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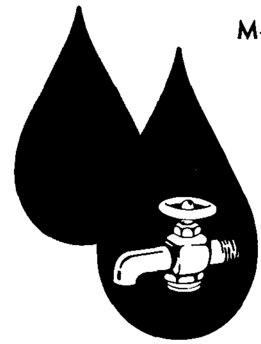
M-156
1971



Chlorination of Private Water Supplies

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There is no substitute for a safe and sanitary water supply. If your water supply becomes contaminated you should remove the source of contamination if possible. If not possible, you must obtain a new and safe water supply or eliminate the contamination by water treatment. The latter is less desirable for private water supplies.

Chlorination is the process of adding chlorine to a water source or system. Chlorine destroys nuisance bacteria, pathogenic (disease-causing) bacteria, other micro-organisms, and oxidizes iron, manganese, and hydrogen sulfide so they can be filtered out. Chlorine may be added to safe well water as a safety factor in case pathogenic organisms get into the system between the well and the faucet. Continuous chlorination to kill pathogenic bacteria in a contaminated water source should be a temporary measure used only until you can develop a new, sanitary water supply.

Effects of Chlorination

Mineral removal—You can remove large amounts of iron from water by adding chlorine to oxidize the clear water ferrous iron into the filterable red water ferric form. Chlorine helps remove manganese and hydrogen sulfide in the same way. For a complete discussion of iron removal, refer to Agricultural Extension Service publication M-154, "Iron in Drinking Water."

Controls nuisance organisms—You can keep nuisance organisms under control with chlorine treatments. Iron bacteria feed on the iron in the water or on the iron parts of the water system. They may appear as a slimy, dark-red mass in the toilet flush tank; but microscopic examination is needed to confirm their presence. Iron bacteria colonies may break loose from the inside of pipes and flow through faucets to cause stains in laundry, plumbing fixtures, etc. A thorough shock chlorination of the well and water system may destroy all iron bacteria colonies. Where iron bacteria have penetrated the water bearing formation they will be difficult to destroy and will likely re-infest the system. In this situation you will have to repeat the chlorination treatment at intervals.

Other nuisance organisms include slime bacteria and sulfate-reducing bacteria which produce a rotten-egg odor. Chlorination will kill or control these bacteria. Note that the nuisance bacteria do not cause disease.

Controls disease causing bacteria—These bacteria may enter your well during construction, repair, or flooding. Proper chlorination will kill these bacteria. If pathogenic bacteria enter your water supply on a continuous basis you must eliminate their source or construct a new water supply.

No nitrate removal—Chlorine will not remove nitrates from water. The claims of some water treatment firms imply that nitrates can be removed by chlorination. This is not true. Adding chlorine may prevent nitrates from being reduced to the toxic nitrite form; however, nitrates are not removed from water by chlorination.

Causes smell and taste—Chlorine in water is not poisonous to humans or animals. However, if the concentration is sufficiently great the water will taste bad and not be consumed. Some people object to the smell and taste of even small amounts of chlorine. For this reason you may want to use a charcoal filter to remove the excess chlorine from drinking water.

Contamination Indicators

Detergents (or surfactants), nitrates, and coliform bacteria are indicators of well contamination. None of these indicators is necessarily harmful but they do indicate that disease may occur if other conditions are favorable. If a test indicates that your water is contaminated you should locate the source of pollution and eliminate it from your water supply.

Detergents—When surfactants or detergents appear in well water you can be sure that the well has been contaminated with human sewage or other wastewater containing surfactants. No other source in nature is comparable to surfactants or detergents. While detergents are not poisonous, their presence proves contamination by a sewage disposal system.

