Engineering Bulletin No. 8

DISINFECTION

OF

WATER SYSTEMS

August 1978

ARIZONA DEPARTMENT OF ENVIRONMENTAL QUALITY

Engineering Bulletin No. 8

DISINFECTION OF WATER SYSTEMS

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I. GENERAL

A. REQUIREMENTS

The following sections of the Department's Rules and Regulations for Public Water Supply Systems require the proper and adequate disinfection of unsafe water supplies and facilities prior to usage by the general public.

R9-8-210. GENERAL POLICY

A. These regulations shall apply to all water sold or distributed to the public or used in the production, processing, storing, handling, serving and transportation of food and drink.

B. All public and semi-public water systems shall obtain water from an approved source or sources and shall be located, constructed and operated in a manner to protect the water against entrance of any pollution, contamination or unclean substace. In the event water from a stream, lake or other source not protected against contamination is to be used, or if water from any source is subject to contamination, adequate purification, disinfection, or both, shall be carried out.

C. In addition to the maximum contaminant levels contained in these regulations, the Department will maintain a list of recommended contaminant levels which gives consideration to aesthetics and public satisfaction.

R9-8-211. LEGAL AUTHORITY

The regulations in this Article are adopted pursuant to the authority granted by A.R.S. §36-132, A., 12 and 36-136, G., 5.

R9-8-266. DISINFECTION

A. The Department may require the continuous application of an approved disinfectant in sufficient quantities to effectively disinfect the water whenever:

1. Sample test results exceed any applicable maximum contaminant level specified in R9-8-221 (A); or

2. There is a failure to meet the sampling requirements specified in R9-8-223(A); or

3. The location or construction of the water system creates a reasonable probability of contamination.

B. The supplier of water shall not place into service any new well, main, standpipe, reservoir, tank or other pipe or structure through which water is delivered to consumers for use until it has been effectively disinfected.

C. The supplier of water shall not resume the use of a well, main, standpipe, reservoir, tank or other pipe or structure through which water is delivered after cleaning or repairing until it has been effectively disinfected.

B. OBJECTIVE

The purpose of disinfection is to kill disease producing organisms (pathogens) which may have gained entrance into a water supply. The pathogens involved are primarily those causing intestinal diseases such as typhoid, the paratyphoids, infectious hepatitis and dysenteries; most of the other harmful bacteria are not considered to be spread by contaminated waters because of their short life outside an animal host or an especially favorable culture media. Surface waters also contain many typical soil and water organisms regarded as harmless which may persist for long periods since they are well adapted to their environment. The only certain method for completely killing all living forms is sterilization by vigorous boiling for one full minute, but this procedure is inapplicable except on an individual basis. Other disinfection methods are effective against disease causing organisms but may still allow reputedly harmless bacteria to survive. Disinfection refers to the destruction of pathogenic and intestinal or fecal type bacteria in water treatment terminology. Please note that hereafter the term milligram per liter (mg/l) is used instead of parts per million (ppm). One mg/l equals one ppm.

C. TYPES OF DISINFECTANTS

1. Physical Treatment - Raising water to its boiling point will disinfect it. This is resorted to as an emergency measure in the form of 'boil water orders.'

2. Irradiation - Ultra-violet radiation treatment consists of passing water, which must be clear, in a thin film over a quartz-enclosed mercury vapor lamp. Its sterilizing action is almost complete; no chemicals are required, no odors are formed and there is no possibility of overdosage. However, there is no residual effect with this type of disinfection and as such, it is not suitable for water distribution systems.

3. Metal Ions - Silver ions are neither vivicidal nor cysticidal in acceptable concentrations, but they are bactericidal. Disinfection at low concentrations employed is slow and silver is costly at practicable concentrations. Copper ions are strongly algicidal but only weakly bactericidal.

4. Oxidants -

a. Ozone - Ozone is produced by passing a high voltage current through air or oxygen. It is an effective but relatively expensive disinfectant that normally leaves no measurable monitoring residual in the water.

b. Halogens - Bromine has been employed on a limited scale for the disinfection of swimming pool waters, but it has less disinfecting power than other halogens. Iodine has been used for the disinfection of swimming pools and small quantities of drinking water in the field. Gaseous chlorine and a number of chlorine compounds are the most effective and economical disinfectants in usage today. As such, chlorine is the only approved disinfectant for usage in treating public water supplies in the State.

II. CHLORINATION

A. PROPERTIES AND FORMS OF CHLORINE

1. **Properties** - Chlorine is a yellowish, green gas that is extremely active and unites, when moist, with all common metals, except silver. Chlorine gas may be detected by its cucumber-like odor in air in concentrations as low as 3.5 mg/l. The membrane lining of the respiratory system is violently irritated by a chlorine concentration above 30 mg/l. As a disinfectant, chlorine acts upon bacteria through its strong oxidizing effect and its power to attack the enzyme system. Chlorine forms a series of chloramines in conjunction with ammonia and ammonium compounds which are important as water supply disinfectants. Gaseous chlorine is approximately 2.5 times as heavy as air and liquid chlorine is approximately 1.5 times as heavy as water.

2. **Forms of Chlorine Compounds** -

   a. **Gaseous Element** - Chlorine is available in the uncombined state compressed as a liquid into cylinders of the following sizes; 100 pound, 150 pound, 1 ton, and in 16 and 30 ton tank cars. Cylinders containing liquid chlorine are subject to a pressure of 85 psi at 70° F. since 500 cubic feet of gas is compressed into each cubic foot of liquid chlorine. Cylinders are seamless steel drums containing a fusible safety plug to prevent explosive bursting by thermal expansion of the liquid. Liquid chlorine can be shipped only under the strict regulations of the Interstate Commerce Commission.

   b. **Calcium and Sodium Hypochlorite** - Hypochlorite is a chemical combination of chlorine with an alkali like lime. The true calcium hypochlorites contain approximately 70% chlorine since the inert calcium chloride has been substantially removed. Being solid, hypochlorites are easily transported and administered. They should always be stored in relatively airtight containers in a dry room since they readily absorb moisture. Hypochlorites are usually fed in solution.

      Sodium hypochlorite solution, usually containing not more than 15 per cent available chlorine, is in limited use as a convenient source of chlorine for installations where the chemical requirement is extremely small. When freshly and properly prepared, such a solution should be stable for at least three months if stored in a cool, dark location. The household bleach solutions of sodium hypochlorite available locally are so dilute (usually from 3 to 5.25 per cent available chlorine) that they are prohibitive in price except for emergency use.

   c. **Chlorinated Lime** - Chlorinated lime is available commercially as a white, dry powder, having a mild odor of chlorine. It contains from 25 to 35% available chlorine and loses strength rapidly when exposed to air. Chlorinated lime, or bleaching powder, dissolves with difficulty in water and leaves behind a slurry of slaked lime.

   d. **Chlorine Dioxide** - Because of its instability, chlorine dioxide must be generated at the point of use. It is formed by adding chlorine to a solution of sodium chlorite which generates a gas of greater chemical activity than chlorine. Chlorine dioxide reacts with various organic compounds and provides a more rapid oxidation of these substances than does chlorine alone. Due to its instability and cost, it is not recommended for usage.

B. CHLORINE REACTIONS WITH WATER

1. **Hydrolysis** - Chlorine reacts with water to form hypochlorous acid (HOCl) plus hydrogen (H+) and chlorite (Cl^-) ions according to the equation:

$$Cl_2 + H_2O \rightleftarrows HOCl + H^+ + Cl^- \qquad (1)$$

This reaction is reversible.

2. **Dissociation** - In turn, the chlorine, as hypochlorous acid, ionizes or dissociates into hydrogen ions (H^+) and hypochlorite ions (OCl^-) according to the equation:

$$HOCl \rightleftarrows H^+ + OCl^- \qquad (2)$$

This reaction, like the first, is reversible. Free available HOCl and OCl^- forms of chlorine that might exist in water do not have equal disinfecting properties. HOCl is a markedly superior disinfectant due to its strong oxidizing power, electrical neutrality, and small molecular size which allows it to readily penetrate bacterial cells. Hypochlorite ion has little disinfecting power and its negative charge is presumed to impede cell penetration.

3. **pH and Temperature Dependence** - Both of the chemical reactions above are dependent upon the pH and temperature of the water. Reaction (1) predominates at low pH values and reaction (2) predominates at high pH values. An increase in the temperature and a decrease in the pH will accelerate the chemical reactions and the converse conditions will reduce both the rate and the extent of these reactions.

C. DEFINITIONS

1. **Free available residual chlorine** is that residual chlorine that exists in water as hypochlorous acid and hypochlorite ion.

2. **Chlorine demand** is the difference between the amount of chlorine applied to water and the amount of free, combined or total available chlorine remaining at the end of a specified contact period.

3. **Plain or simple chlorination** is the application of chlorine to water that receives no other treatment as it enters the distribution system or pipeline leading thereto.

4. **Prechlorination** is the application of chlorine to water prior to any other unit treatment process.

5. **Rechlorination** is the application of chlorine to water, following previous chlorination treatment, at one or more points in the distribution system.

6. **Combined available residual chlorine** is that residual chlorine that exists in water in chemical combination with ammonia or organic nitrogen compounds.

7. **Available chlorine** is a measure of the oxidizing power of a solution expressed in terms of elemental chlorine (by definition, 100 per cent). It is determined by titrating the iodine that the solution will liberate from an acidified iodide solution. The calculated weight of elemental chlorine required to liberate the same amount of iodine is the available chlorine content of the solution.

8. **Free residual chlorination** is the application of chlorine in water to produce, either directly or through the destruction of ammonia, a free available chlorine residual and to maintain that residual through part or all of a water treatment plant or distribution system. (Break-point chlorination is encompassed by this practice.)

9. **Combined residual chlorination** is the application of chlorine in water to produce, with natural or added ammonia, a combined available chlorine residual and to maintain that residual through part or all of a water treatment plant or distribution system.

10. **Dechlorination** is the partial or complete reduction of residual chlorine in water by any chemical or physical treatment.

11. **Postchlorination** is the application of chlorine to water subsequent to any other unit treatment process.

D. FACTORS INFLUENCING CHLORINATION

1. **Constituents of Water** - Natural waters represent complex solutions of many substances, most of which can be ignored, but some of which influence chlorination, as follows:

   a. **Suspended solids** - may shield bacteria from the action of chlorine.

