

Water Treatment

NOTES

Cornell Cooperative Extension, College of Human Ecology

Chlorination of Drinking Water

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Understanding Drinking Water Standards

mg = milligram = one-thousandth of a gram

mg/L = milligram per liter = part per million (ppm) =

\$1 in \$ 1,000,000

µg = microgram = one-millionth of a gram

µg/L = microgram per liter = part per billion (ppb) =

\$1 in \$ 1,000,000,000

Water used for drinking and cooking should be free of **pathogenic** (disease causing) microorganisms that cause such illnesses as typhoid fever, dysentery, cholera, and gastroenteritis. Whether a person contracts these diseases from water depends on the type of pathogen, the number of organisms in the water (density), the strength of the organism (virulence), the volume of water ingested, and the susceptibility of the individual. Purification of drinking water containing pathogenic microorganisms requires specific treatment called disinfection.

Although several methods eliminate disease-causing microorganisms in water, chlorination is the most commonly used. Chlorination is effective against many pathogenic bacteria, but at normal dosage rates it does not kill all viruses, cysts, or worms. When combined with filtration, chlorination is an excellent way to disinfect drinking water supplies.

This fact sheet discusses the requirements of a disinfection system, how to test the biological quality of drinking water, how to calculate the amount of chlorine needed in a particular situation, chlorination equipment, by-products of disinfection, and alternative disinfection methods.

Disinfection requirements

Disinfection reduces pathogenic microorganisms in water to levels designated safe by public health standards. This prevents the **transmission** of disease.

An effective disinfection system kills or neutralizes all pathogens in the water. It is automatic, simply maintained, safe, and inexpensive. An ideal system treats all the water and provides residual (long term) disinfection. Chemicals should be easily stored and not make the water foul-tasting.

State and federal governments require **public** water supplies to be biologically safe. The U.S. Environmental Protection Agency (EPA) has set regulations to increase the protection provided by public water systems, and they are enforced by the designated state agencies. Water supply operators will be directed to disinfect and, if necessary, filter the water to prevent contamination from *Giardia lamblia*, *Cryptosporidium*, coliform bacteria, viruses, heterotrophic bacteria, turbidity, and *Legionella*.

Private systems, while not federally regulated, also are vulnerable to biological contamination from sewage, improper well construction, and poor-quality water sources. Since more than 30 million people in the United States rely on private wells for drinking water, maintaining biologically safe water is a major concern.

Testing water for biological quality

The biological quality of drinking water is determined by tests for **total coliform** (which includes *E. coli* and **fecal coliforms**). These organisms are found in the intestinal tract of warm-blooded animals and in soil. Fecal coliforms and *E. coli* only come from human and animal fecal waste. The presence of coliform in water **indicates** pathogenic contamination, but they

are not considered to be pathogens. Most certified laboratories run all tests routinely, though some first run a total coliform test, and when positive, test separately for *E.coli* presence. The drinking water standard for coliform bacteria in water is zero.

Public water systems are required to test regularly for coliform bacteria. Private system testing is done at the owner's discretion. Drinking water from a private system should be tested for biological quality **at least once each year**, usually in the spring. Testing is also recommended following flooding, repair or improvements in the well.

Coliform presence in a water sample does not necessarily mean that the water is hazardous to drink. A high positive test result, however, indicates substantial contamination requiring prompt action. Such water should not be consumed until the source of contamination is determined and the water purified.

A **certified** testing laboratory provides specific sampling instructions and containers. Names and addresses can be obtained from the health department or county Cooperative Extension office. Also lists of certified laboratories for your state can be found through the website of the EPA at <http://www.epa.gov/safewater/labs/index.html>.

If no guidelines are available, use the given below.

- Use sterile sample container and handle only the outside of container and cap.
- Run water for a few minutes to clear the lines.
- Upon collecting sample, immediately cap bottle and place in chilled container if delivery to lab exceeds 1 hour (never exceed 30 hours). Many laboratories do not accept samples on Friday due to time limits.

Chlorine treatment

Chlorine readily combines with chemicals dissolved in water, microorganisms, small animals, plant material, tastes, odors, and colors. These components "use up" chlorine and comprise the **chlorine demand** of the treatment system. It is important to add sufficient chlorine to the water to meet the chlorine demand and provide residual disinfection.

