

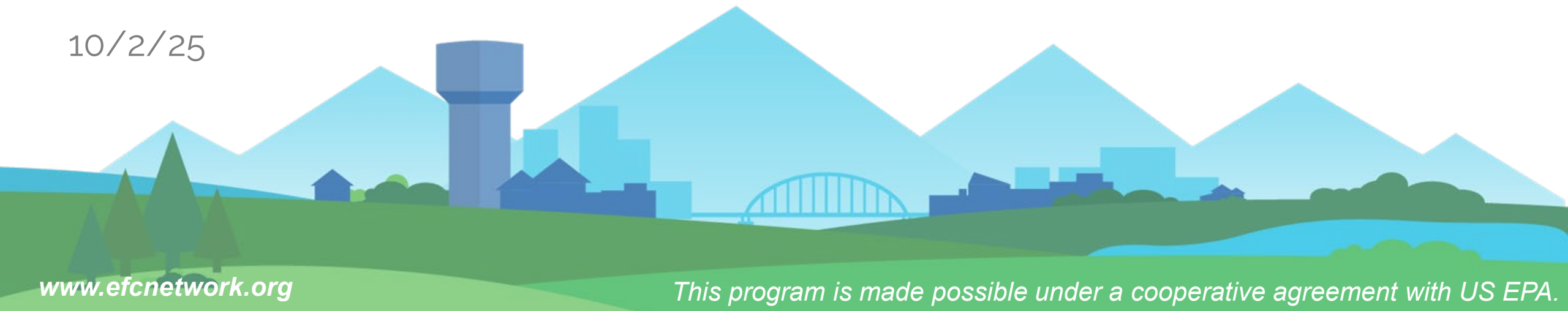


SOUTHWEST
ENVIRONMENTAL
FINANCE CENTER

US Territories Water Operator Training Series

Session 8: An Introduction to Disinfection (part 1 of 4)

10/2/25



Your trainer for today

Matt Ziegler
Program Director



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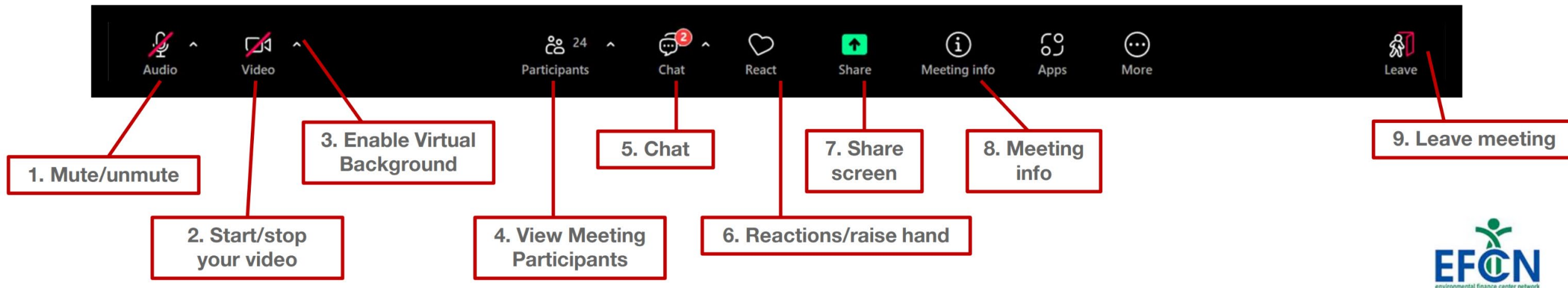
SCHOOL OF
ENGINEERING



This training series is funded by the US EPA

Attendee Meeting Controls

- Locate your control bar
- All attendees will see a black horizontal bar on their screen
- If your control bar is not visible, it may be hidden
 - Move your cursor to the screen's bottom (or top) to reveal this control bar.



Schedule for 2025:

Date	Topic
6/26/25	Program Overview, Test Format, Study & Test Tips
7/10/25	Drinking Water System Overview - (Source, Treatment, & Distribution)
7/24/25	Basic Operator Math (+, -, /, x, Exponents and basic algebra)
8/7/25	Applied Operator Math (e.g. Areas, Volume, Flow Rates, Detention Time, Pressure/Hydraulic Head)
8/21/25	Drinking Water Regulations
9/4/25	Source Water Characteristics
9/18/25	Surface Water Intake Components, Well Components, and O&M
10/2/25	Disinfection 1: Chloramines, UV, Chlorine Dioxide, Chlorine
10/16/25	Disinfection 2: Chlorine Disinfection Application for Sodium Hypochlorite and Gas Chlorine (including storage and safety)
10/30/25	Disinfection 3: Distribution System Application, Residual Measurement, Evaluation & Adjustment,
11/13/25	Disinfection 4: Chlorine Disinfection Math
12/4/25	Surface Water Treatment 1: Coagulation, Flocculation, Sedimentation (including chemistry, process controls, operations)
12/18/25	Surface Water Treatment 2: Filtration

Links to recordings and material are available on our website at <https://swefc.unm.edu/home/op-cert-trainings/>

Pacific Island Territories Operator Certification Trainings

This page is a repository of Wastewater and Drinking Water Operator Certification (Op Cert) Training Webinars offered by the SW EFC for systems in the Pacific Territories. Below you will find the **training webinar schedules (wastewater, then drinking water)** followed by a **training webinar recordings library**.

[Jump to Wastewater Trainings](#) ↓

[Jump to Drinking Water Trainings](#) ↓

Wastewater Training Schedule

Please note all times are local to CNMI and Guam. The times in American Samoa are one day earlier at 11 am.

Session	Date	Training Topic & Link to Recording (click to view)	Supporting Materials (click to download)
1	6/25/2025	Program Overview, Test Format, Study & Test Tips	PPT slides
2	7/9/2025	Treatment Overview	PPT slides
3	7/23/2025	WW Math Part 1 (Areas & Volumes)	PPT slides
4	8/6/2025	WW Math Part 2 (Flow Rates & Detention Times)	PPT slides
5	8/20/2025	Collection Systems – Gravity systems	PPT Slides

Sign in for every session to ensure you get credit for attending



**US Territories Water & Wastewater Operator Certification
Virtual Training Series Group Attendance Sheet**

Session Title: _____

Session Date: _____

Training Location: _____

Attendee Name	Attendee Signature	Arrival Time	Departure Time

I hereby certify that the individuals listed above attended the referenced training session.

