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# DRINKING WATER DISINFECTION

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**Chlorine** kills bacteria, including disease-causing organisms and the nuisance organism, iron bacteria.

## Water disinfection by chlorine

Chlorine has been used since 1908 to disinfect water supplies in the United States to protect public health. Disinfection in water treatment is required by the Surface Water Treatment Rule which was created in June, 1990. This rule mandates two components for effective disinfection.

- Removal by filtration
- Inactivation of organisms (bacteria, viruses) by disinfectants (chlorine/ ozone/chlorine dioxide)

The effectiveness of chlorination depends on the chlorine demand of the water, the concentration of the chlorine solution added, the time that chlorine is in contact with the organism, and water quality. These effects can be summarized in the following manner:

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

The purpose of inactivation is to kill pathogens and microorganisms in the water. Chlorine is one of the more common methods for achieving this.

<u>Advantages of Chlorine</u>

- Chlorine provides a strong residual in the distribution system.
- Chlorine can be easily converted to chloramines which also provide a strong residual and do not produce by-products.
- Chlorine is easy to apply.

- Chlorine is a relatively inexpensive disinfecting agent.
- Chlorine is effective at low concentrations.

Disadvantages of Chlorine

- When chlorine reacts with organic material its concentration is reduced; trihalomethanes (THM’s), and disinfection-by-products (DBP’s) are formed. These compounds are a concern because they are carcinogenic.

Effectiveness

The pathogens causing such diseases as typhoid fever, cholera and dysentery succumb most easily to chlorine treatment.
As yet, little is known about viruses, but some authorities place them at neither extreme in resistance to chlorination.

- Chlorine provides poor control for cyst producing protozoa such as Cryptosporidium, Amoebas and Giardia. Filtration is one method that can be used in addition to chlorination to destroy protozoa in the water (Hoehn,1997).

Chlorine demand, chlorine residual

The first chlorine fed into the water is likely to be consumed in the oxidation of any iron, manganese or hydrogen sulfide that may be present. Some of the chlorine is also neutralized by organic matter normally present in any supply, including bacteria, if present. When the "chlorine demand" due to these materials has been satisfied, what's left over - the chlorine that has not been consumed - remains as a "chlorine residual."

**Chlorine.** There are three basic terms used in the chlorination process: chlorine demand, chlorine dosage and chlorine residual.

> **Chlorine demand** is the amount of chlorine which will be reduced or consumed in the process of oxidizing impurities in the water. Chlorine demand is the amount of chlorine impurities in the water.
>
> **Chlorine dosage** is the amount of chlorine fed into the water.
>
> C**hlorine residual** is the amount of chlorine still remaining in water after oxidation takes place. This chlorine residual must be maintained for several minutes depending on chlorine level and water quality.

Kits are available for measuring the chlorine residual by looking for a color change after the test chemical is added. The test is simple and easy for a homeowner to perform. If chlorination is required for the water supply, the chlorine residual should be tested regularly to make sure the system is working properly. The kit should specify that it measures the free chlorine residual and not the total chlorine. Once chlorine has combined with other chemicals it is not effective as a disinfectant. If a test kit does not distinguish between free chlorine and chlorine combined with other chemicals, the test may result in an overestimation of the chlorine residual.

Chlorine will kill bacteria in water, but it takes some time. The time needed depends on the concentration of chlorine.

Two methods of chlorination are used to disinfect water are: **simple chlorination** and **superchlorination**.

