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Technical Bulletins: Disinfection Options for Potable Water Systems

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TECHNICAL bulletin

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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 water sources. In the treatment plant the coagulation, flocculation, sedimentation, and filtration processes provide physical and chemical barriers. Disinfection methods are used to deactivate pathogens at the plant and to provide some level of protection in the distribution system.

The rules of Tennessee Department of Environment and Conservation, Bureau of Environment; Division of Water Supply, include chapter 1200-5-1, which 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 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 treatment methods:

- Chemical disinfectant;
- Ozone application;
- Ultraviolet light application; and
- Mixed oxidants.

A. CHEMICAL DISINFECTION

Different chemicals can be used to disinfect potable water. They 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 public water systems 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.

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 Cl_2)
Chloramines	4.0 (as Cl_2)
Chlorine dioxide	0.8 (as ClO_2)

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 in which there is dissolved organic material, two groups of potential carcinogens can form: trihalomethanes (THM) and halo acetic acids (HAA5). Water systems have modified how they treat water to reduce the potential of forming these two groups of carcinogens.

Chlorine can be used in the water treatment/ distribution area as either a gas, a liquid, or a solid. Each form has unique characteristics. **Safety** must be a primary consideration when using chlorine. Users should follow the equipment manufacturer's instructions and must also 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 in the water. In general terms, chlorine works better around a pH of 7. As the pH increases the effectiveness is reduced. Chlorine works better in warmer water than in cold, but it dissipates faster in warmer water.

The length of time that water is in contact with the disinfectant is the key to proper disinfection. To address this issue, TDEC has provided Section 1200-5-1-.31 in the rules for public water systems. This section provides an in-depth discussion of disinfection and CT values applicable to different sources. CT is defined in section 1200-5-1-.04 (20).

> "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).
> "CT 99.9" is the CT value required for 99.9 percent (3-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.

$$\frac{\text{CT calc}}{\text{CT 99.9}}$$

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

$$\Sigma \quad \frac{(CT\ calc)}{(CT\ 99.9)}$$

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 3-log inactivation of *Giardia lamblia* cyst. Disinfectant concentrations must be determined by tracer studies or an equivalent demonstration approved by the department.

Gaseous chorine (CL_2) is produced from pressurized liquid chlorine, which is ~ 99.5 percent pure chlorine. The gas is greenish-yellow in color, is 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 also will 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.

Sodium hypochlorite (NaOCl) is a liquid sometimes called "bleach" by water staff. It is available in various strengths with the norm used 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 equipment maintenance.

NaOCl is a corrosive liquid that 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.

On-site generation of sodium hypochlorite (NaOCl) is another option for public water systems. The on-site generator combines NaCl (salt) and water to produce a brine solution, which is then electrolyzed to produce a weak sodium hypochlorite solution and hydrogen gas. The hydrogen gas is vented, and the product is ready to be used to disinfect the water.

Calcium hypochlorite ($Ca(OCl)_2$) is a solid chemical that has 65 percent available chlorine. It is sometimes referred to as "HTH" by those in the water industry. It is usually used in the treatment process by extremely small systems and to disinfect pipes and tanks by larger systems.

$Ca(OCl)_2$ has the same problems as NaOCl concerning use and application.

Chlorine dioxide (ClO_2) is produced at water plants. 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 ClO_2.

ClO_2 may add up to one log of removal credit in the proposed Long Term 2 Enhanced Surface Water Treatment Rule depending on dose and source water characteristics.

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

B. OZONE APPLICATION (O_2)

Ozone is an oxidant produced from air at water treatment plants. 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, along with some operational issues, that a system must address if it is going to be used.

O_2 may add up to two logs of removal credit in the proposed Long Term 2 Enhanced Surface Water Treatment Rule depending on dose and source water characteristics.

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 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 depending on 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 formation of trihalomethanes (THM) and halo acetic acids (HAA5) as well as producing other added benefits to the process.

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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 as safer Liquid Provides a residual	Higher cost than chlorine Limited shelf life THMs and HAA5 formation
On-site generation of sodium hypochlorite	Ease of use of product produced Same chemical process as chlorine Lower pH than purchased sodium hypochlorite	Cost of equipment/operation THMs and HAA5 formation Brine byproduct produced Hydrogen gas produced
Calcium hypochlorite	Same chemical process as chlorine Ease of maintenance and use Perceived as safer Dry powder or tablet Provides a residual	Higher cost than chlorine Limited shelf life THMs and HAA5 formation
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 or odor problems	Cost of equipment/operation No residual disinfectant Short life span Corrosive gas
Ultraviolet light	No THM and HAA5 formation No chemical addition No taste or 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

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Water utilities have options of which disinfectant process to use in their systems. The choice of 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 operation and maintenance 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.
5. "A Safe Option for Disinfection; Sodium hypochlorite Generation," white paper from Clor Tec Web site.
6. Chlor Tec product information from Chlor Tec Web site.

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