Name: _____
Signature: _____
Title: _____
Date: _____

Please scan this sheet after each training session and email it to swefc@unm.edu with the subject line: "US Territories Op Cert Attendance Sheet"



An Introduction to Disinfection

What is Disinfection?

Disinfection is the **inactivation** of **pathogenic** microorganisms

Sterilization is the **destruction** of all living organisms and is NOT disinfection

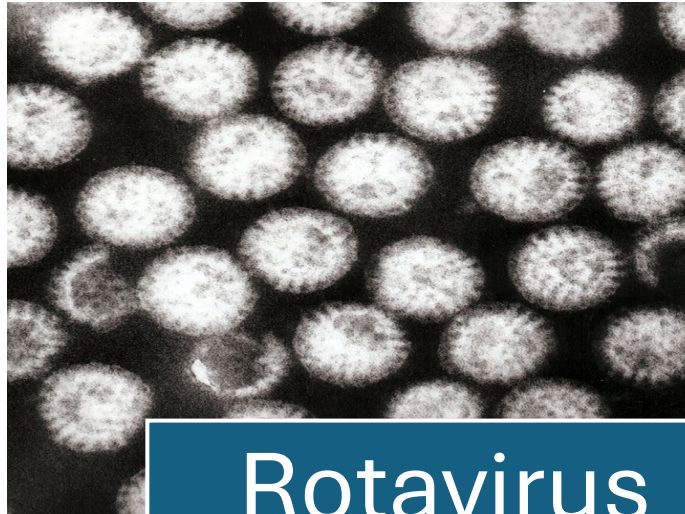
Disease Causing Viruses

Acute
Health
Effects



Hepatitis A

Fatigue, Nausea,
Abdominal Pain,
Loss of Appetite,
Low-grade Fever



Rotavirus

Gastroenteritis



Norovirus

Gastroenteritis

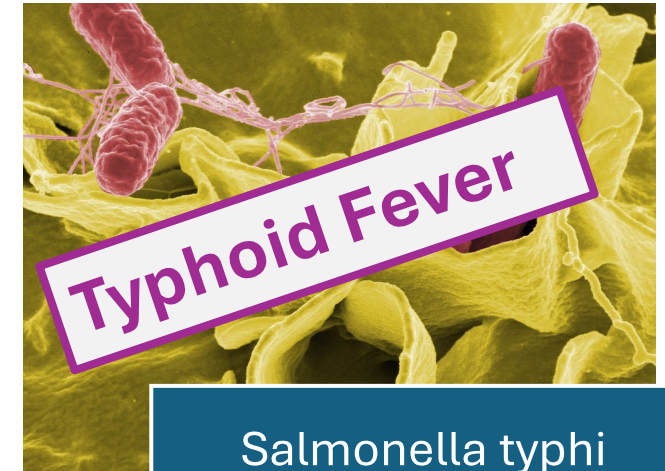
Disease Causing Bacteria



Escherichia coli



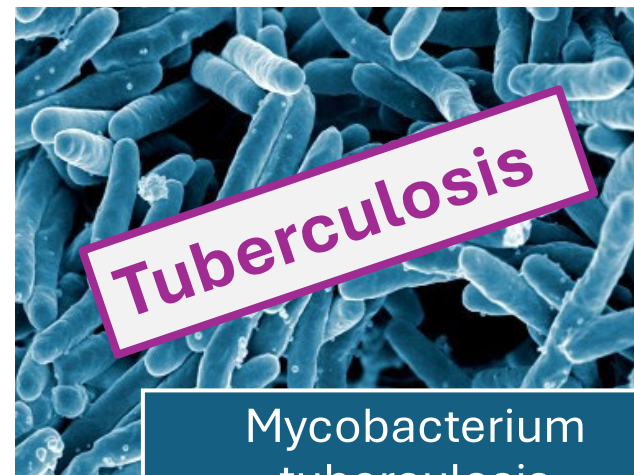
Shigella dysenteriae



Salmonella typhi



Vibrio cholerae



Mycobacterium tuberculosis



Disease Causing Protozoa

Acute
Health
Effects



Giardiasis

Giardia lamblia



Cryptosporidiosis

Cryptosporidium

How can
pathogens enter
our drinking water
systems?



Source
Contamination



Treatment
Contamination



Distribution
Contamination

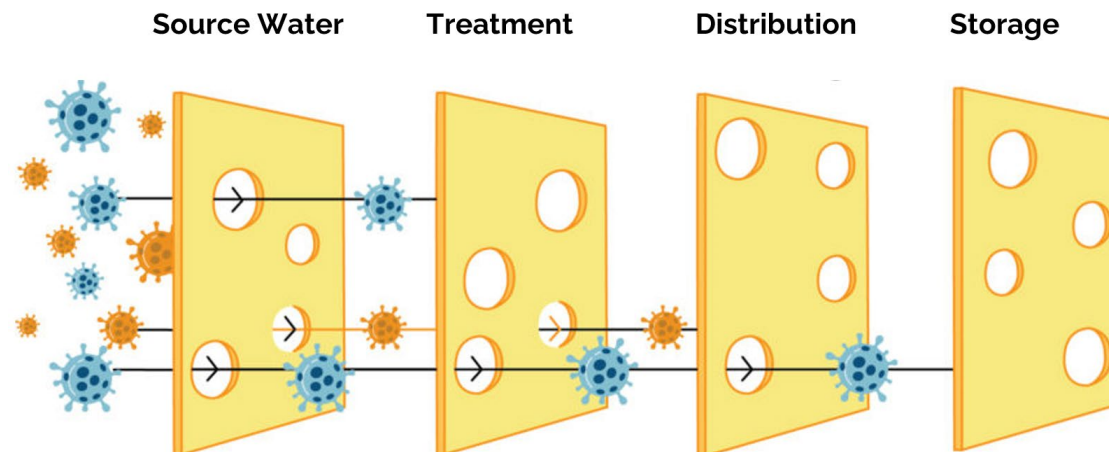


Storage
Contamination

DISINFECTION

WATER TREATMENT

The second barrier to preventing waterborne disease using the ***Multiple Barrier Approach***