The chlorine that does not combine with other components in the water is **free** (residual) chlorine, and the **breakpoint** is the point at which free chlorine is available for continuous disinfection. An ideal system supplies free chlorine at a concentration of 0.3-0.5 mg/l. Simple test kits, most commonly the DPD colorimetric test kit (so called because diethyl phenylene diamine produces the color reaction), are available for testing breakpoint and chlorine residual in private systems. The kit must test free chlorine, not total chlorine.

Contact time with microorganisms

The **contact (retention) time** (Table 1) in chlorination is that period between introduction of the disinfectant and when the water is used. A long interaction between chlorine and the microorganisms results in an effective disinfection process. Contact time varies with chlorine concentration, the type of pathogens present, pH, and temperature of the water. The calculation procedure is given below.

Contact time must increase under conditions of low water temperature or high pH (alkalinity). Complete mixing of chlorine and water is necessary, and often a holding tank is needed to achieve appropriate contact time. In a private well system, the minimum-size holding tank is determined by multiplying the capacity of the pump by 10. For example, a 5-gallons-per-minute (gpm) pump requires a 50-gallon holding tank. Pressure tanks are not recommended for this purpose since they usually have a combined inlet/outlet and all the water does not pass through the tank.

An alternative to the holding tank is a long length of coiled pipe to increase contact between water and chlorine. Scaling and sediment build-up inside the pipe make this method inferior to the holding tank.

Table 1. Calculating Contact time

To calculate contact time, one should use the highest pH and lowest water temperature expected. For example, if the highest pH anticipated is 7.5 and the lowest water temperature is 42 °F, the "K" value (from the table below) to use in the formula is 15. Therefore, a chlorine residual of 0.5 mg/l necessitates 30 minutes contact time. A residual of 0.3 mg/l requires 50 minutes contact time for adequate disinfection.

$$\text{Minutes required} = \frac{K}{\text{chlorine residual (mg/L)}}$$

K values to determine chlorine contact time

Highest pH	Lowest Water Temperature (degrees F)		
	>50	45	<40
6.5	4	5	6
7.0	8	10	12
7.5	12	15	18
8.0	16	20	24
8.5	20	25	30
9.0	24	30	36

Chlorination levels

If a system does not allow adequate contact time with normal dosages of chlorine, **superchlorination** followed by **dechlorination** (chlorine removal) may be necessary.

Superchlorination provides a chlorine residual of 3.0-5.0 mg/l, 10 times the recommended minimum breakpoint chlorine concentration. Retention time for superchlorination is approximately 5 minutes. Activated carbon filtration removes the high chlorine residual (see: *Fact Sheet 3: "Activated Carbon Treatment of Drinking Water"*).

Shock chlorination, outlined below, is recommended whenever a well is new, repaired, or found to be contaminated. This treatment introduces high levels of chlorine to the water. Unlike superchlorination, shock chlorination is a "one time only" occurrence, and chlorine is depleted as water flows through the system; activated carbon treatment is not required. If bacteriological problems persist following shock chlorination, the well should be carefully inspected for avenues of contamination. If a source of contamination can not be isolated, a continuous chlorination

Procedure for Shock Chlorination of Wells

(Adapted from NYSDOH, *Don't be Left in the Dark* and Georgia's Cooperative extension *Disinfecting Your Well Water Shock Chlorination*)

1. Run water until clear, using an outdoor faucet closest to the well or pressure tank
2. Mix 3 pints of 5% chlorine, per 100 gallons water volume in your well (see table for calculation), with 10 gallons of water in a bucket or pail in the area of the well casing. Add 3 extra pints of bleach to treat household plumbing.
3. Turn electrical power off to the well pump. Carefully remove the well cap and well seal if necessary. Set aside.
4. Place hose connected to outdoor faucet inside well casing. Turn electrical power back on to the well pump and turn water on to run to pump.
5. Carefully pour the water and bleach mixture from the bucket or pail down the open well casing. At the same time, continue to run the water from the hose placed inside the well casing.
6. At each indoor and outdoor faucet, run the water until a chlorine odor is present, and then shut each faucet off.
7. Continue running water through the hose inside the well casing to recirculate the chlorine treated water. Use the hose also to wash down the inside of the well casing.
8. After one hour of recirculating the water, shut all faucets off to stop the pump. Disconnect power supply to pump. Remove circulator hose from well.
9. Disinfect the well cap and seal by rinsing with a chlorine solution. Replace well seal and cap. Allow the well to stand idle for at least 8 hours and preferably 12 to 24 hours. Avoid using the water during that time. After the well has idled for the recommended period of time, turn the pump on and run the water using an outdoor faucet and garden hose in an area away from grass and shrubbery until the odor of chlorine disappears.

