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Technical Bulletins: Disinfection Options for Potable Water Systems

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DISINFECTION OPTIONS FOR POTABLE WATER SYSTEMS

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Public water systems protect their customers from exposure to potential pathogens found in potable water. This monumental task begins at the source and continues through the treatment plant into the distribution system. Source water assessments and wellhead protection plans are used by systems to protect their source water. In the treatment plant, the coagulation, flocculation, sedimentation, and filtration processes provide a physical/chemical barrier. Disinfection methods are used to deactivate pathogens at the plant and to provide some level of protection in the distribution system.

In the Rules of Tennessee Department of Environment and Conservation, Bureau of Environment's Division of Water Supply, Chapter 1200-5-1 governs public water systems. Specific sections of this rule define the use of disinfection.

Section 1200-5-1-.17 (28) states

All public water systems using surface water shall provide disinfection to control the biological quality of the water. Due consideration shall be given to the contact time of the disinfectant in the water with relation to pH, ammonia, taste-producing substances, temperature, presence and type of pathogens, and trihalomethane formation potential. All disinfection basins must be designed to prevent water from short circuiting the system. The disinfectant will be applied in the manner needed to provide adequate contact time.

Section 1200-5-1-.17 (29) states

All community water systems using ground water as the raw water source serving water to more than 50 connections or 150 people will apply the disinfectant in the manner needed for adequate contact time. Contact time for ground water systems shall not be less than 15 minutes prior to the first customer.

Section 1200-5-1-.17 (30) states

The free residual disinfectant concentration in the water entering the distribution system cannot be less than 0.2 mg/l for more than four hours.

Disinfection of potable water can be accomplished by different methods of treatment.

A. Chemical disinfectant
B. Ozone application
C. Ultraviolet light application
D. Mixed oxidants

A. Chemical disinfection

Different chemicals may be used to disinfect potable water. These include iodine, potassium permanganate, chlorine, chlorine dioxide, and chloramines. Ozone is technically a chemical disinfectant, but it will be discussed separately from the other chemical disinfectants. Iodine and potassium permanganate are not normally used in a public water system for disinfection. Chlorine in its many forms is the most widely used chemical disinfectant. Chemical disinfectants also act as oxidants for various chemicals found within the water.

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The various forms of chlorine have Maximum Residual Disinfectant Levels (MRDL).

TDEC Rule 1200-5-1-.06 (c) 1 states

Disinfectant residual	MRDL (mg/L)
Chlorine	4.0 (as Cl2)
Chloramines	4.0 (as Cl2)
Chlorine dioxide	0.8 (as ClO2)

If a public water system exceeds an MRDL, it must inform customers by public notification; per TDEC Rules Section 1200-5-1-.19.

If chlorine is added to water that has dissolved organic material, two groups of potential carcinogens may form—trihalomethanes (THM) and halo acetic acids (HAA5). Water systems have modified how they treat water as a means of reducing the potential of forming these two groups of carcinogens.

Chlorine can be used in the water treatment/ distribution area as a gas, liquid, or solid. Each form has unique characteristics. Safety must be a primary consideration when using chlorine. Users should follow the manufacturer's instructions for the equipment. The user must completely understand the Material Safety Data Sheet for each chemical.

The effectiveness of chlorine to deactivate a pathogen is determined by pH, temperature, time, dosage, and material found within the water. In general terms, chlorine works better around a pH of 7. As the pH increases, the effectiveness is reduced. Chlorine works better but dissipates faster in warm water than it does in cold water.

The length of time that water is in contact with the disinfectant is paramount to proper disinfection. To address this issue, TDEC has provided Section 1200-5-1-.31 in the rules for public water systems. This section discusses in depth disinfection and CT values applicable to different sources. CT is defined in Section 1200-5-1-.04 (15).

