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HOME WATER DISINFECTION METHODS

by

Joseph L. Taraba, Thomas W. Ilvento and Linda M. Heaton[1]

DISINFECTION METHODS

The source of bacteria in your water supply can come from the water source itself, the contamination of the well and/or piping system during maintenance or construction or improper well construction. There are four disinfection methods available for the private water system:

-Chlorination (simple chlorination, super chlorination and shock chlorination)
-Ultraviolet(UV) light
-Ozonation

CHLORINATION

The effectiveness of chlorination to kill disease causing bacteria depends on the chlorine demand of the water, the concentration of the chlorine in the water, the time that the chlorine is in contact with the microorganism, and the water quality. These effects can be summarized in the following manner:

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-As the concentration of the chlorine increases, the required contact time to disinfect decreases.
-Chlorination is more effective as water temperature increases.
-Chlorination is less effective as the water's pH increases (becomes more alkaline).
-Chlorination is less effective when the water is cloudy (turbid).
-When chlorine is added to the water supply, part of it combines with other chemicals in the water (like iron, manganese, hydrogen sulfide, ammonia and organics) and is not available for disinfection. After this demand for chlorine is satisfied (chlorine demand), then the rest of the chlorine is available for disinfection (free chlorine residual).

The free chlorine residual needed for a certain contact time depends on the temperature and the pH of the water. Table 1 lists the chlorine residual required for various contact times, pH and temperature. To achieve a given contact time when the water supply is to be continuously disinfected, it is necessary to place a contact volume, either a contact tank or pipe length, before the water is used. It is necessary to know the flow rate of the water in the piping system as it passes the point of chlorination so that the proper volume can be determined. Tables 2 and 3 give the holding times for a 50-gallon tank or 1000 feet of 1-1/4 inch pipe for various water flow rates. The typical water pressure tank in a water system is not a contact tank since at many times the water simply bypasses the tank.

Simple chlorination involves maintaining a residual or free chlorine concentration of 0.3 to 0.5 mg/l. This low level of chlorine is more difficult to maintain. Public water systems use this concentration range but they constantly measure the concentration. This level of chlorine also has a low taste that is tolerable to most people. Shorter contact times can be achieved with higher levels of free chlorine. A level of 2 mg/l free chlorine has been recommended by many water treatment specialists and reduces the contact time to less than 10 minutes. This concentration leaves a taste that many people may not find tolerable. **Super chlorination** maintains a 3.0 to 5.0 mg/l of free chlorine. This level has a very strong chlorine taste. The use of a carbon filter will remove this taste (see "Using Activated Carbon Filters to Treat Home Drinking Water", IP-6, College of Agriculture, University of Kentucky).

The homeowner can measure the concentration of the free chlorine using a test kit that measures the free chlorine. **Do not buy a test kit that only measures the total chlorine.**

For some water supplies it may only be necessary to disinfect a well and the plumbing system. In this case the source of the contamination came about during construction of the well and plumbing or during the maintenance or repair of the system. The

disinfection process for this situation is called shock chlorination in which the free chlorine concentration is maintained at 50 to 100 mg/l. Table 4 gives the amount of chlorine bleach (5.25 percent solution of sodium hypochlorite (NaOCl)) that will need to be added to a well for a given well pipe diameter and the depth of water in the well. If the water in the well is cloudy or turbid , it will be necessary to double the amount added. Table 5 gives the substitutes for liquid chlorine bleach.

Adequate shock chlorination involves the following steps:

-Dilute the chlorine bleach with 12 parts of water before adding to the well to prevent corrosion.
-Thoroughly mix the chlorine solution in the well by attaching a hose to a nearby faucet and turn on the pump to recycle the water from well and back into the well.
-The chlorinated water needs to move outside the well screen into the surrounding gravel or rock. This can be achieved by adding water from a tank into the top of the well. The added water pressure will force some of the water outside of the well casing.
-Fill the water distribution plumbing with the chlorinated water. Open each faucet in the house till a strong smell of chlorine is detected. Remove or bypass a carbon filter. Remove or bypass a pressure tank if it has a rubber bladder. Strong chlorine solution can damage the rubber. Disinfection though can be achieved with a 10 mg/l solution. Drain and refill water heaters and storage tanks. Back wash the water softener.
-Allow the water to stand in the well and the water distribution system for at least 2 hours, overnight if possible.
-Thoroughly pump the water supply source and flush the distribution system till the chlorine level is acceptable to drink. Strongly chlorinated water is harmful to lawns and the septic tank. Up to 100 gallons will be flushed from the water system.

Advantages:

-Provides residual disinfection.
-Residual easy to measure.
-Chlorine readily available at reasonable cost.
-Low electrical input.
-Can be used for multiple water problems(bacteria, iron, manganese, hydrogen sulfide).
-Can treat large volumes of water.

Disadvantages:

-Requires a contact time of up to 30 minutes for simple chlorination.
-Cloudy water can reduce the effectiveness of chlorine.
-Gives water a chlorine taste.

-Can form by-products (THMs) that have human health implications.

ULTRAVIOLET LIGHT

UV light has disinfection properties that kill bacteria viruses and some cysts. Water is passed through a disinfecting chamber containing a quartz mercury lamp that emits ultraviolet light rays. The UV irradiation kills or inactivates microorganisms almost instantly. UV light is a very effective disinfectant. However, disinfection only occurs inside the unit. No residual disinfectant is retained in the water to continue to kill bacteria that may be introduced into the water after it is disinfected.