Types of Disinfectants

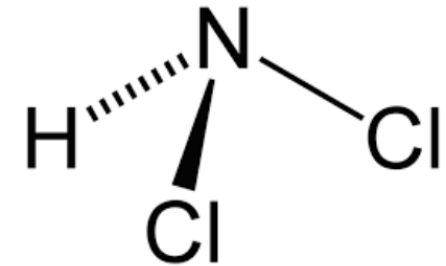


Ultraviolet Light
(UV)

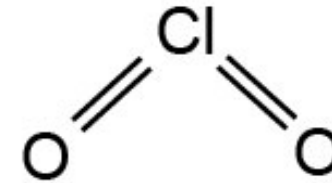
Physical



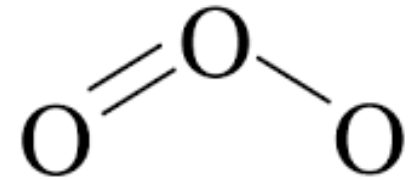
Chlorine



Chloramines



Chlorine Dioxide

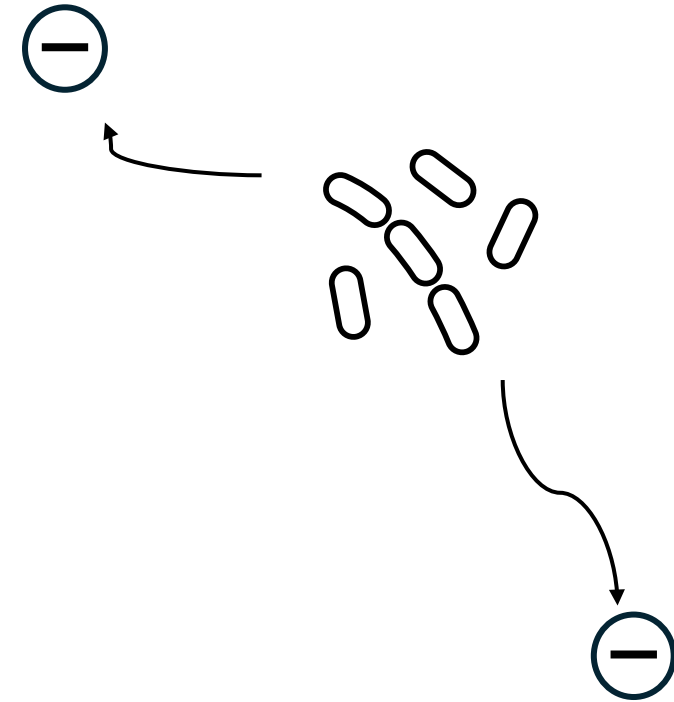
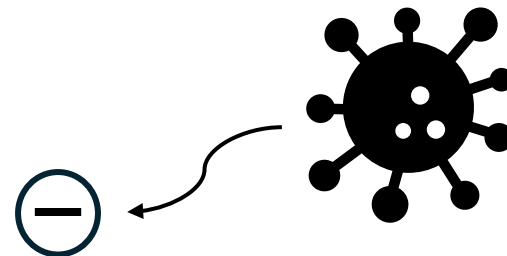
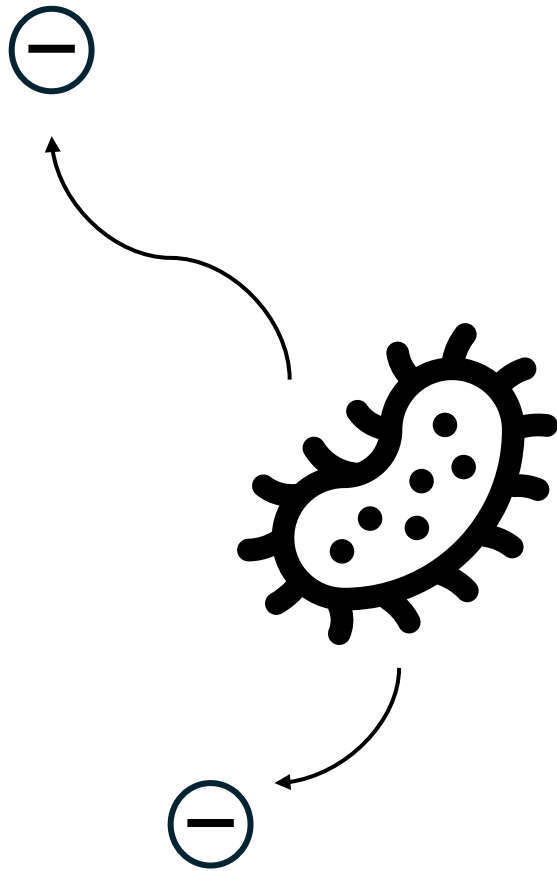


Ozone

Chemical

Chemical Disinfection Process

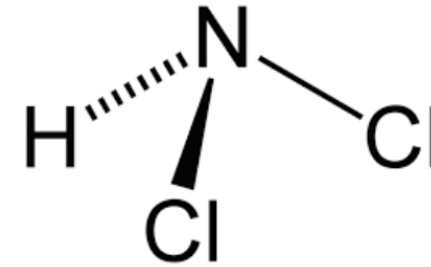
Oxidation – the oxidant steals electrons from the virus or cell's enzymes so they can no longer perform metabolic functions