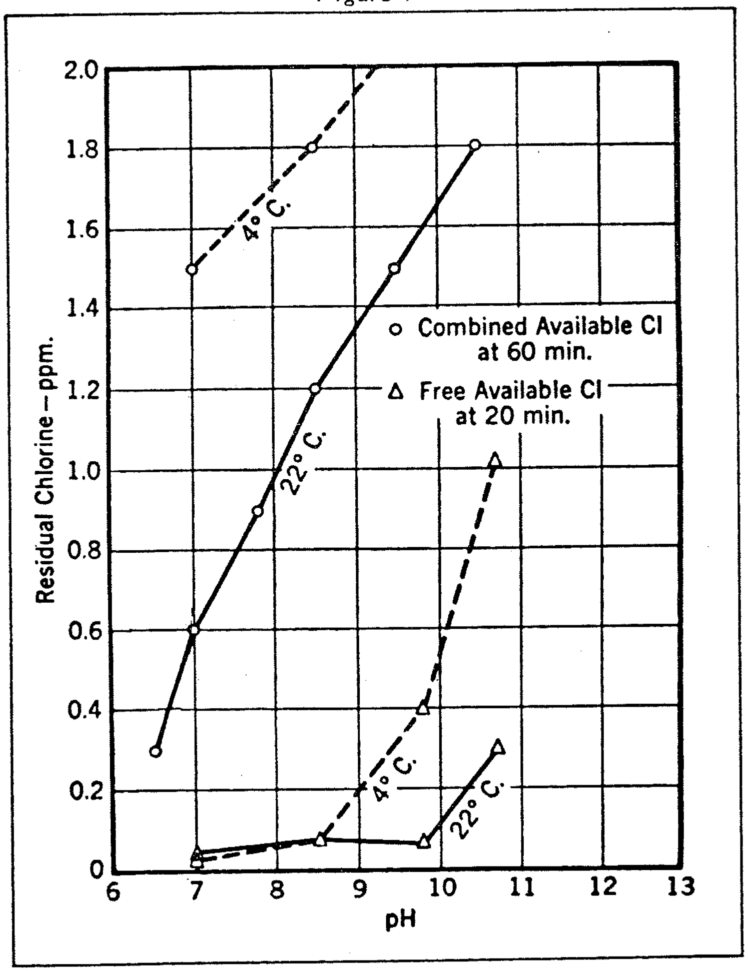
   b. **Organic Matter** - reacts with chlorine and removes it from the water so that it no longer has disinfecting properties.

   c. **Ammonia** - reacts with chlorine to form a chlorine compound (chloramine) having much lower disinfecting qualities than chlorine itself.

   d. **Nitrates, Manganese and Iron** - react with and remove chlorine and may produce a false color when testing water for chlorine content (orthotolidine test).

2. **Temperature** - The temperature of water markedly affects the disinfecting action of residual available chlorine. Other things being equal, chlorination is most effective with high water temperatures. At lower temperatures, bacterial kill tends to be slower and higher residual concentrations are needed. The effect of low temperatures is greater with combined available chlorine than with free available chlorine as shown in Figure I.

Figure I

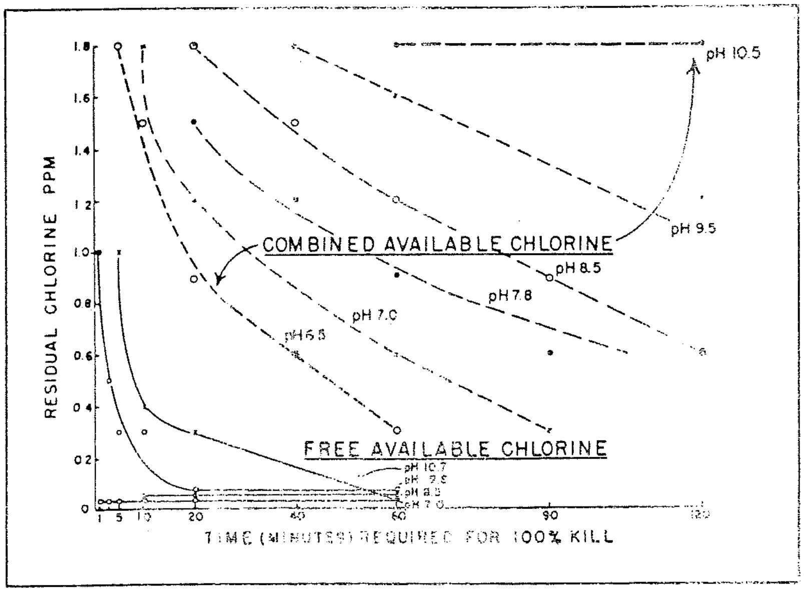


EFFECT OF TEMPERATURE ON RESIDUAL CHLORINE

3. **pH** - The pH of the water affects the disinfecting action of chlorine, particularly combined available chlorine residual. Figure 2 illustrates that the disinfecting action of chlorine is more efficient at lower pH values of the normal pH range of water supplies.

4. **Time - Concentration** - These two mutually related factors take into consideration the period of reaction time available for disinfection and the quantity and kind of chlorine residual. If reliance is to be placed on combined available chlorine, which is a weak disinfectant, a greater concentration acting over a longer period of time must be provided. On the other hand, if free available chlorine residual, an active disinfectant, is to be maintained, the reaction period can be correspondingly less as indicated in Figure 2. The minimum contact time should be 30 minutes and preferably several hours so that effective disinfection may be insured without the water reaching the consumer with an undesirable concentration of residual chlorine.

Figure 2



EFFECT OF TYPE OF RESIDUAL, AND TIME

E. CHLORINE DOSAGE

The amount of chlorine needed to accomplish disinfection or other treatment objectives depends on the chlorine demand of the water, the amount and kind of chlorine residual desired, the time of contact of the chlorine with the water and the volume of flow to be treated. Chlorine demand depends on the kind and concentration of chlorine reactive materials in the water, temperature and contact time. In brief, the chlorine required is that amount necessary to effect a specific chlorine residual at the end of a fixed contact period, the combination of which, under well defined operating conditions (pH and temperature) is demonstrably effective in accomplishing disinfection as well as providing the desired free chlorine residual at the end of the specific contact time. The required dosage (rate of chlorine application per unit of water flow) to disinfect water supplies not subject to significant contamination normally should not exceed 2 mg/l. Table I serves as a guide to required chlorine dosages for various treatment objectives and other uses for chlorine in water treatment technology. When the expected maximum dosage is determined, the required chlorine feed rate is obtained as follows:

$$\text{Chlorine feed rate (pounds per day)} = \frac{(\text{Max. Chlorine Dosage (mg/l)})\ (\text{Max. flow (mgd)})\ (8.34)}{\text{Percentage of free chlorine available}} \qquad (3)$$

(1 mg/l = 8.34 lb. of free chlorine per million gallons); Note - 1 mg/l = 1 ppm

Table I

Representative Chlorine Dosage Required for Various Treatment Objectives and Other Uses

Treatment Objective	Chlorine Dosage *ppm*	Contact Time *min*	ph Range	Chlorine Residual Recommended		Alkalinity Consumed as $CaCO_3$
				Type	*ppm*	
Disinfection						
Combined available chlorine residual	1.0–5.0	*		*	*	1.22 per ppm Cl_2
Free available chlorine residual	1.0–10.0	30		free	0.2–1.0	1.22 per ppm Cl_2
Breakpoint reaction	10 x NH_3 (as N) content	30+	6.5–8.5 (7.5 optimum)	*	*	1.22 per ppm Cl_2
Ammonia Removal						
Monochloramine formation	5 x NH_3 (as N) content	20+	>8.5	free	0.1	1.22 per ppm Cl_2
Dichloramine formation	10 x NH_3 (as N) content	20+	4.4–5.0	free	0.1	
Taste and Odor Control	10 x NH_3 (as N) content plus 1–5 ppm	20+		free	1.0	1.22 per ppm Cl_2
Phenol destruction (up to 200 ppm)	6–20 x phenol content	1.5–5 hr (stepwise)	7.0	free	variable	
Hydrogen Sulfide Removal						
Oxidation to sulfur	2.2 x H_2S content	instantaneous	5.0–9.0 (5 optimum)	free or combined	0.1	2.6 per ppm H_2S
Oxidation to sulfate	8.5 x H_2S content	instantaneous	6.5–9.0 (9 optimum)	free or combined		10 per ppm H_2S
Manganese Removal						
Oxidation to *ic* form	1.3 x Mn content	up to 3 hr (variable)	7.0–10.0 (10 optimum)	free	0.5	3.4 per ppm Mn oxidized
Iron Removal						
Oxidation to *ic* form	0.64 x Fe content	instantaneous	4.0–10.0 (>7.7 optimum)	free or combined	0.1	0.9 per ppm Fe oxidized
Red Water Prevention	maintain free residual in dead ends	variable		free	0.1	
Color Removal	1.0–10.0	15		free or combined	0.1	
Algae Control	1.0–10.0	variable		free	0.5+	
Slime Control	1.0–10.0	maintain residual throughout distribution system		free	0.5+	
Fe & S Bacteria Control	1.0–10.0	maintain residual throughout distribution system		free	1.0+	
Aid to Coagulation						
Chlorination of Copperas	1 part per 7.8 parts $FeSO_4 \cdot 7 H_2O$					
Activated silica	1.42 lb/gal 41° Baumé sodium silicate					
Chlorine Dioxide Preparation						
Chlorination of sodium chlorite	equal parts (in practice), at pH 4 or less					

* As needed, or required by local authority.

F. CHLORINE RESIDUAL

The required chlorine residual to be maintained throughout the distribution system is a free available chlorine residual of 0.2 to 1.0 mg/l after a contact time of 30 minutes. Free available chlorine can be tested for qualitatively by the "flash" test method and quantitatively by the orthotolidine-arsenite (OTA) test. (See part VII., B. and C.)

III. CHLORINE FEED EQUIPMENT

A. GASEOUS TYPE CHLORINATORS

Apparatus for feeding gaseous chlorine into water falls into two broad classes: dry feed and solution feed. Dry feed machines are useful at points not served by a pressure water supply. In cases where the type of feed is open to choice, the solution feed chlorinator is preferable. Gas chlorinators consist of pressure-reducing valves actuated by metal diaphragms or hydraulically operated floats, orifices for measuring the rate of flow of gas after it has been reduced to a uniformly low pressure and devices for injecting the gas into the supply.

1. **Dry Feed** - Dry feed chlorinators function by piping chlorine gas in tubes through a check valve directly into the water to be treated, in which case the tubing leads either to a perforated, solid silver diffuser inserted in the water pipe through a corporation cock, or to a carborundum diffuser which is inserted in the water pipe in the same way. **Dry feed equipment should be used only at points where the water pressure is less than twenty-five pounds per square inch** and may give difficulty during cold weather because of the formation of "chlorine ice" at the diffuser where the gas comes in contact with the cold water.