Maintaining the UV light intensity is important so that effective disinfection can continue. Films will coat the lamp surface and reduce the UV intensity or the aging of the lamp will reduce the intensity of the radiation with time. Some UV light units have detectors that either warn of reduced UV intensity with a warning light. The UV unit should then be cleaned or the lamp will need to be replaced. Cleaning the lamp surface with a solution that is left overnight or using a built-in wiper will return the unit to full effectiveness.

The bacteria in the water to be treated may be shielded from the UV radiation if the water is cloudy from suspended particulates, high numbers of bacteria (An upper limit is 1000 coliform bacteria/100 ml or 100 fecal coliforms/100 ml), high mineral content or colored water. In these cases pretreatment of the water will be necessary.

Advantages:

-Does not change taste or odor of the water.
-Kills bacteria almost immediately.
-Compact and easy to use.

Disadvantages:

-High electrical demand.
-No disinfection residual.
-Requires pretreatment for cloudy or colored water.
-Requires cleaning and a new lamp annually.

OZONATION

Ozone is a form of oxygen that contains three oxygen atoms, rather than the two atoms of typical atmospheric oxygen. Ozone has greater germicidal effectiveness against bacteria and viruses than chlorine. Further its potency is not affected by pH or temperature. Because ozone is unstable, it quickly reverts to normal oxygen. Therefore disinfection must occur at the point of use.

Advantages:

-No chemical residual exists.
-Ozone is the strongest germicidal available for use.
-Ozone eliminates problems of taste and odor in the water supply.
-Ozone is effective over a wide range of pH, so pH adjustment is not necessary.
-The by-products of ozonation have less potential human health effects than chlorination.

Disadvantages:

-Higher equipment costs and operating costs than chlorination.
-Unreliability of the equipment.
-There is no germicidal residual.

Table 1. Necessary chlorine residual to disinfect water for various contact times, water temperatures and pH

Water Temp. 50° F

Contact time (minutes)	Necessary chlorine residual (mg/l) pH 7	pH 7.5	pH 8
40	0.2	0.3	0.4
30	0.3	0.4	0.5
20	0.4	0.6	0.8
10	0.8	1.2	1.6
5	1.6	2.4	3.2
2	4.0	6.0	8.0
1	8.0	12.0	16.0

Water Temp. 32 – 40° F

Contact time (minutes)	Necessary chlorine residual (mg/l) pH7	pH7.5	pH8
40	0.3	0.5	0.6
30	0.4	0.6	0.8
20	0.6	0.9	1.2
10	1.2	1.8	2.4
5	2.4	3.6	4.8
2	6.0	9.0	12.0
1	12.0	18.0	24.0

Table 2. Available contact time from a 50-gallon holding tank

Water flow rate (gallons per minute)	Holding time (minutes)
5	7
7	5
10	3.5

Another way to maintain necessary contact time is to run the chlorinated water through a coil of pipe (Table 6).

Table 3. Available contact time from 1000 feet of 1-1/4 inch pipe

Water flow rate (gallons per minute)	Holding time (minutes)
5	9.2
7	6.6
10	4.6

Table 4. Amount of laundry bleach containing 5.25 percent hypochlorite to add to wells of various sizes (mix bleach with 12 parts of water)

Diameter of well in inches	Depth of water in well								
	Less than 50 feet	100	150	200	250	300	350	400	500
	quarts of laundry bleach								
2	¼	¼	¼	¼	½	½	½	½	1
4	¼	½	1	1	1½	1½	2	2	2
5	½	1	1	1½	2	3	3	3	4
6	½	1	1½	2	3	3	4	4	5
8	1	2	3	4	5	6	7	8	9
	gallons of laundry bleach								
12	½	1	1	1	2	2	2	2	3
18	1	1½	2	3	3	4	4	.....	.....
24	2	2½	3½	4½	.....	.....	.....	.....	.....
30	2	3½	5½	.....	.....	.....	.....	.....	.....

Table 5 Chlorine mix ratio for shock chlorination.

Chlorine source	Percent active chlorine	Form	Amount to add to water*
Laundry bleach† Clorox, Purex, Hi-Lex, etc.	5¼	Liquid	3 pt/100 gal.
Swimming pool† disinfectant or concentrated chlorine bleach	12-17	Liquid	1 pt/100 gal.
Chlorinated lime.	25	Powder	11 oz/100 gal
Dairy sanitizer	30	Powder	9 oz/100 gal.
High-test calcium hypochlorite, HTH Pittchlor, Perchloron, etc.	65–75	Powder	4 oz/100 gal.
High-test calcium hypochlorite, HTH Pit-Tabs, Chlorets	65–75	Tablets	4 oz/100 gal.

*Makes approximately 200 ppm (200 mg/l) concentrations For stronger concentration increase the amount: for a weaker solution decrease the amount.

†Be sure chlorine is the only active ingredient. Sometimes other materials such as algicides may be added to bleaches or swimming pool disinfectants. Material intended for disinfection normally contains only chlorine as the active ingredient. However, other halogens such as iodine or bromine may also be included. These normally should be avoided because they do not evaporate as chlorine does, so remain in the water. If used, greater care should be exercised when disposing of the treatment solution.