Chemical

Chloramine Disinfection

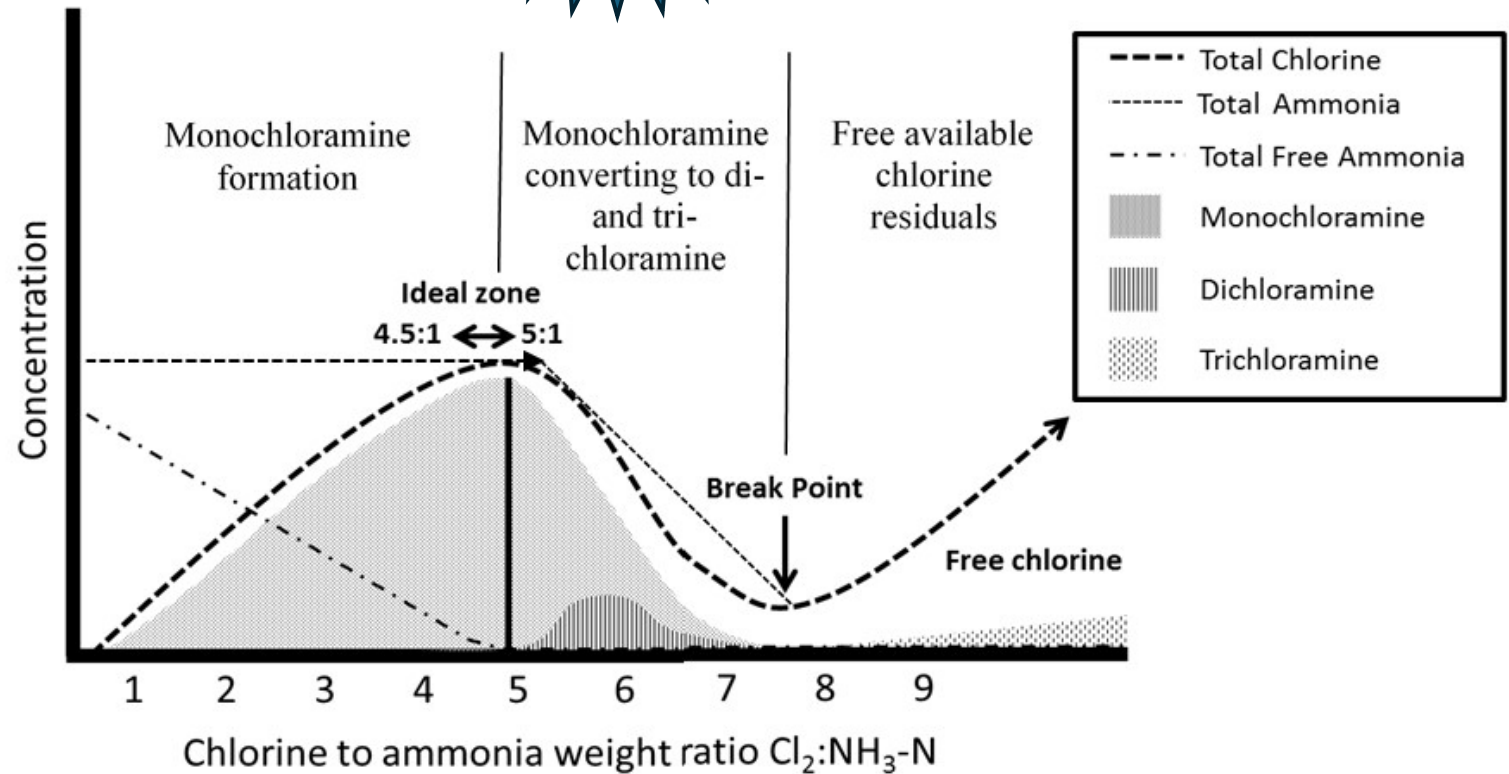
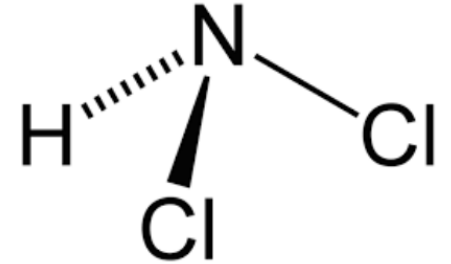
- Used as a drinking water disinfectant for >90 years
- Used by >1 in 5 larger systems in the U.S.
- Generated on-site when ammonia is added to water containing chlorine



Chloramine Disinfection Objectives

- Maximize monochloramines
- Minimize free ammonia
- Prevent excess dichloramines
- Prevent breakpoint

Measure
TOTAL
Chlorine



From Guidelines for Canadian Drinking Water Quality
Technical Document Chloramines

Chloramine Disinfection

Advantages

- Used as a secondary disinfectant with a long-lived combined chlorine residual that produces fewer halogenated disinfection byproducts

Disadvantages

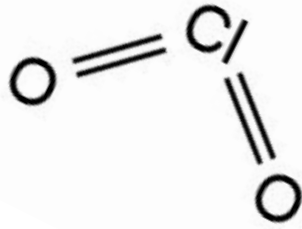
- Less effective as a primary disinfectant than chlorine
- Can change water chemistry and impact lead & copper pipes – follow EPA guidance
- Taste & odor issues