"CT" or "CTcalc" is the product of "residual disinfectant concentration" (C) in mg/1 determined before or at the first customer, and the corresponding "disinfectant contact time" (T) in minutes, i.e., "C" x "T." If a public water system applies disinfectants at more than one point prior to the first customer, it must determine the CT of each disinfectant sequence before or at the first customer to determine the total percent inactivation or "total inactivation ratio." In determining the total inactivation ratio, the public water system must determine the residual disinfectant concentration of each disinfection sequence and corresponding contact time before any subsequent disinfection application point(s). "CT99.9" is the CT value required for 99.9 percent (three-log) inactivation of Giardia lamblia cysts. CT99.9 for a variety of disinfectants and conditions appear in Tables 1.1-1.6, 2.1, and 3.1 of 1200-5-1-.31(5)(b)3.

$$\frac{\text{CTcalc}}{\text{CT99.9}}$$

is the inactivation ratio. The sum of the inactivation ratios, or total inactivation ratio shown as

$$\frac{(\text{CTcalc})}{\sum (\text{CT99.9})}$$

is calculated by adding together the inactivation ratio for each disinfection sequence. A total inactivation ratio equal to or greater than 1.0 is assumed to provide a three-log inactivation of Giardia lamblia cyst. Disinfectant concentrations must be determined by tracer studies or an equivalent demonstration approved by the department.

Gaseous chlorine (Cl2) is produced from pressurized liquid chlorine which is ~99.5 percent pure chlorine. The gas is greenish-yellow in color, 2.5 times heavier than air, and has a pungent odor. The odor can be detected in the air at 0.3 parts per million. Death can occur in concentrations at or above 0.1 percent. Chlorine gas will not burn, but it can support a fire in that it can replace oxygen in the burning process. Gaseous chlorine will also react with organic material, ammonia, and other flammable material. The gas is very corrosive if not kept dry.

Gaseous chlorine is usually the least expensive form of chlorine when compared to the other two forms. It may be purchased in 150-pound cylinders, one-ton cylinders, tank trucks, and railroad cars. The gas within the container does not degrade during the normal use of a cylinder at a treatment plant. Maintenance of the chlorinators can be tedious.

Chlorine gas can be produced at a water treatment plant. This alleviates having to store large amounts of chlorine gas, which will add a measure of safety at the plant.

Sodium hypochlorite (NaOCl) is a liquid sometimes called “bleach” by water staff. It is available in various strengths with the norm being utilized by water systems around 15 percent available chlorine. NaOCl has replaced gaseous chlorine in a number of systems for a couple of reasons. The most common is the perception that NaOCl is “safer” than gaseous chlorine. The other is the ease of maintenance of the equipment.

NaOCl is a corrosive liquid, which can produce a fire when it contacts organic or other materials. The liquid degrades over time so that after 45 to 60 days, the available chlorine is not 15 percent.

NaOCl can be produced at a water treatment plant. This allows the plant to produce only the amount of chlorine for immediate needs, so degradation does not occur because the chlorine is used within a day or two of when it is produced.

Calcium hypochlorite (Ca(OCl)2) is a solid chemical that has 65 percent available chlorine. It is sometimes referred to as “HTH” by individuals within the water industry. It is usually used by extremely small systems in the treatment process or in disinfection of pipes and tanks by larger system.

Ca(OCl)2 has the same problems that NaOCl has concerning use and application.

Chlorine dioxide (ClO2) is produced at a water plant. It reduces production of trihalomethanes (THM) and halo acetic acids (HAA5). It also works over a wider pH range than chlorine. Some systems have reported odor problems in certain circumstances when using ClO2.

ClO2 may add up to one log of removal credit in the proposed Long Term 2 Enhanced Surface Water Treatment Rule, dependent upon dose and source water characteristics.

Chloramines are utilized to reduce trihalomethanes (THM) and halo acetic acids (HAA5) formation. This process blends chlorine and ammonia together during the disinfection process to form chloramines. When a system utilizes chloramines, the chlorine to ammonia ratio and the sequence of addition are critical.