2. **Solution Feed** - Solution feed chlorinators apply chlorine after first dissolving the gas in injection water. A compensating valve provides a constant chlorine pressure regardless of fluctuations in cylinder pressure caused by outside temperature changes and chilling effects of withdrawals. A typical gas chlorinator flow diagram is shown in Figure 3. Figure 4 illustrates a typical gas chlorinator installation.

   The following should be observed when solution feeding elemental chlorine:

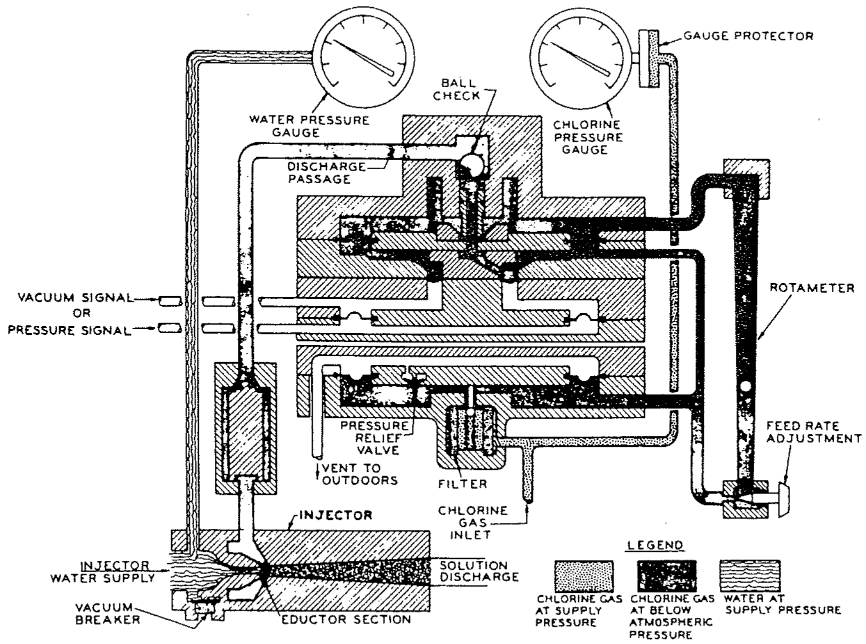
   a. **Weighing the Chlorine** - The chlorine cylinders attached to the apparatus should be placed on accurate weighing scales of proper range and the weights of the cylinders should be recorded at regular intervals, at least once a day, in order to ascertain the actual quantity of gas being used. These recorded weights assist the operators in detecting stoppages or other difficulties and also in determining when the chlorine cylinders are nearly empty. Recording scales are available for charting the actual rate of flow of the chlorine, thus furnishing a permanent record of the dose of chlorine applied. The smallest of these scales records on a chart calibrated from zero to ten pounds. Such scales are not applicable to small-sized plants, where chlorine doses are less than one pound per day. All cylinders must be secured to the scale or support by chain or other approved means.

   b. **Amount of Chlorine to be Fed from One Cylinder** - No small cylinder (100-150 lb.) should be made to furnish to the apparatus more than thirty-five pounds of chlorine per day. Otherwise the excessive drop in temperature in the cylinder will prevent evaporation. If more than thirty-five pounds is needed, an additional cylinder for each thirty-five pounds, or part thereof, should be attached to the apparatus.

   c. **Reserve Supply of Chlorine** - An ample supply of chlorine should be kept on hand to tide over any delays in shipment or in transit. Table 2 gives some recommended working chlorine inventories.

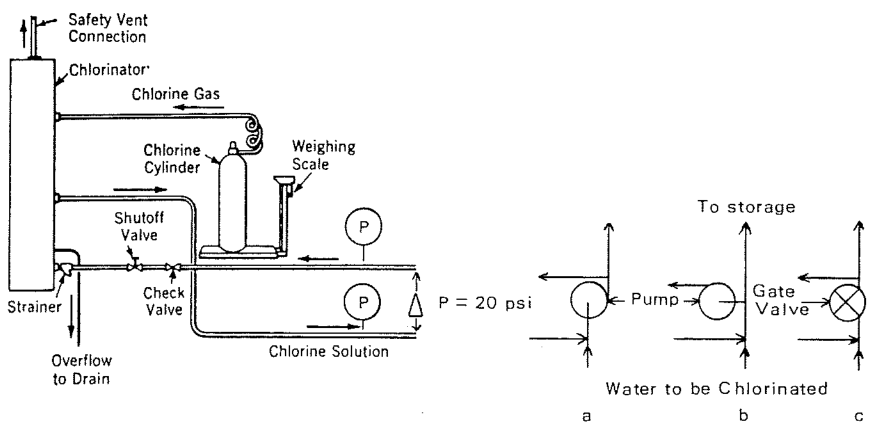
   d. **Duplicate Apparatus** - Precautions should be taken against any interruption in the application of chlorine to the water delivered to the consumers through breakdowns or repairs to the apparatus. For this reason duplicate apparatus should be provided. Duplicate parts of important portions of the apparatus, such as glass meter tubes, control valves and gaskets, should be available in order that repairs may be made immediately.

Figure 3



CHLORINATOR FLOW DIAGRAM
(BUILDERS)
COURTESY OF B.I.F. INDUSTRIES, INC.

Figure 4



Typical Gas Chlorinator Installation

Table 2

*Recommended Working Chlorine Inventories**

Average Anticipated Daily Use *lbs*	Number of Cylinders† 100 lb	Number of Cylinders† 150 lb	Number of Ton Containers†
2	1	1	
5	1	1	
10	4–5	3	
20	6–8	4–5	
50	12–18	8–12	
100	24–36	16–24	1–2
200			3–4
300			4–6
500			8–10
1000			12–18
2000			22–35
>2000			‡

* Data do not include containers in use.
† The limits represent normal deliveries of 2 and 15 days, respectively.
‡ Single-unit tank or other bulk deliveries should be considered.

Auxiliary equipment, such as hydraulic pumps, should be in duplicate, or an electric motor-driven pump should be available as stand-by equipment. Chlorinators or auxiliary pumps driven by electric motors require a reliable source of current, otherwise the chlorinators may fail during sleet or electric storms. One alternative is to use a pneumatic pressure storage tank for water to be used to operate the chlorine injector during short periods of current interruption.

e. **Temperature of Apparatus** - The room housing the chlorinator must be kept warm. The temperature of the chlorine cylinders and apparatus must not drop below 50° Fahrenheit. The operating panel must always be the same temperature or a higher temperature than the cylinders, but never lower, otherwise the warmer gas will condense when it enters the colder apparatus and cause erratic operation.

f. **Detecting Leaks and Preventing Corrosion** - Corrosion of the apparatus may be prevented by covering all exterior parts with some suitable oil or grease, such as vaseline mixed with gasoline and by immediately stopping all leaks which develop in the apparatus. The location of a leak can be readily detected by removing the cork of a bottle of ammonia and holding the neck of the bottle near the various parts of the apparatus. If chlorine is escaping, white fumes of ammonium chloride will be formed. The corrosive effect of chlorine on exposed metal surfaces should be kept in mind and all leaks promptly repaired.

g. **Repairs** - The supply of gas to a chlorinator should be shut off **at the tank** and the equipment drained of chlorine through the vent before repairs are attempted. All joints should be made tight with new gaskets and then tested for leakage. Permanent joints should be made by applying a thin paste of litharge and glycerine to the inner surfaces of the joints.

Apparatus not in service should be disconnected, thoroughly cleaned, oiled, kept in a dry place and all openings into the apparatus should be plugged to exclude moisture from the interior.

h. **Cleaning** - Parts of the apparatus which are not readily accessible for cleaning may be reached by using an ordinary tobacco pipe cleaner. The liquid in the manometer tube is carbon tetrachloride (CCl_4).

i. **Application of Chlorine Solution** - Chlorine should be applied to the water at a point where all the water being treated comes in contact with the chlorine solution.

j. **Operation** - The essential point to observe in starting a solution feed chlorinator is that the water valves must be opened first and then the chlorine valves. On closing, the reverse order is followed. Functions of some of the valves vary with the make of equipment, but most chlorinators are sufficiently similar for the following general steps to apply:

1) Ascertain that the delivery hose to the point of application is clear. If injected into a main, insert the silver solution tube through the corporation cock connection.

2) Turn on the water supply to the injector and other water connections. Adjust pressures at gages.

3) Open chlorine cylinder valve about one-half turn, then auxiliary gas valve about one and one-half turns.

4) Regulate chlorination control valve slowly until desired chlorination feed is indicated on the meter.

Daily routine includes a search for chlorine leaks with an ammonia water tracer, noting water gage reading and adjusting if needed, weighing cylinders, replacing empties and maintaining cleanliness in the chlorination booth. At least several times a day a residual test should be made on the treated water and the feed adjusted if required.

To shut off chlorination the above general steps are reversed:

1) Close the cylinder valve and the auxiliary tank valve.

2) When the chlorine gage has dropped to zero and the machine has been flushed out by the air relief, close down the water supply valves.

3) Remove solution tube if application is in a main and close the corporation cock. Do not crush the silver tube by closing the corporation cock before withdrawing the tube.