Chloramine Disinfection

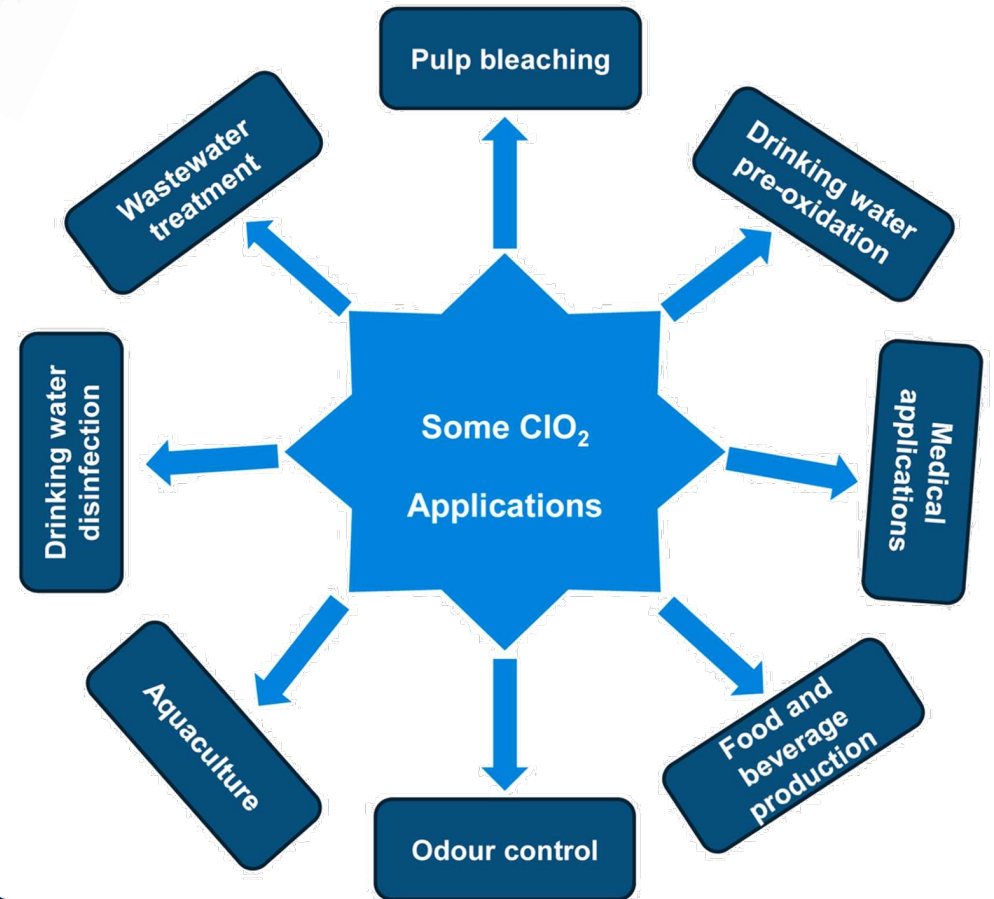
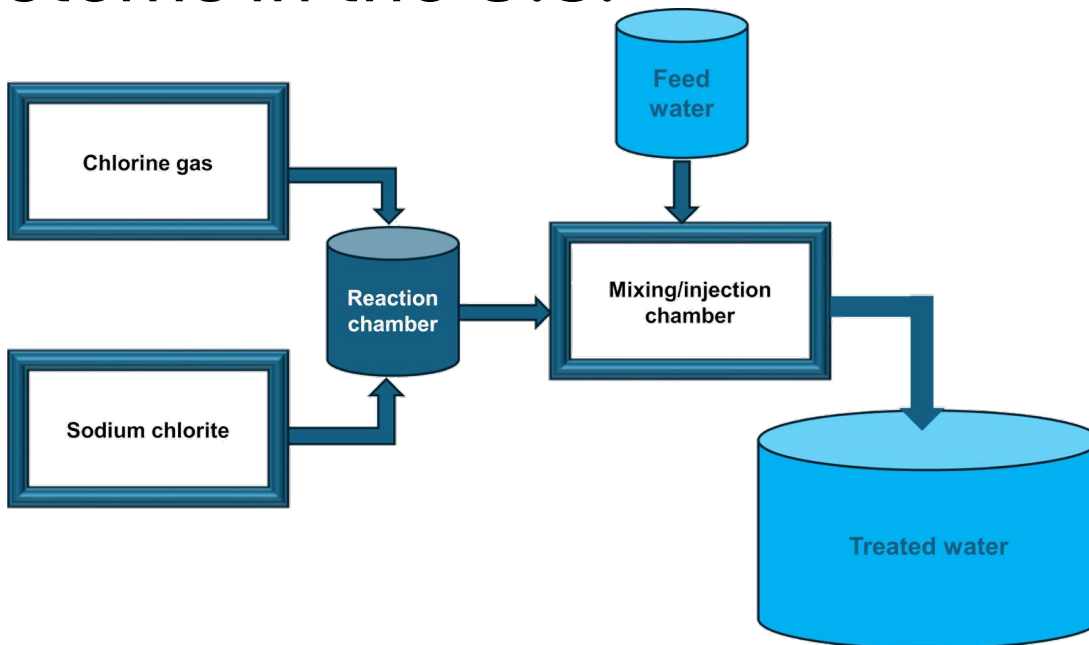
SDWA Regulations

- Maximum Residual Disinfectant Level (MRDL) = 4.0 mg/L
- Subject to the Stage 1 & 2 Disinfectant and Disinfection By Products Rules (D/DBPR)
 - Monitor for Total Trihalomethanes (MCL = 80 ug/L)
 - Monitor for Haloacetic Acids (MCL = 60 ug/L)

Chlorine Dioxide



- Yellow to reddish-yellow gas
- On-site generation
- Used by ~5% of large water systems in the U.S.



Chlorine Dioxide Disinfection

Advantages

- Very effective disinfectant against viruses, bacteria, and cysts
- Improves taste, odor, & color caused by chlorophenols and algae
- Removes Fe & Mn
- pH neutral
- Less likely to form DBPs

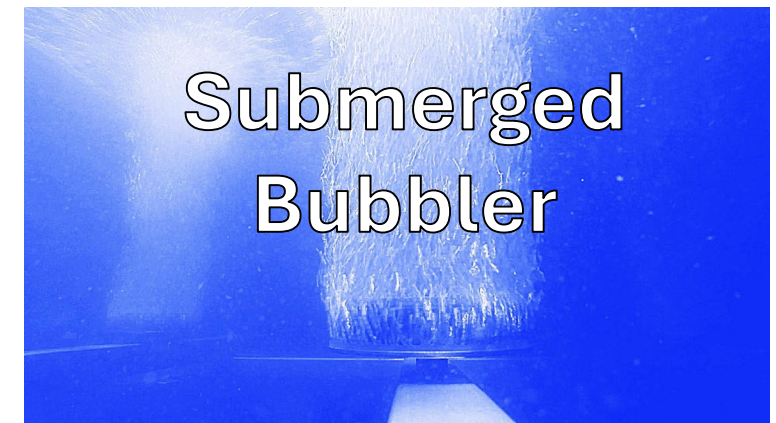
Disadvantages

- Storage and handling hazards of chemical precursors
- More volatile than liquid chlorine
- Chlorite byproduct (daily monitoring)
- Higher initial costs