Nitrates—Nitrate ion (or nitrate-nitrogen) often occurs naturally in groundwater in concentrations from 0.1 to 3 or 4 parts per million (ppm). Amounts as high as 100 ppm have been found in water supplies. By itself nitrate-nitrogen is not considered harmful in concentrations less than 10 ppm. Above this level it is not harmful to healthy, adult humans, but it does cause methemoglobinemia (commonly called blue-baby disease), an oxygen-starved condition in infants which can be fatal. The nitrate-nitrogen is converted to nitrite and ties up the oxygen carrying capacity of the blood. Infants develop a type of anemia which causes a bluish discoloration of the skin. If you suspect that your water supply might have a high nitrate content you should check with your doctor immediately and send a sample of the water to the State Department of Public Health for test—especially if infants drink your water.

However, it is not only the threat to infant health that concerns public health officials about the presence of nitrates. In addition, nitrate-nitrogen can be a tracer or indicator of pollution by sewage or animal wastes. As organic materials such as sewage or animal manures decompose a chemical change known as oxidation takes place. Nitrate-nitrogen is one of the end products of oxidation.

Thus, the appearance of nitrate-nitrogen in a well may be evidence of pollution from septic systems or animal waste. In ground-water which is known to contain little or no nitrate-nitrogen naturally, the presence of appreciable concentrations is almost a certain indication that pollution has occurred.

Coliform Bacteria—Pathogenic organisms can infect humans and animals in several ways. Fecal waste from an infected host is a frequent carrier of pathogenic organisms which cause diseases such as typhoid fever, paratyphoid fever, bacillary dysentary, infectious hepatitis, and others. Pathogenic organisms are transmitted from host to host in many ways including a contaminated water supply. Concentrated human population or concentrated livestock population together with improperly constructed wells or shallow wells can cause contamination of water supplies by sewage or fecal waste.

Coliform bacteria are present in the colon and feces of warm-blooded animals or aerated surface soil. Laboratory tests can identify coliform bacteria more easily than the other types. For this reason, coliform bacteria are used as an indicator of water contamination.

Tests for the presence of coliform bacteria may be made by the most probable number (MPN) method or the membrane filter (MF) method. If no coliform bacteria are detected in a test the MPN will be reported as less than 2.2 and the MF as zero.

The test result will indicate negative coliform. If any coliform are detected by the test, the number will be stated and the result will indicate positive coliform.

Organisms can enter a well or water system during construction or repair. Consequently, you should thoroughly disinfect any new well with chlorine before the water system is connected. Any time you repair a well or water system be sure to shock chlorinate to kill any nuisance or pathogenic bacteria that might be introduced.

If a water test indicates positive coliform you should thoroughly chlorinate the water supply and system. Take another sample 48 hours after all chlorine has been removed from the system. If the test of this sample shows negative coliform, the bacteria likely are not entering on a continuous basis. However, some authorities suggest at least three negative test results before sampling is stopped.

If repeated tests show positive coliform you may have a continuous source of contamination. However, make as many as 10 repeated shock chlorinations before abandoning the well. If you can't remove the contamination you must find a new water supply. If you must use the present contaminated water supply until a new supply can be developed be sure to follow a process of continuous chlorination.

Chlorination Methods

Chlorine can be added periodically as a shock treatment or it can be added continuously similar to the practice of a municipal water supply system. To chlorinate a water supply properly you need to understand chlorine demand, free available chlorine residual, and contact time.

Chlorine demand is the amount of chlorine required to kill bacteria, oxidize iron or other elements in the water, and oxidize any organic matter that may be present. There is no easy way to measure the amount of chlorine required—just add until chlorine odor persists.

Free available chlorine residual is the amount of chlorine remaining in the water after the chlorine demand has been met. If the chlorine demand is greater than the amount of chlorine introduced, there will be no free available chlorine residual. Unless a chlorine residual is present, adequate amounts of chlorine have not been added to the water.

You can determine free available chlorine residual by using a simple test kit which sells for less than $10.00. Swimming pool owners use this kind of kit to test the chlorine level of the water. Kits are available from local plumbing or water supply equipment dealers.

Contact time is the amount of time that the chlorine is present in the water. The combination of chlorine residual and contact time determines the effectiveness of the chlorination treatment. The bacterial "kill factor" is defined as the product of free available chlorine residual and contact time. Thus, the greater the chlorine residual the shorter the required contact time for bacterial kill.

