup in the solution tank and tubing. Remove accumulated sediment when changing chlorine solution. Wash the tank with vinegar and pump vinegar through the tubing to remove scale, as needed. Rinse the tank and tubing thoroughly before putting chlorine solution back in the tank.
- Recommend installing an inline indicator in the tube, so it is visually apparent that chlorine is being injected.
- Check for and fix any leaks.
Metering pumps are sized to deliver a chlorine dose based on well-pump capacity, chlorine demand, and solution strength.

**Well-pump capacity** is the rate that the well pump moves water while it is pumping. If a flowmeter is between the pump and a water storage tank, the pump capacity can be read directly from the flowmeter. If the flowmeter is after the tank (figure 71), calculate the pump capacity as follows:

Open a valve until the pump starts, then turn off the valve. Time how long the pump runs. Then open a valve and read the flowmeter and time how long it takes for the pump to start again.

For example:
If the flowmeter reads 5 gallons per minute (gal/min), and it takes 30 minutes (min) to start the pump, and the pump runs for 15 min to refill the tank, then:

Pump capacity = (5 gal/min x 30 min)/15 min = 10 gal/min

**Demand** refers to everything in the water that chlorine reacts with. Chlorine reacts with many impurities found naturally in water. Enough chlorine must be added to the system to meet the demand before a free chlorine residual is achieved. Free chlorine protects the water in the distribution system from bacterial contamination.

Iron, ammonia, organic material, and sulfur compounds consume free available chlorine. Use the results from the initial water test to approximate the water’s chlorine demand. Iron consumes 1 milligram per liter (mg/L) chlorine for 1 mg/L iron. Sulfur consumes 3 mg/L chlorine for 1 mg/L sulfur.

For example:
If the well water has 2 mg/L iron, and 1 mg/L sulfur, and a 1 mg/L residual is desired, then:

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\begin{align*}
(2 \text{ mg/L iron}) \times 1 &= 2 \text{ mg/L Cl}_2 \\
(1 \text{ mg/L sulfur}) \times 3 &= 3 \text{ mg/L Cl}_2 \\
\text{Desired residual} &= 1 \text{ mg/L Cl}_2 \\
\text{Dose} &= 6 \text{ mg/L Cl}_2
\end{align*}
\]

The strength of solution in the chlorine solution tank also must be known.

If undiluted 5.25 percent sodium hypochlorite (bleach) is used, and the well pump capacity is 10 gal/min, and the estimated dose is 6 mg/L Cl$_2$, then:

\[
\begin{align*}
(10 \text{ gal/min}) \times (6 \text{ mg/L}) \times 1,440 &= 1.6 \text{ gallons per day (gal/day)}, 6.23 \text{ liters per day (L/day)}, \text{ or } 0.6 \text{ milliliter per minute (mL/min)}
\end{align*}
\]
In this example, select a metering pump sized for 3 gal/day (or 1 mL/min). The initial setting would be $1.6/3 \times 10 = 5.3$ on a 10 position dial.

Size the meter pump to operate near its midpoint (the point where the pump operates most efficiently, while allowing room to adjust the dose).

Adjust the initial setting to keep the chlorine residual throughout the distribution system. During the period of lowest water use, test the chlorine residual at the farthest tap in the distribution system. If no chlorine is detected, increase the chlorine dose. **Caution**—assure that the tap closest to storage tank does not have too much chlorine if the chlorine dose is increased.

Sodium hypochlorite (liquid bleach) is available in 5.25 to 12.5 percent chlorine concentration. Sodium hypochlorite can lose up to 4 percent of its available chlorine content per month. Most manufacturers recommend a shelf life of 3 months.

**Onsite Chlorine Generation**

Onsite chlorine generators use a saltwater brine solution to make chlorine. Saltwater is pumped through an electrolytic cell to make chlorine gas, sodium hypochlorite, or hypochlorous acid depending on the brand of generator. Store the liquid hypochlorite solution in a solution tank and meter it into the water system. The chlorine gas or liquid hypochlorite may be injected directly into the water system. Directly injecting the chlorine into the water system requires a chlorine monitor to control the chlorine dose.

**Maintenance checklist:**

- Check the salt level in the brine tank. Add salt as needed.
- Check the flow through the cell. Clean the orifice if the flow is too low.
- Because the electrolytic cell is subject to scale buildup in hard water, acid wash or return to the manufacturer for cleaning periodically.
- Check the percent chlorine produced. Collect 1 mL chlorine from the cell. Dilute with 50 mL water. Test for chlorine concentration.