B. HYPOCHLORINATORS

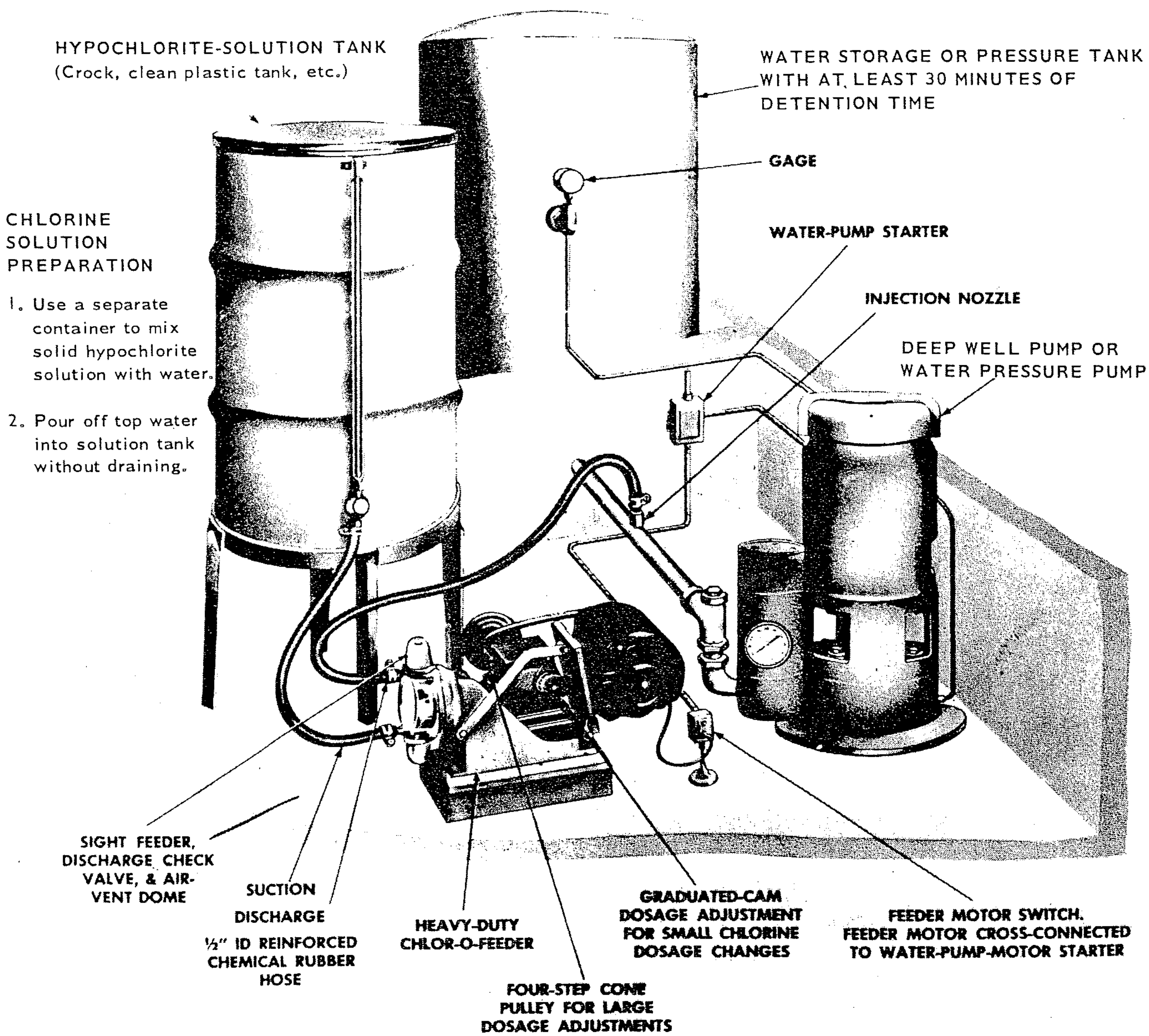
Hypochlorites are applied to water as a solution by means of a hypochlorinator. This may consist of a constant-head orifice feeder or of a small positive displacement chemical feed pump, the desired amount of a solution of a specific strength being delivered on each stroke of the pump which has the proper capacity and speed of operation. In either case, great flexibility is possible because, in addition to the adjustments available on the feeding equipment, the strength of the solution can be controlled. When the **rate of flow is not uniform, it is essential that a proportional feed hypochlorinator be used,** generally of the meter-paced type.

1. **Constant Level Type** - This type of chlorinator utilizes an upper crock to dissolve the hypochlorite powder and after settling the insolubles, the clear supernatant (top liquid) is fed into a stock solution tank where dilution water is added to reduce the concentration as desired. Uniformity of feed is maintained by a constant level box emptying through an orifice in the bottom. By separately feeding seal water to supply sufficient volume, this simple device is also applicable directly connected into pump suctions; when aided by an injector, it works against slight pressures.

2. **Pump Type** - Reciprocating positive-displacement pump-type hypochlorinators are applicable to water supplies ranging from 100 to 100,000 gallons per day consumption. Injection pressures may reach 100 psi. Pistons are driven through a speed reducer by a small electric motor or by a water

driven meter in the main. In the latter case, the pump discharges in proportion to the rate of flow. Motor driven pumps must be activated at the same time the well pump or water pump is activated by means of a water pressure switch or other controls either automatic or manual. A typical hypochlorinator installation is shown in Figure 5. Equipment applying hypochlorite solutions to water supplies should be kept in clean condition and should be located in a relatively dry room. More accurate control is possible when dilute solutions are used to insure a rapid rate of flow through the equipment. The storage tank may hold sufficient solution to treat a water supply for a period of one to two weeks; nevertheless, the equipment should be visited at least once a day for adjustment and for making orthotolidine tests of the treated water to ascertain whether the dose is sufficient to provide the desired concentration of residual chlorine in the water supply.

Figure 5



Motor-driven hypochlorinator with semiautomatic control.

3. Dosage and Calculations

a. **Stock Solution** - The quantity of hypochlorite solution prepared at one time for the stock solution should be sufficient to last for about two weeks. A common strength for the solution to be fed into the system is 1% available chlorine; this means that every gallon, or 8.34 lb., will contain 0.0834 lb., or 1.34 oz., of active chlorine. If 70% hypochlorite is used, each gallon of 1% solution will contain 1.34/0.7, or 1.92 oz. of material. The weights in ounces of hypochlorite required to chlorinate various quantities of water from a 1 mg/l to a 200 mg/l dosage are given in Table I of Appendix A. The gallons of water needed to prepare a 1% solution using this quantity of hypochlorites is found by dividing the weight in ounces by 1.92 in the case of 70% hypochlorite.

b. **Feed Rate** - The rate at which stock hypochlorite solution is fed into the system should be based on the actual pumpage, in gallons per minute, and not on the average over-all 24-hour consumption. The volume of 1% chlorine solution needed per minute to furnish a 1 mg/l chlorine dosage when injected into a pipeline flowing 1,000 gpm is:

$$(\text{dose (mg/l)}) \quad (\text{flow (mgpm)}) \;/\; (\text{percent of chlorine}) = \text{feed rate (gpm)} \qquad (4)$$

$$(1) \quad (.001)/(.01) = 0.1 \text{ gpm}$$

This small feed rate is usually expressed in milliliters which are easier units to work with when dealing with small volumes of liquid. Since a gallon contains 3,785 milliliters (ml), this hypochlorite stock solution feed is equal to 378 ml per minute. In general, for any desired dosage and pumpage rate, when using 1% chlorine solution, the rate of injection is given by the formula:

$$\text{Hypochlorite solution (ml/min.)} = 0.3785 \times \text{dosage (mg/l)} \times \text{flow (gpm)} \qquad (5)$$

If another strength of chlorine solution other than 1% available chlorine is used, this formula is modified accordingly. Thus for a 0.5% solution, results in formula (5) are divided by 0.5.

c. **Example** - It is required to treat 10,000 gpd of water with calcium hypochlorite (70% available chlorine) utilizing a hypochlorinator. The hypochlorite is to be injected into a pipe flowing at 500 gpm at a chlorine dosage of 1.0 mg/l.

Solution:

a) Prepare a 1% stock solution of hypochlorite for feed to last approximately two weeks.

From Table I, Appendix A - 2 oz. of 70% calcium hypochlorite is required to chlorinate 10,000 gal. to 1 mg/l. Multiplying this by 14 days gives 28 oz. of 70% calcium hypochlorite as the total required for two weeks. Total gallons of water required for 1% stock solution =

$$\frac{28 \text{ oz}}{1.92 \text{ oz/gal}} = 14 \text{ gal.} \qquad \text{(see 3. a., above)}$$

b) The feed rate of stock solution into the flow to be chlorinated is:

$$\text{Stock Solution Feed Rate (ml/min)} = 0.3785 \times 1 \times 500 = \underline{189.5 \text{ ml/min.}} \qquad \text{(see equation 5)}$$

$$\text{or} \quad \frac{189.5 \text{ ml}}{\text{min}} \times \frac{\text{gal}}{3{,}785 \text{ ml}} = \underline{0.05 \text{ gpm}}$$

IV. TYPES OF CHLORINATION

A. POST-CHLORINATION

Post-chlorination, the simplest method of application, consists of feeding chlorine after filtration. Its main object is to provide a chlorine residual to operate as a factor of safety in the distribution system and occasionally to reinforce the filtration process by killing some organisms that may have persisted through the plant. Dosages may vary from 2.5 lb. per million gallons to over 8 lb. per million gallons, depending upon the hardness, the amount of organic matter present and the distance in the system where a predetermined residual is desired. The upper limit of dosage is the taste and odor threshold for excess chlorine and for chlorinous tastes and odors formed by reactions with organic materials present. High sodium alkalinity tends to permit large dosages without incurring chlorine tastes. Untreated well supplies which are aerated receive simple chlorination; many well waters which are used directly without other treatment are chlorinated for a margin of safety or to control organisms that grow in pipelines. A reaction time of at least 30 minutes should be allowed before the water reaches the first consumer.

B. PRECHLORINATION

Prechlorination denotes addition of chlorine at any point in the plant prior to filtration and in amounts that do not produce unusual residuals. The doses usually exceed those employed in post-chlorination. By prechlorinating raw water, some types of algae may be controlled and organic material oxidized, thus aiding coagulation. Where employed mainly to keep filter beds clear of algae, prechlorination of settled water is generally more economical than prechlorinating raw water. The bacterial loads on the filter are reduced. Prechlorination of a well supply is useful in retarding algae growths on an unhoused aerator, in oxidizing iron and in combining with any small amount of hydrogen sulfide present.

C. SUPERCHLORINATION

Superchlorination implies heavy dosage, always before filtration, to furnish so high a residual that some of the excess must be destroyed by allowing the water to stand, by adding ammonia, or by employing a dechlorinating agent. Superchlorination is useful mainly to destroy by oxidation certain types of tastes and odors, such as from phenols, and to reduce populations of susceptible algae. Other benefits accrue incidentally, such as enhancement of coagulation and increased disinfection rate. Dechlorinating agents include activated carbon, sodium thiosulfate and sulfur dioxide.