Chemical

Ozonation

- Effective disinfectant for relatively clean source waters
- Onsite generation with UV and compressed air
- Can damage lungs due to oxidizing effect on tissue
 - PPE = canister (carbon) respirator at low concentrations (0.3-10 ppm)



Ozone Disinfection

Advantages

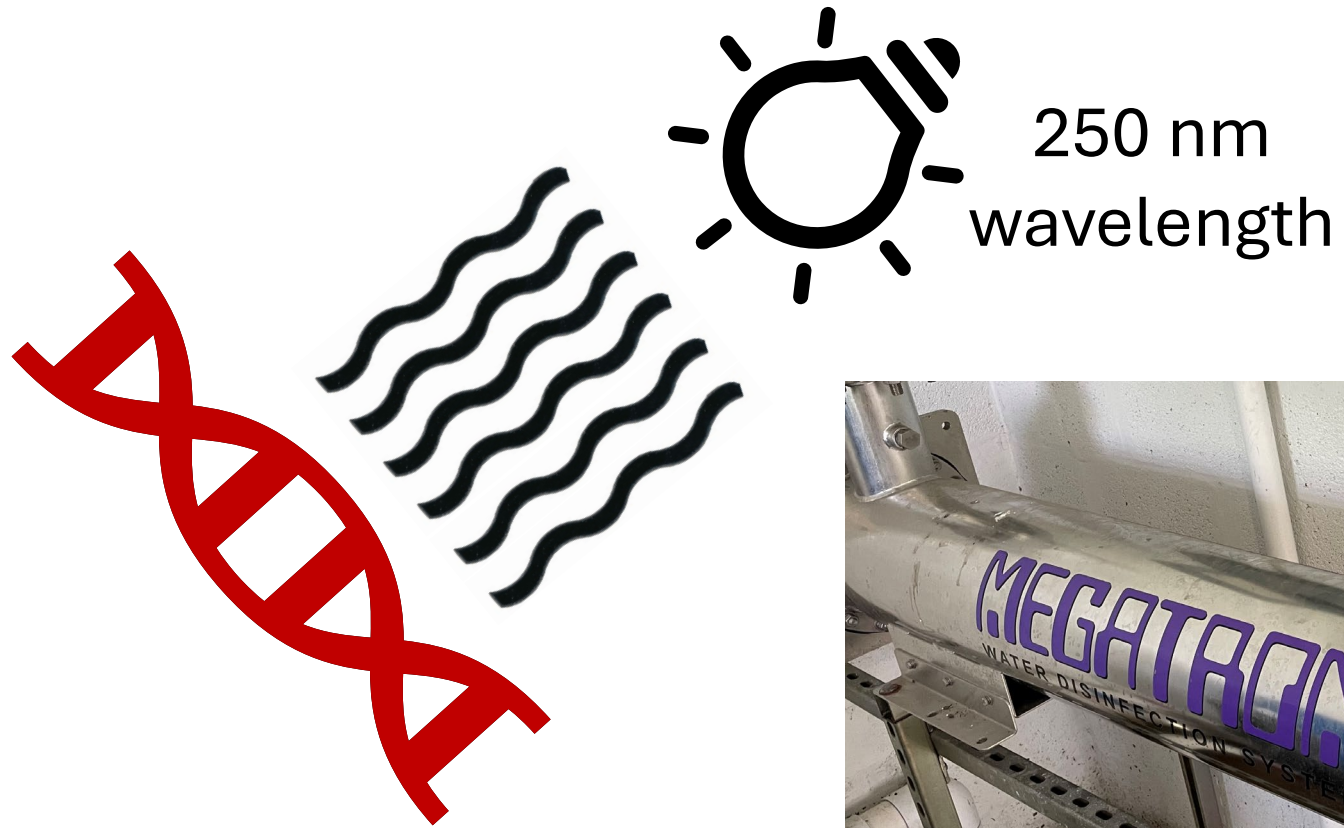
- Rapid and effective against Crypto oocysts, E.coli and other pathogens
- Removes precursors of organic DBPs

Disadvantages

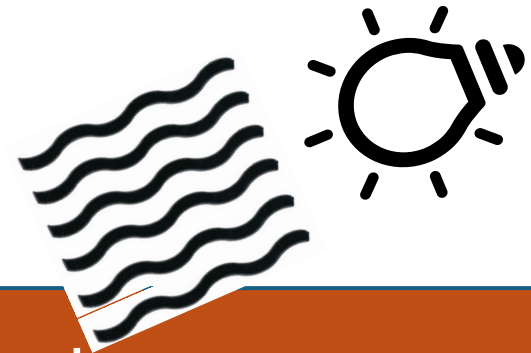
- Quick decomposition
- No residual
- Bromate byproduct (monthly monitoring)

Physical

Ultraviolet Light



UV Disinfection



Advantages

- Effective against Crypto and Giardia
- Short contact time
- No chemical handling
- No halogenated DBP formation
- User friendly with minimal maintenance