With shock chlorination, a chlorine residual of at least 50 to 100 parts per million (ppm) is used with at least 2 hours contact time to be sure that all bacterial colonies are destroyed.

Continuous chlorination may use a chlorine residual of 3 to 5 ppm, or greater, with adequate contact time to develop the proper bacterial kill factor.

Neither shock nor continuous chlorination can substitute adequately for a safe water source. A well should be located and constructed by accepted sanitary standards. The water system must also be properly constructed to prevent bacterial contamination between the well and the faucet.

Shock Chlorination Procedures

It is far better to add too much chlorine to a well during the shock chlorination process than to add too little. Normally the desired chlorine residual is at least 50 to 100 ppm. Table 1 shows the amounts of chlorine bleach needed for an initial concentration of about 100 ppm.

In a dug well or cistern 1 gallon of chlorine laundry bleach for each 1,000 gallons of water (1 cubic foot = 7.5 gallons) will provide an initial concentration of 50 ppm. If you have a high chlorine demand because of organic matter or other contaminants use 2 to 4 gallons of bleach per 1,000 gallons of water. Wash the walls with the disinfectant.

Be sure to wash or expose all parts and inside surfaces of the well, pump, and distribution system to the disinfectant solution.

Table 1. 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	......	......	......	......	......	......

Reference: Manual of Water Supply Sanitation, Section VII, Paragraphs 701-722. Minnesota Department of Health, 1965.

If you have chlorine materials, other than laundry bleach, table 2 shows the amount of material and water required to obtain a 5.25 percent solution. Then you can use table 1 to determine the proper amount to add to the well. Dilute the 5.25 percent chlorine solution with 12 parts of water before placing it in the well to prevent corrosion of metal parts.

Even if you are going to use continuous chlorination your well and water system should be shock chlorinated one or more times before you install the continuous chlorination equipment. The shock chlorination may eliminate the need for continuous chlorination if the contamination is not of the recurring type. However, if you want continuous chlorination the initial shock chlorination will destroy or satisfy the chlorine demanding materials and thus simplify the establishment of a uniform chlorine residual when you start the continuous chlorination process.

Adequate shock chlorination involves 5 steps:

1. Pump and clean the water supply or well thoroughly. Remove any debris or other foreign matter. If the water is stored in a cistern or other reservoir be sure to scrub the interior surfaces to remove sediments or deposits.

2. Calculate the depth of water in the well or the amount in the storage reservoir. Determine the amount of chlorine required from table 1. Add and thoroughly mix the required amount of chlorine into the water supply.

The best way to add chlorine to a drilled well is to pump well water into a tank or other container that holds more water than the amount stored inside the well diameter. Mix the chlorine with the water in the tank and then allow the chlorinated water to flow back into the well. Attach a hose to a nearby faucet or hydrant, then start the pump to recirculate the chlorinated water out of the well and back into it. Wash down the well casing and drop pipe with the hose as the water is returned to the well. The returning water must have a strong chlorine odor. If it does not, add more chlorine to the well. If your well has a single-pipe, packer jet water system you can disinfect it thoroughly only by removing the drop pipe from the well. Add the chlorine solution into the jet pump by disconnecting the tube at the air-charging device and placing it in the chlorine solution. The solution will be drawn through the pump, the jet fittings, the upper portion of the well, the drop pipe, and the distribution system (see figure 1).

Because there is a foot valve at the bottom of the drop pipe, very little, if any, chlorine solution can enter the well below the packer leathers (see figure 2). That's why you must pull the drop pipe to disinfect the well thoroughly. With a packer jet water pump, chlorinate the water system before you remove the jet fitting from the well.