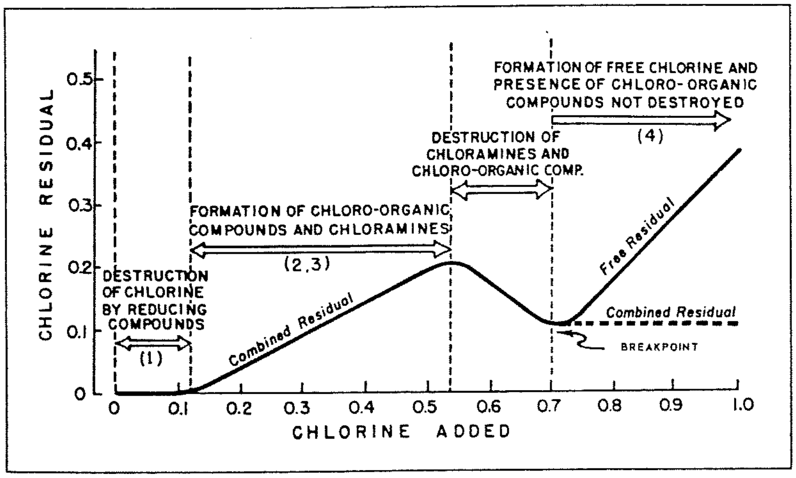
D. BREAK-POINT CHLORINATION

Break-point chlorination involves the addition of at least a sufficient amount of chlorine to produce a minimum residual after first satisfying the chlorine demand. The amount of chlorine added to produce a minimum free residual is the break-point and any further addition of chlorine results in a corresponding increase of chlorine residual as shown in Figure 6. From the standpoint of disinfection, bacteria are much more rapidly killed beyond the break-point by the free chlorine residual than by ordinary chlorination. This practice also provides a more economical method of chlorination with assurance of bacteriological kill. Figure7 illustrates the relationship between time and destruction of viruses and bacteria with free chlorine.

E. AMMONIA-CHLORINE TREATMENT

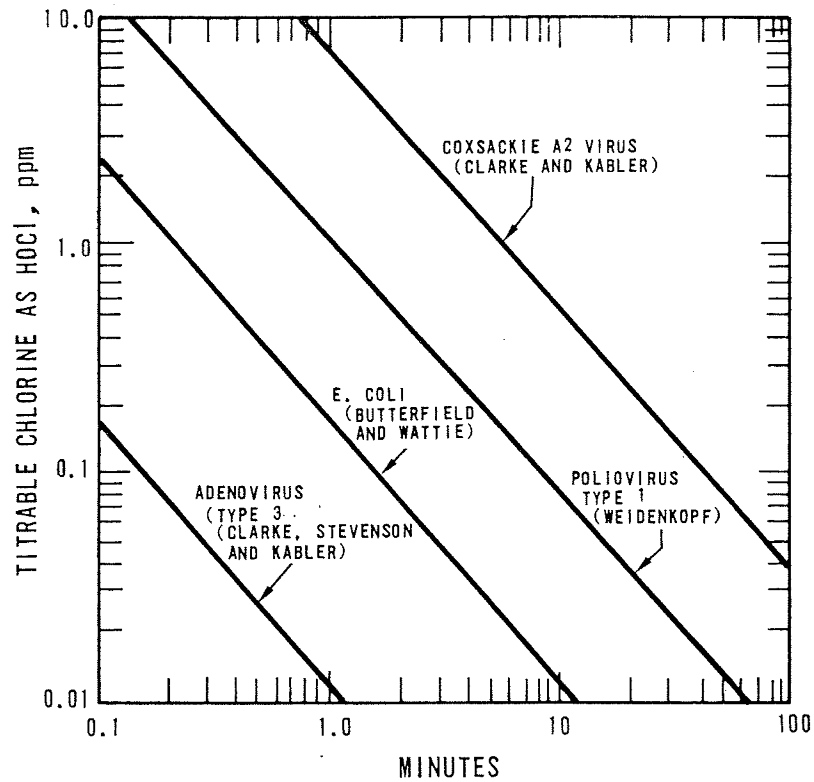
Chloramination is the joint application of some form of ammonia with chlorine. The source of ammonia may be liquid ammonia, in 100-pound steel cylinders fed through an ammoniator analogous to a dry feed chlorinator; aqua ammonia, that is ammonia water; or an ammonium salt, generally ammonium sulfate which may be fed through a dry feeder or in solution. A widely used mixing ratio is four parts of chlorine to every one part of ammonia. The ammonia is usually applied just prior to chlorination, at some point where a complete mix is assured. The combination products of chlorine and ammonia are termed chloramines; a

Figure 6



REACTIONS OF CHLORINE IN WATER

Figure 7



Concentration-time relationship for 99 percent destruction of Escherichia coli and several viruses by HOCl at 0 to 6°C.

series of these compounds may be formed, the particular members present depending on the pH of the water. Below pH 7 and at low temperatures, the chloramine formation is sluggish; this leaves some free chlorine in the water for a time with resultant rapidity in disinfection. As germicides, chloramines act slowly on organisms; for the same rate of kill, twenty to thirty times the free chlorine concentration is required. Chloramines possess the valuable advantage of greater stability over plain chlorine in solution.

Whereas chlorine residuals, especially below the break-point, ordinarily dissipate rapidly on standing and in most distribution systems disappear completely within a certain distance of the plant, a chloramine residual is more persistent and cases are known for it to take over a week to vanish from a water sample. In water mains, a chloramine residual may retain almost its original value far out to the end of the system. In this way chloramines provide a factor of sanitary safety exceeding that of chlorine out to the dead ends. However, because of the slower action of chloramines on bacteria, a residual no less than double the usual value carried with chlorine should be maintained. At least two hours' contact period with the water should be allowed before delivery to the first consumer in those cases where filter performance must be supplemented by disinfection. Particularly above pH 8 is the killing effect sluggish.

V. WATER MAIN, STORAGE TANK AND WELL DISINFECTION

A. WATER MAINS

The basic water main disinfection procedure is as follows:

1) Preventing contaminating materials from entering the water pipeline during construction, repair or removal.

2) Flushing to waste any materials that may have entered the pipeline.

3) Superchlorination of any residual contamination using methods outlined in this Bulletin.

4) Flushing to waste all superchlorinated water prior to placing system into service.

5) Collection of samples for laboratory examination to determine acceptability of bacteriological quality of the water in the pipeline. If laboratory examination shows the water to be bacteriologically unacceptable, the entire disinfection procedure must be repeated.

1. **Preventive Measures During Construction** - Precautions must be taken to protect pipe interiors, fittings and valves against contamination. Pipe delivered for construction should be strung so as to minimize entrance of foreign material. When pipelaying is not in progress, as, for example, at the close of the day's work, all openings in the pipeline must be closed by water tight plugs. Joints of all pipe in the trench should be completed before work is stopped. If water accumulates in the trench, the plugs must remain in place until the trench is dry. If dirt that, in the opinion of the purchaser's engineer, job superintendent, or water system representative, will not be removed by the flushing operation (Sec. 2) enters the pipe, the interior of the pipe should be cleaned and swabbed, as necessary, with a 5 per cent hypochlorite disinfecting solution.

2. **Preliminary Flushing** - The main must be flushed prior to disinfection, except when the tablet method is used. The sites and velocities of flushing should be as specified in the purchaser's supplemental specifications.

NOTE 1: It is recommended that the flushing velocity be not less than 2.5 ft/sec. The rate of flow required to produce this velocity in various diameters is shown in Table 3. No site for flushing should be chosen unless it has been determined that drainage is adequate at that site.

Table 3

REQUIRED OPENINGS TO FLUSH PIPELINES

Pipe Size (inches)	Flow Required to Produce 2.5 fps Velocity (gpm)	Orifice Size (inches)	HYDRANT OUTLET NOZZLES	
			Number	Size (in.)
4	100	15/16	1	2 1/2
6	220	1 3/5	1	2 1/2
8	390	1 7/8	1	2 1/2
10	610	2 5/16	1	2 1/2
12	880	2 13/16	1	2 1/2
14	1,200	3 1/4	2	2 1/2
16	1,565	3 5/8	2	2 1/2
18	1,980	4 3/16	2	2 1/2

* With 40 psi residual pressure, a 2½ inch hydrant outlet nozzle will discharge approximately 1,000 gpm and a 4½ inch hydrant nozzle will discharge approximately 2,500 gpm.

NOTE 2: Flushing is no substitute for preventive measures taken before and during pipelaying. Certain contaminants, especially in caked deposits, resist flushing at any velocity. Furthermore, with diameters of 16 in. or more, even the minimum recommended flushing velocity of 2.5 ft/sec is sometimes difficult to achieve.

3. **Methods of Superchlorination**

   a. **General Method** - This method is suitable in most cases of initial disinfection. Water from the existing distribution system or other approved sources of supply should be made to flow at a constant, measured rate into the newly-laid pipeline. The water should receive a dose of chlorine, also fed at a constant, measured rate. The two rates should be proportioned so that the chlorine concentration in the water in the pipe is maintained at a minimum of 50 mg/l available chlorine. To assure that this concentration is maintained, the chlorine residual should be measured at regular intervals.

   Table I, Appendix B, gives the amount of chlorine needed to obtain the required residual for each 100 ft. of pipe of various diameters. During the application of the chlorine, valves should be manipulated to prevent the treatment dosage from flowing back into lines supplying the water. Chlorine application should not cease until the entire main is filled with the chlorine solution. The chlorinated water should be retained in the main for at least 24 hr., during which time all valves and hydrants in the section treated should be operated in order to disinfect the appurtenances. At the end of this 24 hr. period, the treated water should contain no less than 10 mg/l free chlorine residual throughout the length of the main.

   b. **Tablet Method** - Tablet disinfection is best suited to short extensions (up to 2,500 ft.) and smaller diameter mains (up to 12 in.). Because the preliminary flushing step must be eliminated, this method should be used only when scrupulous cleanliness has been exercised during construction. It cannot be used if trench water or foreign material has entered the main, or if the water temperature is below 5° C. (41° F.). Table I, Appendix B gives the number of hypochlorite tablets required for various lengths and sizes of pipe.

      1) Placement of Tablets - Tablets are placed in each section of pipe and also in hydrants, hydrant branches, and other appurtenances. They should be attached by an adhesive, except for those tablets placed in hydrants or in joints between pipe sections. All tablets within the main must be at the top of the main. If the tablets are fastened before a pipe section is placed in the trench, their position should be marked on the section to assure that they are not misplaced through rotation. Tablets placed in joints are either crushed and placed inside the annular space, or, if the type of assembly prevents such placement, they are rubbed like chalk on the butt ends of the sections to coat them with calcium hypochlorite.

      The adhesive may be Permatex No. 1 or any alternative approved by the engineer of the purchaser or water parveyor. There should be no adhesive on the tablet except on the broad side next to the surface to which the tablet is attached.

      2) Filling and Contact - When installation has been completed, the main should be filled with water moving at a velocity of less than 1 ft/sec. This water should remain in the pipe for at least 24 hours.

      Valves should be manipulated so that the strong chlorine solution in the line being treated will not flow back into lines supplying the water.