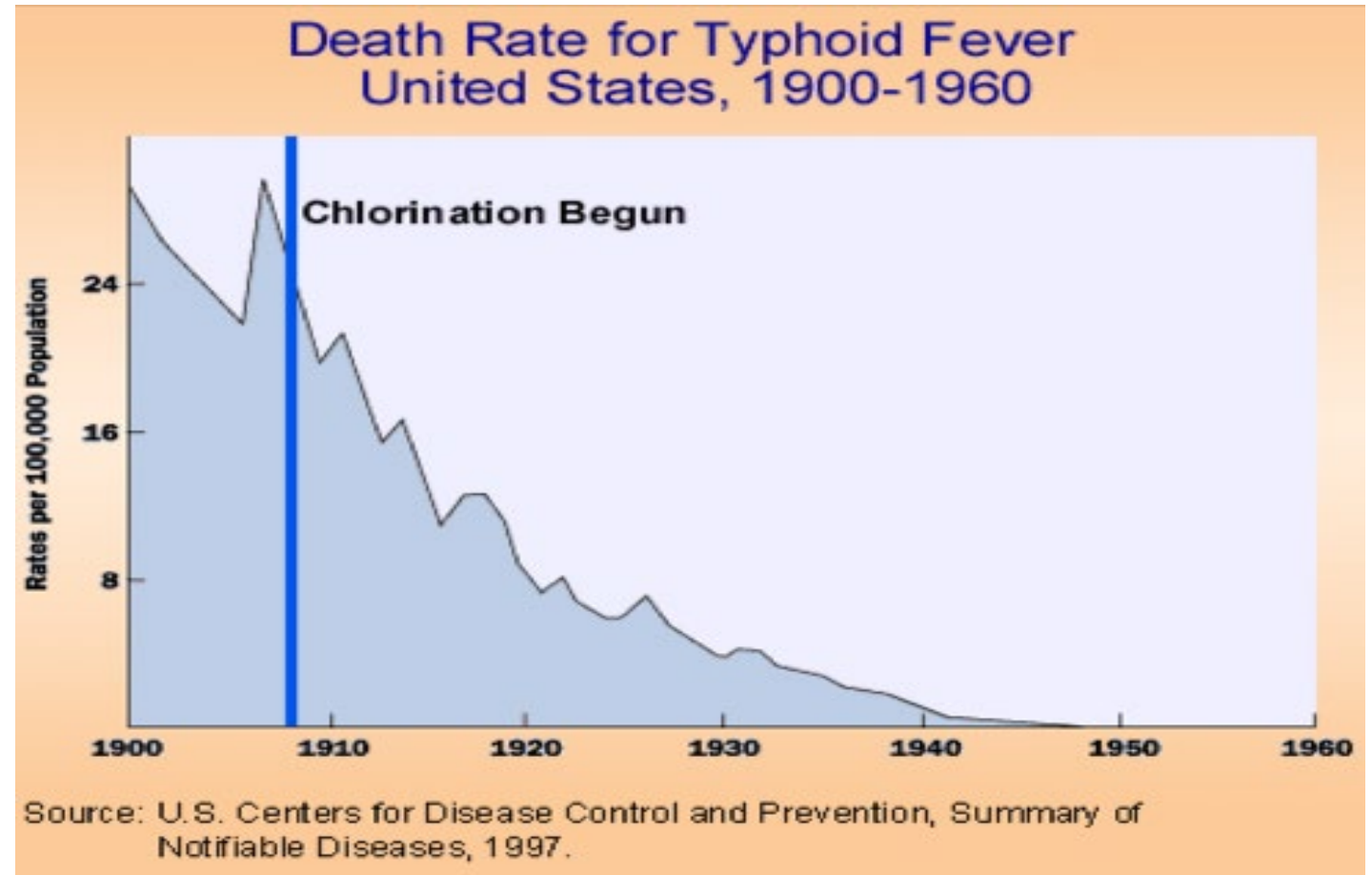
Disadvantages

- Source water needs to be clean
- Ineffective against some bacteria (adenovirus) and bacterial spores
- Organisms may undergo self-repair
- No residual in distribution

**Most Common
Disinfectant in
the U.S.**

**Chlorine
Disinfection**

Chemical



Types of Chlorine

1% = 10,000 mg/L Cl_2



Chlorine (Cl_2)

- Gas
- 100% chlorine
- Compresses to a liquid



Calcium Hypochlorite
(CaOCl)

- Solid
- 1-3% mixed by operator
- ~1-year shelf life
- Handling hazards



Sodium Hypochlorite
(NaOCl)

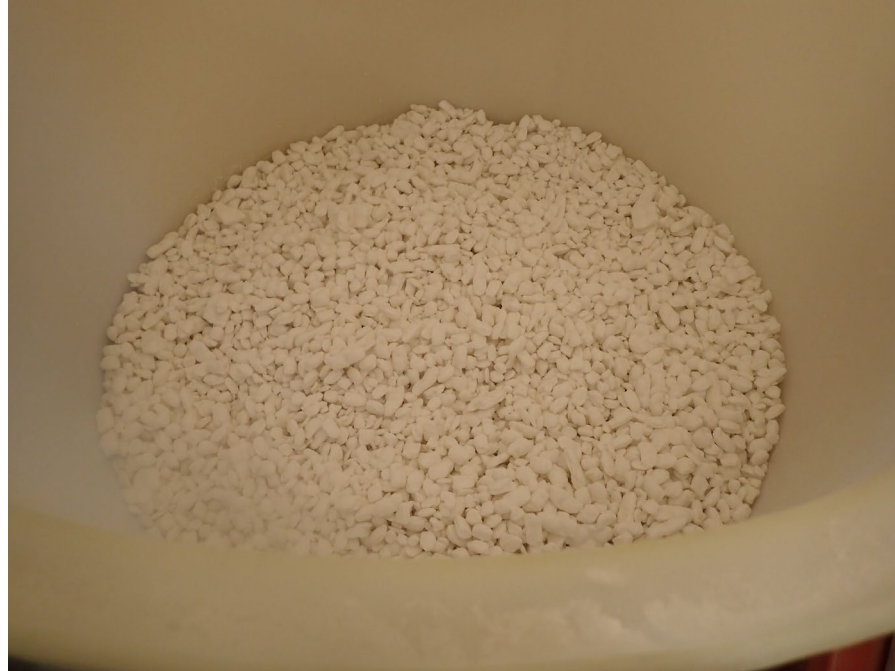
- Liquid
- 10-12.5% (30-50 gallon drums)
- Bleach = 4.75-8.25%
- ~1 month shelf life

