DISINFECTION
For Potable Water Treatment

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Definition

Disinfection for **Potable** Water Treatment

**What is Potable?**

Fit to drink or consume
Why Disinfect?
Many incorrect reasons...
Why Disinfect?

If we were playing Health Department Jeopardy...

Alex says the correct answer is...

To ensure that potable water is safe from microbial pathogens.

Alex the Question is...

Why Disinfect Water?
1,768 waterborne outbreaks
472,228 cases of illness
1,091 deaths

The above numbers do not include the Milwaukee, WI outbreak of Crypto in 1993 which resulted in 400,000 cases of illness and 100 deaths.
Most Common Pathogens

Bacteria
Virus
Protozoa
Most Common Pathogens

**Bacteria**

E coli
H pylori
A hydrophilia
Cholera
Most Common Pathogens

**Virus**

- Coxackie
- Adeno
- Norwalk
- Hepatitis E
- Hepatitis A
Most Common Pathogens

Protozoa

Cryptosporidium
Cyclospora
Microsporidia
Toxoplasma
Acanthamoeba
Giardia lamblia
40 CFR 141.72 contains language stating for **surface water sources** “…disinfection treatment must be provided to ensure at least 99.9% (3-log) inactivation of *Giardia lamblia* cysts and 99.99% (4-log) inactivation of viruses…”

* **Giardiasis** is spread typically by infected beavers, raccoons, or other warm-blooded animals that enter the water supply chain.
Federal Ground Water Rule (12/1/2009)
“groundwater systems*...shall provide 4-log virus reduction.”
- Old State Reg. said 30 minutes of Cl contact time

64 CSR 3-7.6:
“at least 0.2 mg/L of total chlorine residual shall be maintained throughout the distribution system at all times”

* Note: For a groundwater public water system, disinfection is the only required form of treatment.
Significance of pH

- pH is measurement of Hydrogen ion activity
- $7 = $ neutral
- Below 7 is acid, Above 7 is base
- Generally in water disinfection works better at lower pH (than at a higher pH)
Point to Remember

mg/L = ppm

milligram per Liter = part per million
Why Disinfect?  
(Another Code Requirement)

According to the Food Code, U.S. Public Health Service, FDA, Standard 5-102-11:

“Water from a public water system shall meet 40 CFR 141 and State standards”

“Water from a non-public water system shall meet State standards”

The Food Code was implemented in WV on July 1, 2000
Back-up for a second!
What is Disinfect?

To disinfect water is to kill most microorganisms in the water, including essentially all pathogenic (disease causing) bacteria.

Therefore, Disinfection is the process designed to kill *most* microorganisms in the water.

For comparison: Sterilization is the process designed to kill *all* microorganisms.

Chlorination is disinfection, not sterilization.
Numerous ways exist to disinfect water. Some involve *physical* methods while others involve *chemical* methods.

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Where Do We Disinfect?

In typical surface water treatment plants disinfection occurs in one of two places:

Into raw water line (Pre-treatment)
Into clearwell (Post-treatment)

Most do both places unless they have a concern with disinfectant by-products and then they limit or eliminate the “Pre-feed”.
Where Do We Disinfect?

In most groundwater systems...
Water is pumped out of the ground
Chlorine is added into raw water line
Water enters a contact tank
Then enters distribution system

- Some groundwater systems have a need for treatment of secondary contaminates that generally only pose an aesthetic problem.
Has to have separate inlets and outlets

Typical bladder/pressure tank only has one combination inlet/outlet and cannot be considered a contact tank. Plus these tanks have a variable volume due to the changing pressure and the air bladder.
Factors Governing the Efficiency of Disinfection

- Type of Organism
- Type of Water
- Concentration of Microorganisms
- Ambient Temperature
- Time of Contact
- Concentration of Disinfectant
- pH
What is Chlorine?