4. **Final Flushing** - After the applicable retention period, the heavily chlorinated water should be flushed from the main until the chlorine concentration in the water leaving the main is no higher than that generally prevailing in the system, or less than 1 mg/l. Chlorine residual determinations should be made to ascertain that all heavily chlorinated water has been removed from the pipeline.

5. **Bacteriological Examination** - After final flushing and before the water main is placed in service, a sample or samples must be collected from the end of the line and tested for bacteriologic quality and shall show the absence of coliform organisms. At least one sample shall be collected from chlorinated supplies where a chlorine residual is maintained throughout the new main. From unchlorinated supplies, at least two samples shall be collected at least 24 hours apart.

   Samples for bacteriologic examination shall be collected in sterile bottles treated with sodium thiosulphate. Sterile bottles may be obtained from any laboratory of the Arizona State Department of Health. No hose or fire hydrant shall be used in collection of samples. A suggested sampling tap consists of a standard corporation cock installed in the main with a copper tube gooseneck assembly. After samples have been collected, the gooseneck assembly may be removed and retained for future use.

6. **Repetition of Procedure** - If the initial disinfection fails to produce satisfactory bacteriological samples, disinfection procedures must be repeated until satisfactory samples have been obtained. The tablet method cannot be used in these subsequent disinfections. When the samples are satisfactory, the main may be placed in service.

B. STORAGE TANKS

The following directions apply specifically to the disinfection of reservoirs, standpipes and tanks following their construction or repair, to destroy any bacterial pollution incidental to such work. The walls and bottoms of such structures should be thoroughly cleansed when possible, to remove all dirt and loose material; this will greatly improve subsequent disinfection. One of two procedures may be followed in the disinfection of tanks, standpipes and reservoirs. Table I, Appendix A, may be used to determine the amount of chlorine compound required for the required chlorine dose.

1. **Method One** - This method consists of the direct application of a strong chlorine solution to the inner surfaces of the structures. The strong chlorine solution may be prepared by dissolving one ounce of chlorinated lime (25% available chlorine) to each ten gallons of water or one ounce of calcium Hypochlorite (70% available chlorine) to each twenty-six gallons of water. The powder should be made into a paste and then added to the water. If liquid bleach or sodium hypochlorite is used, solutions of 200 mg/l available chlorine are required. This strong solution is sprayed over the inner surface of the empty structure by using fruit-tree spraying equipment or the solution may be applied with whitewash brushes. The surface disinfected should remain in contact with the strong solution at least thirty minutes before the structure is filled with water.

2. **Method Two** - After the tank has thoroughly dried, it should be filled slowly to the overflow level with potable water to which enough chlorine has been added to produce a concentration of 50 mg/l in the full tank. The chlorine, either as high-test calcium hypochlorite, or liquid chlorine, should be introduced into the water as early during the filling operation as possible. A simple and effective method of adding the disinfectant is to make a water mix of the hypochlorite powder (using a minimum of water) and pour it through the cleanout or inspection manhole in the lower course of a standpipe shell, or in the base of the riser pipe of an elevated tank. The inspection manhole cover should then be bolted into place and the filling of the tank started. If elemental chlorine is used, a special tap may be provided in the cleanout manhole cover and the gas-water mixture pumped into the tank as the filling is started. Filling the tank will provide a thorough mix of the chlorine with the water and assure contact with all surfaces for disinfection. If no bottom manhole is available, the chlorine powder or chlorine and water mixture should be scattered over the water surface in the partly filled tank, working from the roof manhole. After the tank has been filled, it should stand full for 24 hours, after which the treated water should contain a free chlorine residual of not less than 10 mg/l.

   At the end of the holding period, the highly chlorinated water in the tank must be completely drained to waste and the tank should be refilled from the regular supply. After refilling, samples of water should be taken from the tank and tested to demonstrate and record the good sanitary condition of the tank before it is placed in or restored to regular service.

C. WELLS

In the construction of a well, the drill hole is subject to contamination from the surface and from undesirable water horizons through which the well may penetrate. Contamination is also introduced through handling of tools and casings and, in the case of wells drilled by rotary methods, through exposure of the drilling mud to atmospheric and surface pollution. A part of the contamination so introduced is carried into the water-bearing formations. Although pumping will normally remove such contamination, the production of safe water can be more quickly attained by disinfection of the well.

1. **Time of Disinfection** - After the well has been completely constructed, it should be thoroughly cleaned of all foreign substances, including tools, timbers, rope, debris of any kind, cement, oil, grease, joint dope and scum. The casing pipe should be thoroughly swabbed, using alkalis if necessary, to remove oil, grease or joint dope. The well should then be disinfected with a chlorine solution. It is desirable to disinfect the well after a permanent pump has been installed or when a pump is replaced after repairs. The concentration of chlorine in the well or in the water applied to the well should be at least 50 mg/l (the standard concentration) and must remain in the well for a period of at least 24 hours with at least a 10 mg/l free chlorine residual remaining. The amount of chlorine required to prepare the standard concentration can be obtained from Table I, Appendix B. A free chlorine residual of at least 10 mg/l after 24 hours is required for all methods of disinfection given hereafter.

2. **Disinfection of Non-flowing Wells**

   a. **Method A** - Where practical, the chlorine solution of standard concentration (50 mg/l) used to disinfect the well should be prepared on the surface in containers having a volume equal to at least twice the volume of water contained in the well. This prepared solution should then be rapidly discharged into the well, care being taken to flush the walls above the water level.

   b. **Method B** - In lieu of the preparation of the solution of standard concentration in containers, a stock chlorine solution of 15,000 ppm could be added to a continuous flow of water into the well to provide the standard chlorine concentration. Either of the above methods will carry the chlorinated water into the voids of the water-bearing formation and should provide effective treatment if the chlorinated water is applied rapidly enough to reach all formations penetrated by the well or is introduced at different levels in it.

   c. **Method C** - Should the above methods not be practical, a stock solution may be added to the well, preferably at different levels, to provide the standard concentration in the water contained in the well. The well should then be agitated with a bit or bailer to spread the chlorine solution throughout the water.

   d. **Method D** - In lieu of using liquid chlorine solutions, a perforated pipe container capped at both ends, containing a granular chlorine compound of 70% calcium hypochlorite may be moved up and down in the well by means of a weighted cable. The amount of compound applied should be such as to provide the standard concentration.

3. **Disinfection of Artesian Wells** - Flowing wells discharging at the surface generally require no disinfection. Nevertheless, a bacteriological examination should be made as soon as possible after the 24-hour period following completion of construction. Should the well prove unsafe, a stock chlorine solution should be applied for 1 hour at a point on or below the horizon producing the artesian condition. This will provide the standard concentration in the flowing water.

   Application of chlorine by means of solution from a pipe container, as described for nonflowing wells, Method D, may also be used for disinfecting artesian wells.

4. **Equipment Disinfection** - If the well is disinfected prior to the insertion of the well pump, it is recommended that all exterior parts of the pump and piping coming in contact with the water should be thoroughly cleaned, wetted and dusted with a powdered chlorine compound. It is also recommended that, if possible, at the start of the operation of the pump, the pump discharge be so regulated that some of the chlorinated water may be returned to the well. After the permanent well pump is installed, the solution may be applied through the vent or air line opening in the pump base.

VI. SAFETY MEASURES AND EQUIPMENT

A. CHLORINE LEAKS

Chlorine gas is extremely toxic and corrosive in moist atmospheres. The gas is highly irritating to mucous membranes and a very small percentage in air causes severe coughing. Heavy exposure can be fatal. Thus, all chlorine leaks should be located and remedied immediately. Leaks are located by passing an open ammonia water bottle in the vicinity of the suspected leak. When the leak is severe, a rag soaked in this material should be used as a swab. Dense white fumes of ammonium chloride will indicate the location of the chlorine leak. All gas fittings must be checked using this procedure after all connections have been made.

B. GAS MASK

Gas masks of the cannister type, designed for chlorine gas and meeting the requirements of the U.S. Bureau of Mines, must be available at all installations where chlorine gas is handled and should be stored outside any room where chlorine is used or stored. At large installations, oxygen supplying equipment should be kept on hand. A list of approved chlorine gas masks is given in Table I, Appendix C.

C. HOUSING

Chlorine cylinders and chlorinators should be housed in separate rooms on the ground floor. The room should permit easy access to all equipment and a clear glass window should be installed in the door or wall to permit viewing of the chlorinator facilities.

1. **Heat** - Chlorinator rooms should be heated to at least 60° F. but should be protected from excess heat.

2. **Ventilation** - Where a gas type chlorinator is used, ventilation must be provided which will give one complete air change per minute. The air outlet from the room should be near the floor and the point of discharge should be located as not to contaminate air inlets to any buildings and areas used by people. Air inlets should be through louvers near the ceiling, with the air of such temperature that it will not affect the chlorinator equipment adversely. Switches for fans and lights should be outside of the room, at the entrance. The vent hose from the machine should discharge to the outside atmosphere above grade. As an alternative, complete containment of the chlorine gas may be practiced with the approval of the Department of the procedures to be followed.

D. CYLINDER HANDLING

The following are general recommendations regarding safe handling of chlorine cylinders:

1. None but reliable and trained men should handle chlorine.

2. Avoid dropping or bumping chlorine containers.

3. Store containers in moderate temperature away from steam lines or fire.

4. Never connect a full container to a header with other containers until temperatures and pressures, or both, are approximately the same.

5. Keep protective valve caps on containers, except when in use and replace when container is empty.

6. Close valve on container as soon as it is empty.

7. Containers must not be refilled except by permission of the owner and in accordance with Interstate Commerce Commission regulations. Even then, refilling is dangerous and should be done only under technical supervision.

8. Never use a container for any purpose other than to contain chlorine. Do not mix gases or allow moisture or air to get into containers. Never use containers as rollers or supports.

9. Never apply a flame or blow-torch to a container.

10. Keep valves closed at all times on all containers, except when they are actually delivering chlorine.

11. It is illegal to ship a defective or leaking container until entirely emptied. Such a container should be plainly marked "Defective".

12. Never be ashamed to call for help in a chlorine emergency.

E. HYPOCHLORITES

Both chlorinated lime and high-test hypochlorites should be stored in a cool, dry location away from organic substances. High-test hypochlorites are extremely active oxidizing agents and will react violently with hot sulfur jointing compounds, activated carbon, oil and finely divided metals. The result of the oxidizing reaction could be a fire or an explosion.