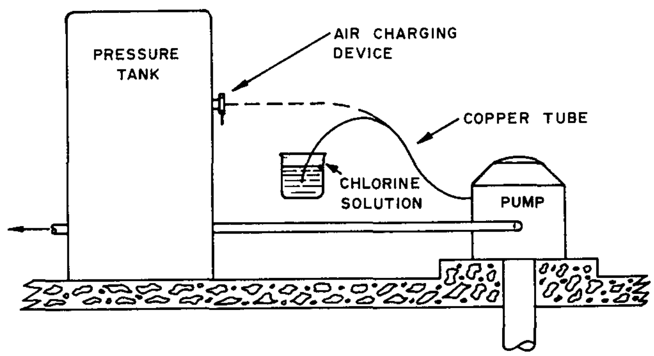

Figure 1. Tube from air-charging device is used to introduce chlorine solution into water system. Note: This process does not adequately disinfect the well.

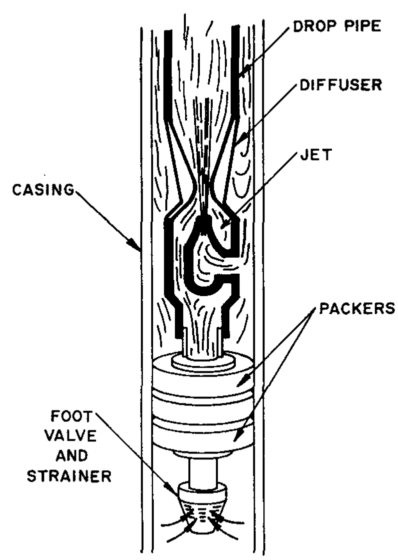

Figure 2. Packer-type jet used for small wells (2 to 4 inch).

Wells with more than 75 feet of water depth may require special methods to get chlorine to the bottom.

One method uses a short pipe filled with high-test hypochlorite powder. Cap both ends of the pipe and drill small holes through each cap or through the sides of the pipe. Fasten an eye to one of the caps and attach a line. The disinfecting agent will be distributed throughout the well as you raise and lower the pipe.

You can use extra chlorine in tablet form to reach the bottom of a deep well. When the tablets settle to the bottom they will dissolve slowly.

3. Fill the distribution system with chlorinated water. However, before disinfecting the distribution system, temporarily remove or bypass any carbon filter used in the system. If a rubber air-water separator is in the pressure tank, this may be damaged by a strong chlorine solution. Remove the rubber separator or bypass the pressure tank with the strong solution. Use a chlorine solution of 10 ppm to disinfect the tank.

Open each faucet and hydrant in the distribution system one at a time and run the water until a strong chlorine odor is present. When you smell chlorine turn the faucet off and open the next one. Add more chlorine to the water in the well if the chlorine odor becomes weak at any faucet.

Drain and refill the water heater and other water system accessories with chlorinated water. Release the air from the pressure tank (except for those tanks with a permanent air cushion) so the tank can fill completely with chlorinated water. Back wash the water softener and all filters (except carbon filters) with chlorinated water.

4. Once the chlorine adequately reaches all points of the distribution system, allow the chlorinated water to stand in the well and the distribution system for at least 2 hours. If possible, allow the chlorine solution to stay in the system overnight.

5. Thoroughly pump the water supply source and flush the system until all of the residual chlorine has been diluted to an acceptable level for use. Pump the wastewater through a hose to a roadside ditch or some other bare area.

Do not irrigate a garden or lawn with this wastewater and do not let more than 100 gallons of the strongly chlorinated water flow into drains which ultimately discharge into a septic tank.

Strongly chlorinated water is not harmful to livestock, but they will refuse to drink it unless they are very thirsty. Remember to fill livestock waterers before starting to shock chlorinate the system particularly if the chlorine solution is to be allowed to remain in the system overnight.

In addition to these 5 steps, two additional steps are suggested if iron bacteria or other nuisance organisms are in the system.

6. Dislodge and remove bacterial masses from the piping system by using compressed air or gas to create water surges or to induce a waterhammer effect. However, take care not to create excessive pressures which may rupture pipelines.

7. Shock chlorinate the water source and the water distribution system again within 24 to 48 hours.

If several shock chlorinations do not get rid of nuisance and disease causing bacteria you should abandon the well or water source and develop a new one. If new construction is not possible or feasible, your water supply should be disinfected continuously by a chlorinator installed in the water system.