Chlorine is a greenish-yellow gas that is 2-1/2 times heavier than air, can be in a liquid form (when under pressure), has a high coefficient of expansion (1 unit volume of liquid equals up to 145 unit volumes of gas), is non-flammable by itself but will support combustion, and has a distinct penetrating odor.
Some Chlorine Theory

- Chlorine is an element (symbol is Cl)
- Atomic number of 17 (no. of protons)
- Atomic weight of 35.453
- A valence of (-1) [loss of 1 electron]
- Two chlorine atoms want to join together to share an electron since they both are missing an electron and thus form the molecule Cl₂. Cl₂ is the form we use when we refer to chlorine.
Some Chlorine Theory

- $\text{Cl}_2$ dose = $\text{Cl}_2$ demand + $\text{Cl}_2$ residual

- Total $\text{Cl}_2$ residual = Combined + Free $\text{Cl}_2$ residuals

- Combined $\text{Cl}_2$ residual is the residual in chemical combination with ammonia or nitrogen compounds

- Breakpoint chlorination is the point where free chlorine residual is directly proportional to chlorine dose
3 Common Forms of Chlorine Used...

Chlorine gas

HTH – Calcium Hypochlorite

Bleach – Sodium Hypochlorite

- Typically 5.25% Chlorine for normal bleach. Formulations for industrial use are common for 10% and 12%. New formulations for household bleach with terms such as “Ultra” are generally higher than 5.25% and are normally around 6%
Use of Chlorine Gas:

\[ \text{Cl}_2 + \text{H}_2\text{O} \rightleftharpoons \text{HOCl} + \text{HCl} \]

(Gas) (Water) (Hypochlorous acid) (Hydrochloric acid)

Note: The formation of HCl (Hydrochloric acid) causes the pH to lower when chlorine gas is used to disinfect.
Chlorine Disinfection

Use of HTH – Calcium Hypochlorite:

\[
\text{Ca(OCl)}_2 + 2\text{H}_2\text{O} \rightarrow 2\text{HOCl} + \text{Ca(OH)}_2
\]

\begin{align*}
\text{(HTH)} & \quad \text{(Water)} & \quad \text{(Hypochlorous acid)} & \quad \text{(Lime)} \\
\end{align*}

\text{Note: The formation of Ca(OH)}_2 \text{ (Lime) causes the pH to raise when HTH is used to disinfect.}
Use of Bleach – Sodium Hypochlorite:

$$\text{NaOCl} + \text{H}_2\text{O} \rightarrow \text{HOCl} + \text{NaOH}$$

(Bleach) (Water) (Hypochlorous acid) (Caustic Soda)

Note: The formation of NaOH (Caustic Soda) causes the pH to raise when Bleach is used to disinfect.
How do we get Chlorine?

Types of Containers

Plastic – for storage of hypochlorite solutions
  ▪ Jugs, bottles, pails, buckets, etc.

Steel Cylinders
  ▪ 100 pounds (Total weight is 173 pounds)
  ▪ 150 pounds (Total weight is 242 pounds)

Steel Ton Tanks (Total wt. up to 3700 lbs.)
Dangers of Chlorine

**Bleach**
Can remove layers of skin

**HTH**
Can produce exothermic reactions

**Gas**
Very toxic
PEL = 0.5 ppm and IDHL = 30 ppm
Can smell around 4 ppm
Detection equipment for levels below 1 ppm
Dangers of Chlorine

Chlorine Gas Leak
Smell
See cloud
Can use ammonia for small leak detection
Never spray water on a leak (forms acid)
Chlorine first aid
▪ Leave area
▪ Call for help
▪ Remove saturated clothing
▪ Avoid coughing
▪ Drink milk
▪ Flush eyes with water for extended time
▪ Give oxygen
Methods to Deliver Chlorine

**Chlorinator**
Used to supply gas
Uses a vacuum to inject into a stream of water

**Hypochlorinator**
Used to supply bleach and HTH solutions
Uses a small pump to inject dilutions

**Evaporator**
Injects pure liquid pressurized chlorine
Withdraws liquid Cl₂ and turns it into a gas by heating
Allows for faster feeds
Most dangerous
A Concern of Chlorine Use

DBP Formation

(DBP = Disinfectant By-Product)

Natural Organic Matter + Disinfectant = DBP

DBP’s formed by chlorine usage
THM’s (Trihalomethane)
HAA’s (Halo-acidic acids)
A Concern of Chlorine Use
(DPB Formation Minimization)

- Remove DBP precursors before disinfection
- Eliminate pre-disinfection
- Evaluate disinfection requirements
- Re-evaluate disinfectant choices
A Concern of Chlorine Use
(Chlorine Resistant Organisms)

- Giardia lamblia cysts
- Cryptosporidium
- Cyclospora
- Microsporidium
- Mycobacterium avium complex
- Enteroviruses
DANGER
CHLORINE GAS
AUTHORIZED PERSONNEL ONLY
Questions?