VII. CHLORINE TESTS

A. COMBINED AVAILABLE CHLORINE

The orthotolidine test (OTO) is used to determine the combined available chlorine residual for control of chlorination treatment. Ortholidine is an organic compound that will react with chlorine in an acid solution to produce a greenish-yellow color, the depth of color being dependent upon the concentration of chlorine. When the chlorine concentration is over 10 mg/l, a red color will be produced. This color test is adapted to measurement by means of comparison with permanent color standards prepared from inorganic colored salts and is sensitive to as little as 0.05 mg/l chlorine. With concentrations greater than 2.0 mg/l, however, the increase in color with significant increments (0.5 mg/l) of chlorine concentration is not visually detectable, but a dilution method can be used to detect higher concentrations.

One of the difficulties involved in use of the test is that substances other than chlorine in water will react with orthotolidine in acid solution to produce a yellowish color of a tint similar to that given by chlorine. Nitrites, oxidized manganese and ferric iron all produce definite interference in that they yield a color with orthotolidine. Experience has indicated that manganese presents the most prevalent and serious interference. The colors produced by manganese and iron cannot be distinguished from that given by chlorine, while that produced by nitrite is a brownish-yellow. Thus, the colors caused by these substances will report the presence of a greater residual chlorine value than is actually present.

B. FLASH TEST METHOD

The reaction of free available chlorine with orthotolidine is an instantaneous one, the color developing in less than five seconds. The appearance of this immediate, or "flash", color can be used as a measure of the free available chlorine present. At temperatures less than 60° F., chloramines and other forms of combined chlorine react more slowly with the orthotolidine and require a longer time for the development of the yellow color. This fact has been used to advantage as a means for differentiating free available from combined available chlorine. The flash test has the disadvantage of requiring the reading of the color within five seconds, insufficient time for an accurate comparison with permanent standards. The value of the test is qualitative rather than quantitative, except when the residual is predominantly free available chlorine. It is, however, a simple and exceedingly useful procedure for the control of chlorination of water supplies where it is desired to maintain a definite amount of free available chlorine in the water. This method, too, has the further limitation of being subject to interference by manganese, nitrites and iron.

C. FREE AVAILABLE CHLORINE

The unique characteristics of sodium arsenite as a reducing agent led to the development of an orthotolidine-arsenite (OTA) test which permits a quantitative estimation of free and combined available chlorine. The addition of sodium arsenite immediately after, or within five seconds after the addition of orthotolidine to the sample, will arrest the development of color due to combined chlorine, without bleaching the color caused by the immediate combination of the free available chlorine with the indicator. Thus, quantitative estimation of the flash color can be made by comparison with permanent color standards. The addition of sodium arsenite before the orthotolidine will neutralize all the chlorine compounds in the water and any yellow color formed with the ortholidine reagent will be due to the presence of interfering substances. This is the only technique that will measure such interferences by manganese, nitrites and iron without affecting precise determination of the residual chlorine present.

D. DAILY LOG

A daily free chlorine residual record should be maintained by every water treatment facility utilizing chlorination. Free available chlorine residuals must be taken and recorded on an appropriate form (Figure I, Appendix D) and submitted to the Department on a monthly basis.

VIII. EMERGENCY DISINFECTION

A. WATER QUALITY STANDARDS FOR EMERGENCY USE

In a full scale emergency situation, the normal water quality standards, as outlined in U.S. Public Health Service publications, will be suspended. Primary consideration will be bacteriological and chemical safety, with a minimum amount of attention given to palatability and appearance.

In accomplishing those objectives, consideration should be given to the following points:

1. Water should be obtained only from sources which can reasonably be sure to be free from radioactive or chemical contamination.

2. Water for drinking and cooking purposes should be stored and transported only in containers which have been disinfected in a manner equivalent to that shown in paragraph B.

3. Where clarification or filtration of raw water is not possible, provision should be made for a 24 hour settling period before dispensing.

4. All water should be disinfected in the manner outlined in Paragraph C.

B. DISINFECTION OF WATER CONTAINERS

All large containers for emergency use should be thoroughly cleaned, rinsed and disinfected by adding one pound of 70% of calcium hypochlorite per 1000 gallon capacity. Other suitable disinfectants may be used in the amount to yield a chlorine concentration in the container of 100 mg/l as determined from Table 1, Appendix A. Allow solution to stand for at least 30 minutes or longer, if possible. Drain the tank and flush with treated water before use.

Tanks or containers not normally used for water supply require special cleaning methods. In severe emergency, gasoline and oil tank trucks or storage tanks may be prepared for use by the following method:

1. Steam with low pressure steam for 15-20 minutes.

2. Scrub thoroughly with a high pressure hot water steam jet. (A "jenny" similar to those used for "steam cleaning" auto engines, etc., may be used.)

3. Fill tank to overflowing with clean untreated water and drain off.

4. Disinfect as shown above in first paragraph.

Small containers may be disinfected by scrubbing, rinsing and treating with a chlorine solution. The solution is prepared by adding one pound of 70% calcium hypochlorite to 8 gallons of water to obtain a 10,000 mg/l solution.

C. DISINFECTION OF WATER

All water for drinking or cooking purposes should be disinfected by adding sufficient chlorine to obtain a dose of 1 mg/l. This can be accomplished by preparing a stock solution containing 1¼ pounds of 70% calcium hypochlorite $Ca(OCl)_2$ in one gallon of water and adding this stock solution to water supplies according to Table 4.

In the event 70% calcium hypochlorite is unobtainable, ordinary household bleach can be used as a stock solution by tripling the dosage of solution as shown in Table 4. The water and chlorine solution

Table 4

AMOUNT OF DISINFECTANT REQUIRED TO OBTAIN A 1 ppm CHLORINE DOSE

Tank Capacity (gallons)	Volume of Chlorine Solution	
	(70% $Ca(OCl)_2$) Stock Solution	5.25% NaOCl Household bleach
100	1 tsp.	1 tbsp.
200	2 tsp.	2 tbsp.
300	3 tsp.	3 tbsp.
400	4 tsp.	4 tbsp.
500	5 tsp.	5 tbsp.
600	6 tsp.	6 tbsp.
700	7 tsp.	7 tbsp.
800	8 tsp.	8 tbsp.
900	9 tsp.	9 tbsp.
1000	10 tsp.	10 tbsp.

NOTE: 1 Tablespoon (tbsp.) = 3 teaspoons (tsp.) = 15 milliliter (ml.)

should be thoroughly mixed after adding chlorine solution and allowed to stand for at least 20 minutes. A sample should then be taken in a sterile bottle containing sodium thiosulfate and submitted to the State Department of Health Laboratory for bacteriological examination. If time permits, the treated water should not be consumed until the bacteriologic analysis of the sample shows that no coliform organisms are present.

D. CURTAILMENT OF NON-ESSENTIAL USES OF WATER

In an extreme emergency, first consideration for use of available water must be for drinking and cooking purposes. Until water to meet these needs is assured, **all other uses** must be considered non-essential.

As additional water becomes available, it will be necessary to separate those waters which can be made suitable for potable use and those which cannot.

Priorities for use of both categories of water will be dictated by the urgency of the demand. All uses of water not directly necessary for the preservation of the health and sanitation of the public must be restricted to sources not suited for potable use. All unnecessary use of water, such as watering flowers or ornamental plants, washing of vehicles, machinery, etc. (except for decontamination purposes), must be prohibited.

Establishment of priorities in all categories should be initiated as soon as estimated demand data is available. Quotas and allotments for essential uses should be provided as soon as available quantities of water are known. No prior listing of priorities by use is possible, since each priority list would have to be based on the specific situation.

IX. EMERGENCY DISINFECTION FOR INDIVIDUAL DRINKING WATER

A. GENERAL

When ground water is not available and surface water must be used, avoid sources containing floating material or water with a dark color or an odor. The water taken from a surface source should be taken from a point upstream from any inhabited area and dipped, if possible, from below the surface.

When the home water supply system is interrupted by natural or other forms of disaster, limited amounts of water may be obtained by draining the hot water tank or melting ice cubes.

In case of a nuclear attack, surface water should not be used for domestic purposes unless it is first found to be free from excessive radioactive fallout. The usual emergency treatment procedures do not remove such substances. Competent radiological monitoring services as may be available in local areas should be relied upon for this information.

There are two general methods by which small quantities of water can be effectively disinfected. One method is by boiling. It is the most positive method by which water can be made bacterially safe to drink. Another method is chemical treatment. If applied with care, certain chemicals will make most waters free of harmful or pathogenic organisms.

When emergency disinfection is necessary, the physical condition of the water must be considered. The degree of disinfection will be reduced in water that is turbid. Turbid or colored water should be filtered through clean cloths or allowed to settle and the clean water drawn off before disinfection. Water prepared for disinfection should be stored only in clean, tightly covered, noncorrodible containers.

B. METHODS OF EMERGENCY DISINFECTION

1. **Boiling** - Vigorous boiling for **ONE FULL** minute will kill any disease-causing bacteria present in water. The flat taste of boiled water can be improved by pouring it back and forth from one container into another, by allowing it to stand for a few hours or by adding a small pinch of salt for each quart of water boiled.

2. **Chemical Treatment** - When boiling is not practical, chemical disinfection should be used. The two chemicals commonly used are chlorine and iodine.

   a. **Chlorine**

      1) Chlorine Bleach - Common household bleach contains a chlorine compound which will disinfect water. The procedure to be followed is usually written on the label. When the necessary procedure is not given, one should find the percentage of available chlorine on the label and use the information in the following tabulation as a guide.

Available Chlorine [1]	Drops per quart of clear water [2]
1%	10
4 - 6%	2
7 - 10%	1

[1] If strength is unknown, add 10 drops per quart to purify.

[2] Double amount for turbid or colored water.

The treated water should be mixed thoroughly and allowed to stand for 30 minutes. The water should have a slight chlorine odor; if not, repeat the dosage and allow the water to stand for an additional 15 minutes. If the treated water has too strong a chlorine taste, it can be made more palatable by allowing the water to stand exposed to the air for a few hours or by pouring it from one clean container to another several times.

2) Granular Calcium Hypochlorite - Add and dissolve one heaping teaspoonful of high-test granular calcium hypochlorite (approximately ¼ ounce) in two gallons of water. This mixture will produce a stock chlorine solution of approximately 500 mg/l, since the calcium hypochlorite has an available chlorine equal to 70% of its weight. To disinfect water, add the stock chlorine solution in the ratio of one part of solution to each 100 parts of water to be treated. This is roughly equal to adding 1 pint (16 oz.) of stock chlorine solution to each 12.5 gallons of water to be disinfected. To remove any objectionable chlorine odor, aerate the water as described above.