Continuous Chlorination Procedures

Continuous chlorination always should be used on surface water supplies such as ponds, springs, lakes or cisterns. You can use chemical feed pumps costing from $100-$300 plus installation and accessories to inject chlorine or other chemicals into your water system. Wire the feed pump to the water pump pressure switch so the pumps operate simultaneously.

Other proportioning devices are available to feed chemicals into the water. If you are chlorinating to control pathogenic bacteria you will need an alarm device to warn when the chlorine solution supply needs replenishing.

A typical chemical feed pump is shown in figure 3 and the operation of the pump is shown in figure 4. Chamber volume increases as the diaphragm is pulled back. This forms a partial vacuum to draw the chemical into the chamber through the lower check valve. As the diaphragm is moved forward the lower check valve closes and forces the chemical out through the upper check valve into the water system.

Chemical feed pumps usually have a variable flow rate. The amount of chemical injected into the water can be changed by either varying the concentration or the pump flow rate or both.

You can use household laundry bleach full strength or dilute it with soft water for injection. Other chlorine agents may be used as noted in table 2. Always use soft water for dilution to avoid a hard water precipitate which could clog the chlorine injection equipment. Mix fresh chlorine solution each week.

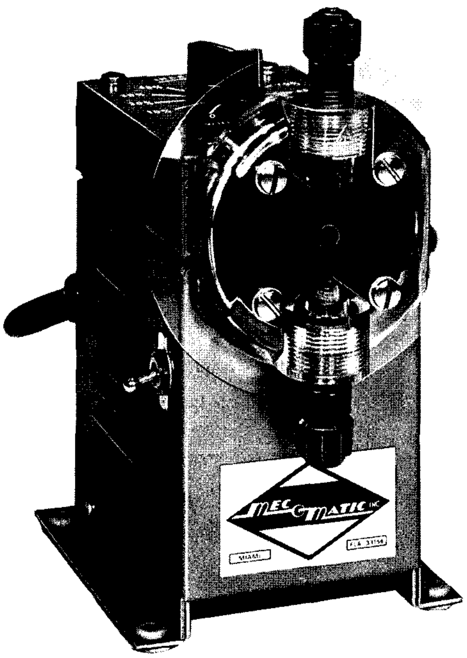

Figure 3. Chemical feed pump photo courtesy of The Lindsay Company, Division of Union Tank Car Co., 455 Woodland Drive, St. Paul, Minnesota 55119.

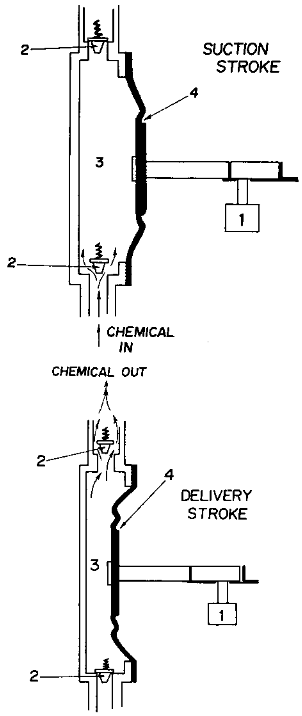

Figure 4. Operation of chemical feed pump—parts are (1) electric motor, (2) check valves, (3) pumping chamber, (4) diaphragm, and (5) housing and connections from motor to diaphragm (figure courtesy of The Lindsay Company as in figure 3).

Table 2. Materials to produce a 5.25 percent chlorine carrier solution

Chlorine agent	Percent chlorine in agent	Amount of agent to use to produce 5.25% solution	Amount of water to add to agent
Laundry bleach	5.25	1 gallon	None
Sodium hypochlorite (liquid)	12	1 gallon	1¼ gallon
Chlorinated lime (powder)	25	5½ cups	1 gallon
B-K (powder)	50	1¼ cups	1 gallon
HTH, Perchloron, etc. (powder)	70	7/8 cup	1 gallon

Because effective organism kill is a function of contact time, the chlorine solution should be injected either into the water source or as close to the source as possible. You may inject the chlorine between the water pump and the pressure tank as shown in figure 5. When iron bacteria are present throughout the water supply, inject the chlorine near the intake of the pump as shown in figure 6. When you inject the chlorine into the well at the pump intake you will need an anti-siphon valve to keep the chlorine solution from draining into the well when the pump is not operating.