| **Necessary Chlorine Residual to Disinfect Water for Various Contact Times, Water Temperatures and pHs** | | | |
|---|---|---|---|
| **Water Temperature 50°F** | | | |
| **Contact time (minutes)** | **Necessary chlorine residual (mg/l)** | | |
| | **pH 7** | **pH 7.5** | **pH 8** |
| 40 | 0.2 | 0.3 | 0.4 |
| 30 | 0.3 | 0.4 | 0.5 |
| 20 | 0.4 | 0.6 | 0.8 |
| 10 | 0.8 | 1.2 | 1.6 |
| 5 | 1.6 | 2.4 | 3.2 |
| 2 | 4 | 6 | 8 |
| 1 | 8 | 12 | 16 |
| **Water Temperature 32°F- 40°F** | | | |
| **Contact time (minutes)** | **Necessary chlorine residual (mg/l)** | | |
| | **pH 7** | **pH 7.5** | **pH 8** |
| 40 | 0.3 | 0.5 | 0.6 |
| 30 | 0.4 | 0.6 | 0.8 |
| 20 | 0.6 | 0.9 | 1.2 |
| 10 | 1.2 | 1.8 | 2.4 |
| 5 | 2.4 | 3.6 | 4.8 |
| 2 | 6 | 9 | 12 |
| 1 | 12 | 18 | 24 |

<u>Simple chlorination</u> involves maintaining a low level of free residual chlorine at a concentration of 0.30.5 mg/1 for at least 30 minutes. The residual is measured at the faucet most distant from the where chlorine is added to the water supply.

To ensure the proper contact time of at least 30 minutes, a holding tank can be installed. Pressure tanks, while often thought to be sufficient, are usually too small to always provide 30 minutes of contact time.

| **Available Contact Time From a 50-gallon Holding Tank** | |
|---|---|
| **Water flow rate (gallons per minute)** | **Holding time (minutes)** |
| 5 | 7 |
| 7 | 5 |
| 10 | 3.5 |

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

| **Available contact time from 1000 feet of $1^{1/4}$ inch pipe** | |
|---|---|
| **Water flow rate (gallons per minute)** | **Holding time (minutes)** |
| 5 | 9.2 |
| 7 | 6.6 |
| 10 | 4.6 |

When the water cannot be held for at least 30 minutes before it is used, superchlorination is an alternative.

For superchlorination, a chlorine solution is added to the water to produce a chlorine residual of between 3.0 and 5.0 mg/1, which is about ten times stronger than for simple chlorination. The necessary contact time for this concentration is reduced to less than five minutes (Table 4). The water will have a very strong chlorine smell. If this is not desirable, the chlorine can be removed from the water, just before it is used, with a carbon filter. (Note: not currently allowed under Ohio Department of Health for private water supplies).

Regulations of Chlorine Use

Maximum contaminant levels (MCL's) limit the maximum concentration of many contaminants that are typically found in water. Primary MCL's (PMCL's) attempt to control substances that can be harmful when ingested, and are enforceable by the government. Secondary MCL's (SMCL's) set desired levels of pollutants to maintain aesthetic standards. SMCL's are not enforceable, but treatment facilities are encouraged to maintain these standards. Two SMCL's apply to chlorine: 4mg/l for $Cl_2$, and 250mg/l for $Cl^-$.

Drinking water regulations are constantly under review, including ammendments to the Safe Water Drinking Act that were adopted in 1996, and new MCL's for chlorine currently being considered. For more information on water quality regulations, the Surface Water treatment Rule, and the Safe Water Drinking Act, visit the Environmental Protection Agency’s homepage. www.epa.gov/epahome/

**Other Chemical Disinfectants**

The most common method of treating water for contamination is to use one of the various chemical agents available. Among these are chlorine, bromine, iodine, potassium permanganate, copper and silver ions, alkalis, acids and ozone. Bromine and iodine are reviewed briefly here:

## Bromine

Bromine is an oxidizing agent that has been used quite successfully in the disinfecting of swimming pool waters. It is rated as a good germicidal agent. Bromine is easy to feed into water and is not hazardous to store. It apparently does not cause eye irritations among swimmers, nor are its odors troublesome.

## Iodine

For emergency purposes iodine may be used for treatment of drinking water. Much work at present is being done to test the effect of iodine in destroying viruses, which are now considered among the pathogens most resistant to treatment. Tests show that 20 minutes exposure to 8.0 ppm of iodine is adequate to render a potable water. As usual, the residual required varies inversely with contact time. Lower residuals require longer contact time, while higher residuals require shorter contact time. While such test results are encouraging, not enough is yet known about the physiological effects of iodine treated water on the human system. For this reason its use must be considered only on an emergency basis.