B. Ozone application (O2)

Ozone is an oxidant produced from air at a water treatment plant. After the ozone has been produced, it is injected into the water through a diffuser of some type. Ozone may also aid flocculation and taste and odor problems.

Ozone has some cost and maintenance factors and some operational issues that a system must address if it is going to be utilized.

O2 may add up to two logs of removal credit in the proposed Long Term 2 Enhanced Surface Water Treatment Rule, dependent upon dose and source water characteristics.

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C. Ultraviolet light application (UV)

UV is more commonly used in wastewater treatment than in water treatment. The use of UV in wastewater treatment has proven that, if properly designed and operated, it will do a good job in disinfecting water. UV appears to be an emerging force in water treatment. As new rules and issues arise, systems are viewing it as a means of conquering these challenges. A couple of issues with UV are that the process does not produce a residual component that is carried into the distribution system, and the light bulbs must be in close proximity to the water for the process to be effective.

Bulb life, cleaning of the bulb/lens, and replacement costs are key issues with the use of UV.

UV adds up to 2.5 logs of removal credit in the proposed Long Term 2 Enhanced Surface Water Treatment Rule, dependent upon dose and source water characteristics.

D. Mixed oxidants

One corporation has a process similar to on-site generation of chlorine gas or bleach. The process has some differences in that, according to the manufacturer, it generates a mixed-oxidant solution. Thus reducing trihalomethanes (THM) and halo acetic acids (HAA5) formation as well as producing other added benefits to the process.

SUMMARY TABLE

DISINFECTANT	ADVANTAGES	DISADVANTAGES
Chlorine	Traditional disinfectant Provides a residual Relatively low cost	THMs and HAA5 formation Toxic corrosive gas Safety concerns
Sodium hypochlorite	Same chemical process as chlorine Ease of maintenance and use Perceived less of a safety concern Liquid Provides a residual	Higher cost than chlorine Limited shelf life THMs and HAA5 formation
Calcium hypochlorite	Same chemical process as chlorine Ease of maintenance and use Perceived less of a safety concern Dry powder or tablet Provides a residual	Higher cost than chlorine Limited shelf life THMs and HAA5 formation

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SUMMARY TABLE *(continued from previous page)*

DISINFECTANT	ADVANTAGES	DISADVANTAGES
Chlorine dioxide	Reduces THM and HAA5 formation Produced on site Provides a residual	Cost of equipment/operation Potential taste and odor Reactive unstable gas
Chloramines	Reduces THM and HAA5 formation Produced on site Provides a residual	Cost of equipment/operation Must feed two chemicals Potential taste and odor
Ozone	No THM and HAA5 formation Produced on site May help treatment process No taste and odor problem	Cost of equipment/operation No residual disinfectant Short life span Corrosive gas
Ultraviolet light	No THM and HAA5 formation No chemical addition No taste and odor problem	Cost of equipment/operation No residual disinfectant Maintenance of bulbs Location of bulbs
Mixed oxidant	Reduces THM and HAA5 formation Produced on site Provides a residual	Cost of equipment/operation Newer disinfection process

Water utilities have options on which the disinfectant process is used in their system. The decision on which method would best fit the needs of the system must be based upon source water quality data, process performance criteria, treatment process information, and regulatory issues. The capital and O&M expenses of each method should also be evaluated as part of the decision-making process. Written plans and specifications of a new disinfection process must be submitted to TDEC-Water Supply for approval prior to installation.

References

1. Rules of Tennessee Department of Environment and Conservation, Bureau of Environment. Division of Water Supply; 1200-5-1. Public Water Systems.
2. “Water Treatment,” Second Edition, American Water Works Association.
3. “Water Treatment Plant Operation,” Volume 1, California State University, Sacramento School of Engineering.
4. MIOX Corporation, Web site.

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