Adequate contact time for pathogenic bacterial kill depends upon free available chlorine residual, water temperature, water pH (acidity), and the specific organism. The symbol K, called the bacterial kill factor, is the product of the free available chlorine residual and the contact time. Values of K are presented in table 3.

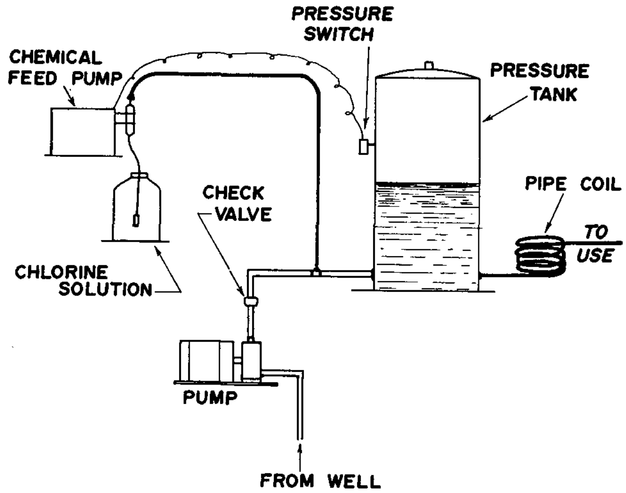

Figure 5. Chlorinator between pump and tank.

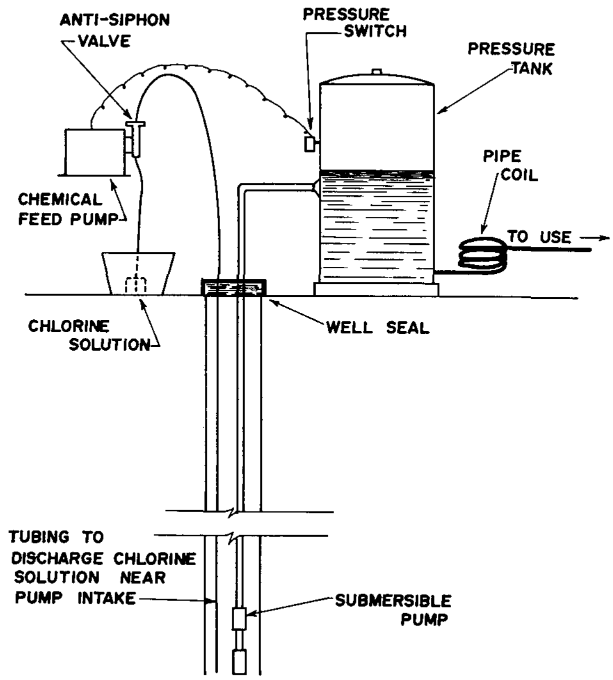

Figure 6. Injection into well near pump intake.

Table 3. K values for chlorine disinfection

Highest expected pH	Coldest expected water temperature: 50° F. or warmer	Coldest expected water temperature: 40° F. or colder
6.5	4	6
7.0	8	12
7.5	12	18
8.0	16	24
8.5	20	30
9.0	24	36

For a home water supply, a K-value of 30 is suggested for pond water supplies and a K-value of 8 for well water. Thus, any combination of chlorine residual multiplied by contact time that equals or is greater than 30 will provide adequate bacterial kill. For example, a chlorine residual of 5 would require a contact time of 6 minutes while a chlorine residual of 3 would require a 10-minute time.

If the water pH is accurately determined by a laboratory test, the K-value can be selected from table 3. For example, with a pH of 7.0 and a 50-degree temperature, the K-value is 8.