NB. To determine the amount of chlorine to mix with your well water, you need to know the amount of standing water in your well. You need to know the distance, in feet between the water level in your well, and the bottom of the well. This is multiplied by the storage per foot of water (see table). Per 100 gallons of water you need to use 3 pints of bleach.

If your drilled well is 6" and has 200 feet of standing water, it has $204 \times 1.47 = 300$ gallons of water. So 9 pints of bleach need to be added plus 3 pints for the plumbing. That is 12 pints or 1.5 gallons of bleach.

If your well has an unlisted diameter, please contact your local extension office or well driller.

Drilled Well/Pipe		Bored Well	
Diameter (inches)	Storage per foot of water (gal/ft)	Diameter (inches)	Storage per foot of water (gal/ft)
4"	0.653	24"	23.5
6"	1.47	36"	52.9
8"	2.61		

Chlorination Guidelines

- Chlorine solutions lose strength while standing or when exposed to air or sunlight. Make fresh solutions frequently to maintain necessary residual.
- Maintain a free chlorine residual of 0.3-0.5 mg/l after a 10 minute contact time. Measure the residual frequently.
- Once the chlorine dosage is increased to meet greater demand, do not decrease it.
- Locate and eliminate the source of contamination to avoid continuous chlorination. If a water source is available that does not require disinfection, use it.
- Keep records of pertinent information concerning the chlorination system.

Types of chlorine used in disinfection

Public water systems use chlorine in the gaseous form, which is considered too dangerous and expensive for home use. Private systems use liquid chlorine (sodium hypochlorite) or dry chlorine (calcium hypochlorite). To avoid hardness deposits on equipment, manufacturers recommend using soft, distilled, or demineralized water when making up chlorine solutions.

Liquid Chlorine

- household bleach most common form
- available chlorine range: 5.25% (domestic laundry bleach) 18% (commercial laundry bleach)
- slightly more stable than solutions from dry chlorine
- protect from sun, air, and heat

Dry Chlorine

- powder dissolved in water
- available chlorine: 4%
- produces heavy sediment that clogs equipment; filtration required
- dry powder stable when stored properly
- dry powder fire hazard near flammable materials
- solution maintains strength for 1 week
- protect from sun and heat

Equipment for continuous chlorination

Continuous chlorination of a private water supply can be done by various methods. The injection device should operate only when water is being pumped, and the water pump should shut off if the chlorinator fails or if the chlorine supply is depleted. A brief description of common chlorination devices follows.

Chlorine pump (see Fig. 1):

- commonly used, positive displacement or chemical-feed device,
- adds small amount, of chlorine to the water,
- dose either fixed or varies with water flow rates
- recommended for low and fluctuating water pressure,
- chlorine drawn into device then pumped to water delivery line

Suction device:

- line from chlorine supply to suction side of water pump,
- chlorine drawn into water held in well pump,
- dosage uniformity not assured with this system,