3) Chlorine Tablets - Chlorine tablets containing the necessary dosage for drinking water disinfection can be purchased in a commercially prepared form. These tablets are available from drug and sporting goods stores and should be used as stated in the instructions. When instructions are not available, use one tablet for each quart of water to be purified.

b. Iodine

1) Tincture of Iodine - Common household iodine from the medicine chest or first aid package may be used to disinfect water. Add 5 drops of 2% United States Pharmaceutical (U.S.P.) tincture of iodine to each quart of clear water. For turbid water, add 10 drops and let the solution stand for at least 30 minutes.

2) Iodine Tablets - Commercially prepared iodine tablets containing the necessary dosage for drinking water disinfection can be purchased at drug and sporting goods stores. They should be used as stated in the instructions. When instructions are not available, use one tablet for each quart of water to be purified.

Water to be used for drinking, cooking, making any prepared drink, or brushing the teeth should be properly disinfected.

Table I

*Chlorine Dosage Calculator**

Instruction for use: Select desired parts per million. Determine strength of solution to be used. Compute number of gallons to be chlorinated. Read across to where lines intersect to obtain quantity of material to be used.

Desired PPM	1	1	1	1	5	5	5	5	25	25	25	25	50	50	50	50	100	100	100	100	200	200	200	200
Strength of chlorine solution	5%	25%	70%	100%	5%	25%	70%	100%	5%	25%	70%	100%	5%	25%	70%	100%	5%	25%	70%	100%	5%	25%	70%	100%
Gallons of water to be chlorinated																								
50,000	1 Gal	1 lb 11 oz	10 oz	6.7 oz	5 Gal	8 lb 6 oz	3 lb	2 lb 2 oz	25 Gal	41 lb 12 oz	14 lb 15 oz	10 lb 7 oz	50 Gal	83 lb 7 oz	30 lb	20 lb 14 oz	100 Gal	166 lb 13 oz	59 lb 10 oz	41 lb 12 oz	200 Gal	333 lb 10 oz	119 lb 4 oz	83 lb 7 oz
25,000	2 Qt	13.4 oz	5 oz	3.34 oz	2.5 Gal	4 lb 3 oz	1 lb 8 oz	1 lb 1 oz	12.5 Gal	20 lb 14 oz	7 lb 8 oz	5 lb 4 oz	25 Gal	41 lb 12 oz	15 lb	10 lb 7 oz	50 Gal	83 lb 7 oz	29 lb 13 oz	20 lb 14 oz	100 Gal	166 lb 13 oz	59 lb 10 oz	41 lb 12 oz
10,000	25.6 oz	5.5 oz	2 oz	1.34 oz	1 Gal	1 lb 11 oz	9.6 oz	6.72 oz	5 Gal	8 lb 6 oz	3 lb	2 lb 2 oz	10 Gal	16 lb 11 oz	6 lb	4 lb 3 oz	20 Gal	33 lb 6 oz	12 lb	8 lb 6 oz	40 Gal	66 lb 12 oz	23 lb 14 oz	16 lb 11 oz
5,000	12.8 oz	2.8 oz	1 oz	.61 oz	2 Qt	14 oz	4.8 oz	3.36 oz	2.5 Gal	4 lb 3 oz	1 lb 8 oz	1 lb 1 oz	5 Gal	8 lb 6 oz	3 lb	2 lb 2 oz	10 Gal	16 lb 11 oz	6 lb	4 lb 3 oz	20 Gal	33 lb 6 oz	11 lb 12.4 oz	8 lb 6 oz
2,000	5.12 oz	1.1 oz	.4 oz	.26 oz	25.6 oz	6 oz	1.92 oz	1.35 oz	1 Gal	1 lb 11 oz	9.6 oz	6.68 oz	2 Gal	3 lb 6 oz	1 lb 4 oz	13.5 oz	4 Gal	6 lb 11 oz	2 lb 62 oz	1 lb 11 oz	8 Gal	13 lb 6 oz	4 lb 12.4 oz	3 lb 6 oz
1,000	2.56 oz	.55 oz	.2 oz	.14 oz	12.8 oz	3 oz	.96 oz	.68 oz	2 Qt	13.6 oz	4.8 oz	3.34 oz	1 Gal	1 lb 11 oz	9.6 oz	6.72 oz	2 Gal	3 lb 6 oz	1 lb 3.1 oz	13.5 oz	4 Gal	6 lb 11 oz	2 lb 6.2 oz	1 lb 11 oz
500	1.28 oz	.28 oz	.1 oz		6.4 oz	1.4 oz	.48 oz	.34 oz	1 Qt	6.72 oz	2.4 oz	1.67 oz	2 Qt	13.5 oz	4.8 oz	3.36 oz	1 Gal	1 lb 11 oz	9.54 oz	6.72 oz	2 Gal	3 lb 6 oz	1 lb 3.1 oz	13.4 oz
200	.512 oz	.11 oz			2.56 oz	.56 oz	.2 oz	.14 oz	12.8 oz	2.68 oz	.96 oz	.68 oz	25.6 oz	5.4 oz	1.92 oz	1.35 oz	51.2 oz	10.7 oz	3.82 oz	2.67 oz	102.4 oz	1 lb 6 oz	7.64 oz	5.34 oz
100	.256 oz				1.28 oz	.28 oz	.1 oz	.07 oz	6.4 oz	1.35 oz	.48 oz	.34 oz	12.8 oz	2.7 oz	.96 oz	.68 oz	25.6 oz	5.4 oz	1.91 oz	1.35 oz	51.2 oz	10.7 oz	3.82 oz	2.67 oz
50	.13 oz				.64 oz	.14 oz			3.2 oz	.68 oz	.24 oz	.17 oz	6.4 oz	1.4 oz	.48 oz	.34 oz	12.8 oz	2.72 oz	.96 oz	.68 oz	25.5 oz	5.4 oz	1.91 oz	1.34 oz
25	.064 oz				.32 oz				1.6 oz	.34 oz	.12 oz		3.2 oz	.68 oz	.24 oz	.17 oz	6.4 oz	1.36 oz	.48 oz	.34 oz	12.8 oz	2.72 oz	.96 oz	.67 oz
10	.026 oz				.128 oz				.64 oz	.14 oz			1.28 oz	.3 oz	.1 oz		2.56 oz	.56 oz	.192 oz	.14 oz	5.12 oz	1.12 oz	.384 oz	.27 oz
5	.013 oz				.064 oz				.32 oz				.64 oz	.14 oz			1.28 oz	.28 oz	.1 oz		2.56 oz	.56 oz	.192 oz	.14 oz

* Materials used are as follows: 5%—sodium hyprochlorite (liquid) 25%—chlorinated lime (solid) 70%—calcium hypochlorite (solid) 100%—gaseous chlorine

Table 1

CHLORINE REQUIRED TO PRODUCE 50 mg/l CONCENTRATION

DIAMETER Pipe or Well (inches)	CAPACITY (gal/100 ft)	DOSAGE PER 100' OF PIPE					NO. HYPOCHLORITE TABLETS (3¾ gm) 1 gm/gal = 264.5 mg/l				
		100% Chlorine (gaseous) (oz)	70% Ca(OCl) (ounces)	25% Ca(OCl) (ounces)	15% (ounces)	5.25% NaOCl (pints)	Length of pipe section (feet)				
							13	18	20	30	40
1	4			0.11	0.17	0.5 oz					
2	16	0.106	0.15	0.42	0.68	2.1 oz	1	1	1	1	1
3	37	0.246	0.35	1.00	1.58	0.35					
4	65	0.432	0.62	1.75	2.8	0.70	1	1	1	2	2
6	150	1.00	1.45	4.0	6.4	1.25	2	2	2	3	4
8	260	1.75	2.5	7.0	11.1	2.4	2	3	3	5	6
10	412	2.75	4.0	11.0	17.6	3.5	3	5	5	7	9
12	600	4.0	5.8	16.0	1.6 pt	5.5	5	6	7	10	14
16	1044	7.0	10.0	30.0	2.8 pt	9.0					

Table I

U.S. BUREAU OF MINES - APPROVED RESPIRATORS FOR CHLORINE

NAME, USE	MANUFACTURERS	NUMBER
	ACID GAS MASKS	
Acme, chlorine gas	Acme Protection Equipment Co.	BM-1421
Bullard, chlorine gas	E. D. Bullard Co.	BM-1426 (Inactive) BM-1430 (Inactive) BM-1453 (Inactive)
Bullard, hydrocyanic acid gas		BM-1428 (Inactive) BM-1431 (Inactive)
Davis, chlorine gas	Davis Emergency Equipment Co., Inc.	BM-1427
Davis, hydrocyanic acid gas		BM-1424
M.S.A., chlorine gas	Mine Safety Appliances Co.	BM-1422 (Inactive)
M.S.A., hydrocyanic acid gas		BM-1413 (Inactive) BM-1414 (Inactive)
Wilson, chlorine gas	Wilson Products Div., The Electric Storage Battery Co.	BM-1426 (Inactive) BM-1453
Wilson, hydrocyanic acid gas		BM-1428
ACID GAS MASKS WITH MECHANICAL FILTERS		
M.S.A. industrial, for chlorine gas and dusts, mists and fogs	Mine Safety Appliances Co.	BM-14F-60
M.S.A. industrial, for hydrocyanic acid gas and dusts, mists and fogs		BM-14F-62
M.S.A. with super-size canister for hydrocyanic acid gas and mists, dusts and fogs		BM-14F-63

NOTE: 1. The word inactive after a BM number denotes that the device is no longer being manufactured but retains its BM approval status.

2. Additional U.S., B.M. - approved respirators for chlorine that have been approved after 1966 are acceptable.

Figure I

ARIZONA DEPARTMENT OF HEALTH SERVICES
Division of Environmental Health Services

DAILY CHLORINE RESIDUAL RECORD

WATER SYSTEM NAME ____________________ LOCATION/TEST ____________________

FOR MONTH OF ______________ 19 ____

DATE	TANK Gallons or Weight	AMOUNT USED	PPM CHLORINE*	DATE	TANK Gallons or Weight	AMOUNT USED	PPM CHLORINE*
1				17			
2				18			
3				19			
4				20			
5				21			
6				22			
7				23			
8				24			
9				25			
10				26			
11				27			
12				28			
13				29			
14				30			
15				31			
16							

* *Test result after 30 minutes contact time. 0.2 PPM minimum, 1.0 PPM maximum measured on the distribution system.*

AMOUNT OF WATER PUMPED FOR MONTH ____________________ gallons

AMOUNT OF CHLORINE FED FOR MONTH ____________________ pounds/gallons (circle one)

Operator ____________________

EHS-WS-9 (11-71)