Tests have shown that there is no dependable contact time in the pressure tank of the water system. Thus, you should not include the volume of water in the pressure tank when you calculate contact time for disinfection.

Also, the piping in home water systems usually provides little contact time. The time between pump and nearest faucet is usually less than one minute when the pump is operating. You can use a coil of plastic pipe, as shown in figures 5 and 6, to provide adequate contact time.

The length of pipe in the coil depends upon the required contact time, the pipe diameter, and the flow rate. Table 4 shows the length of plastic pipe needed for a flow rate of 10 gallons per minute.

Table 4. Length of plastic pipe required* for a flow rate of 10 gallons per minute

	Feet of plastic pipe required		
Contact time, minutes	1½-inch nominal diameter (1.61" inside diameter)	2-inch nominal diameter (2.07" inside diameter)	3-inch nominal diameter (3.07" inside diameter)
2	240	144	64
3	360	216	96
4	480	288	128
5	600	360	160
6	720	432	192
8	960	576	256
10	1,200	720	320

*Mixing efficiency assumed to be 80 percent

For a K-value of 8 and a chlorine residual of 4 ppm, the required contact time is 2 minutes. From table 4, 240 feet of 1½-inch, 144 feet of 2-inch, or 64 feet of 3-inch pipe will provide this time. If your pumping rate is different than 10 gpm change the values in table 4 accordingly. For example, if your pumping rate is 5 gpm, the pipe lengths in table 4 can be divided by two.

Install the plastic pipe coil between the point of chlorine injection and the first outlet of the system. You can wrap the plastic pipe around the pressure tank to keep it out of the way.

If you inject a chlorine solution over the slow sand filter of a pond or lake water treatment system adequate contact time will usually occur within the filter bed. A measurable chlorine residual of 0.5 parts per million or less will usually be adequate. However, determine the required chlorine residual for your system by selecting the appropriate K-value from table 3 and evaluating the actual contact time with a dye test.

Adequate contact time is very necessary if you are chlorinating to kill pathogenic bacteria. Your health may be endangered if the chlorine residual and contact time are too low. Where continuous chlorination is used to control nuisance bacteria or to remove iron the contact time in the pressure tank and water system piping may be adequate.

Dechlorination

The chlorine residual of 3 to 5 ppm required in domestic systems is considerably higher than the 0.2 to 0.5 ppm range of municipal water supplies. In a city water system with large water mains and reservoir tanks, the long contact time allows using a lower chlorine residual.

The additional chlorine required in a domestic system by the shorter exposure time will cause a taste and odor which may be objectionable. Dechlorination removes the chlorine after adequate contact time. You can run chlorinated water through a carbon filter to remove the chlorine. Several types of dechlorinators are available.

If all the water is to be dechlorinated place the unit downstream from the pressure tank and pipe coil. To dechlorinate only drinking and cooking water install a small filter in front of the kitchen faucet. If you use the bathroom water supply for drinking also, install a dechlorinating filter there, too.

Summary

Adequate and effective shock or continuous chlorination require careful application of the procedures discussed. An initial chlorine concentration of 100 ppm is suggested for shock chlorination with a minimum contact time of 2 hours. The recommended chlorine residuals and contact times for continuous chlorination vary according to the properties of the water.

Shock chlorination and continuous chlorination are useful and effective methods to destroy disease causing bacteria or to control nuisance causing organisms. Remember, however, chlorination will not remove nitrates from a water supply.

Shock chlorination and continuous chlorination are not recommended substitutes for sanitary construction of the water source and the water distribution system.

If you plan to use water from ponds or cisterns for drinking you should disinfect continuously.

Because continuous chlorination is expensive and requires frequent and intelligent management, it should not be considered for pathogenic bacteria control until other alternatives such as water source and system reconstruction and repeated shock chlorinations have failed to provide a safe drinking water supply.

Issued in furtherance of cooperative extension work in agriculture and home economics, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Roland H. Abraham, Director of Agricultural Extension Service, University of Minnesota, St. Paul, Minnesota 55101.