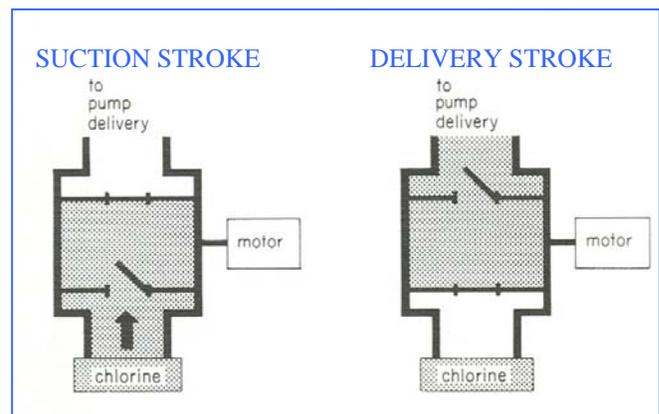


Figure 1. Pump type (positive displacement) chlorinator

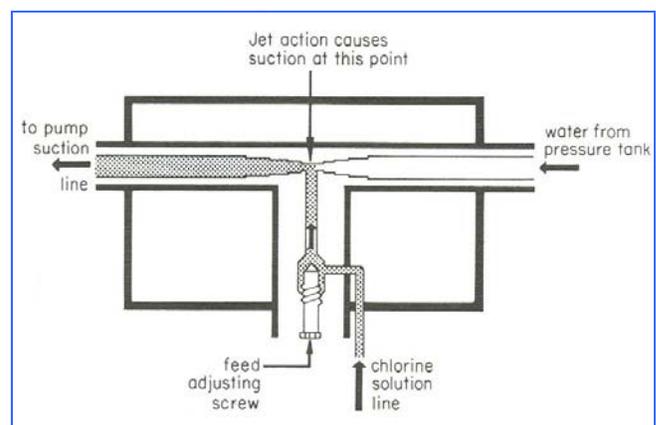


Figure 2. Injector (aspirator) chlorinator

Aspirator (see Fig. 2):

- simple, inexpensive mechanism,
- requires no electricity,
- vacuum created by water flowing through a tube draws chlorine into a tank where it mixes with untreated water,
- treated solution fed into water system,
- chlorine doses not consistently accurate

Solid feed unit:

- waste treatment and swimming pool disinfection,
 - requires no electricity,
 - controlled by flow meter,
- device slowly dissolves chlorine tablets to provide continuous supply of chlorine solution

Batch disinfection:

- used for fluctuating chlorine demand,
- three tanks, each holding 2 to 3 days' water supply, alternately filled, treated, and used

Disinfection by-products

Trihalomethanes (THMs) are chemicals that are formed, primarily in surface water, when **naturally** occurring organic materials (humic and fulvic acids from degradation of plant material) combine with free chlorine. Some of the THMs present in drinking water are chloroform, bromoform, and bromodichloromethane. Since groundwater rarely has high levels of humic and fulvic acids, chlorinated private wells contain much lower levels of these chemicals.

THMs are linked to increases in some cancers, but the potential for human exposure to THMs from drinking water varies with season, contact time, water temperature, pH, water chemistry and disinfection method. Although there is a risk from consuming THMs in chlorinated drinking water, the health hazards of not disinfecting water are much greater. The primary standard (maximum contaminant level) for total THMs in drinking water is 0.080 mg/l or 80 ppb, and activated carbon filtration removes THMs from water.

Other disinfection methods

Although chlorination is the method of choice for most municipal and private water treatment systems, alternatives do exist. Information about these other disinfection methods is on the right.

OTHER DISINFECTION METHODS

Ultraviolet radiation (UV)

- uses light to kill microorganisms
- lamp has 9-month to 1-year lifetime
- needs UV sensor to determine germicidal dose
- effective for bacterial contaminants (viruses more difficult, cysts and worms unaffected)
- advantage in no chemicals added to water
- disadvantage in no residual disinfection; cloudy or turbid water decreases effectiveness

Ozonation

- ozone more powerful disinfectant than chlorine
- disadvantage is ozone cannot be purchased, must be generated on-site
- machinery to generate ozone complicated and difficult to maintain
- effects of ozonation byproducts not fully understood

Boiling

- two minutes vigorous boiling assures biological safety
- kills all organisms in water (chlorination reduces them to safe levels)
- practical only as emergency measure
- once boiled, cooled water must be protected from recontamination

Pasteurization

- uses heat to disinfect but does not boil water
- **flash** pasteurization uses high temperature for short time (160 °F, 15 seconds)
- **low-temperature** pasteurization uses lower temperature for longer time (140 °F, 10 minutes)

Summary

Chlorination is the most common disinfection method for public and private drinking water systems. This treatment has limitations and is not suitable for heavily-contaminated wells or springs, or sources where hazardous materials are present. With adequate residual chlorine and contact time between the disinfectant and the microorganisms, chlorination effectively kills many disease-causing bacteria. Additionally, chlorine is inexpensive, easy to control, generally safe to use, and adapts to municipal or private systems.

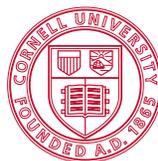
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