On-site Generation of Sodium Hypochlorite

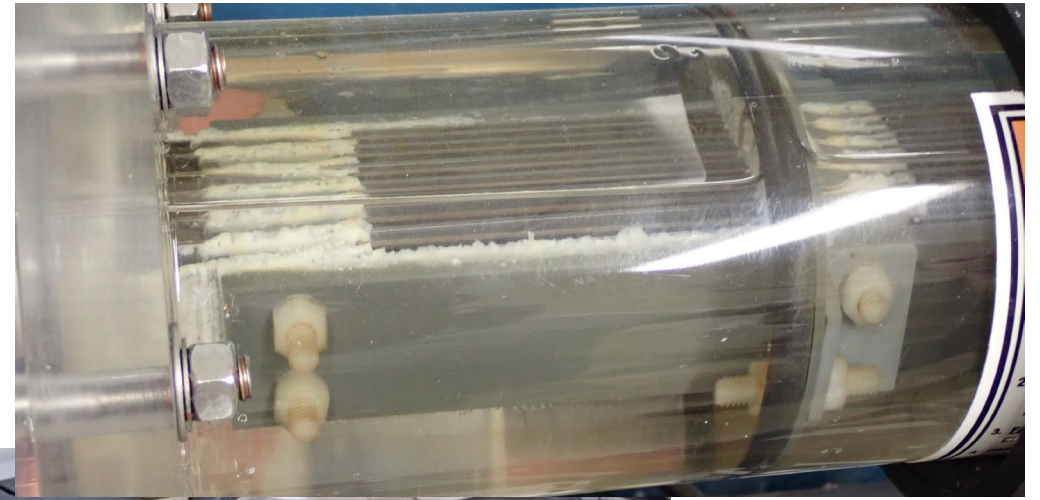
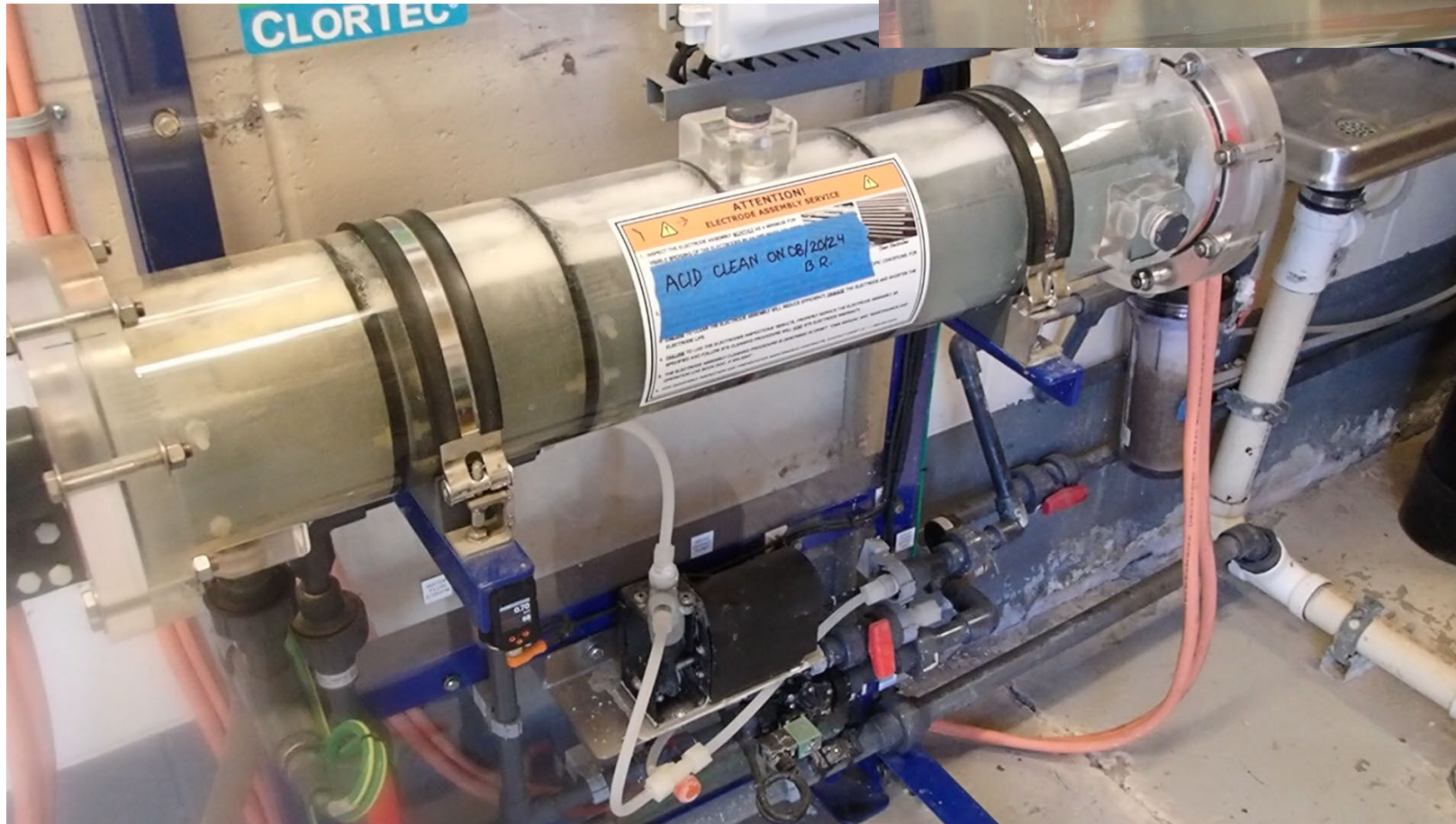
- $\text{NaCl} + \text{H}_2\text{O} + \text{energy} = \text{NaOCl} + \text{H}_2$
- Creates low concentration NaOCl (0.4-0.8 ppm)



On-site Generation of Sodium Hypochlorite



On-site Generation of Sodium Hypochlorite



Chlorine Disinfection

Advantages

- High germicidal power
- Highly soluble in water
- Cost less than other methods & readily available
- Measure residual to evaluate effectiveness
- Strong residual protection in distribution

Disadvantages

- Used up quickly
- Formation of disinfection byproducts (DBPs)
- Increases corrosiveness
- Risk of accidental release

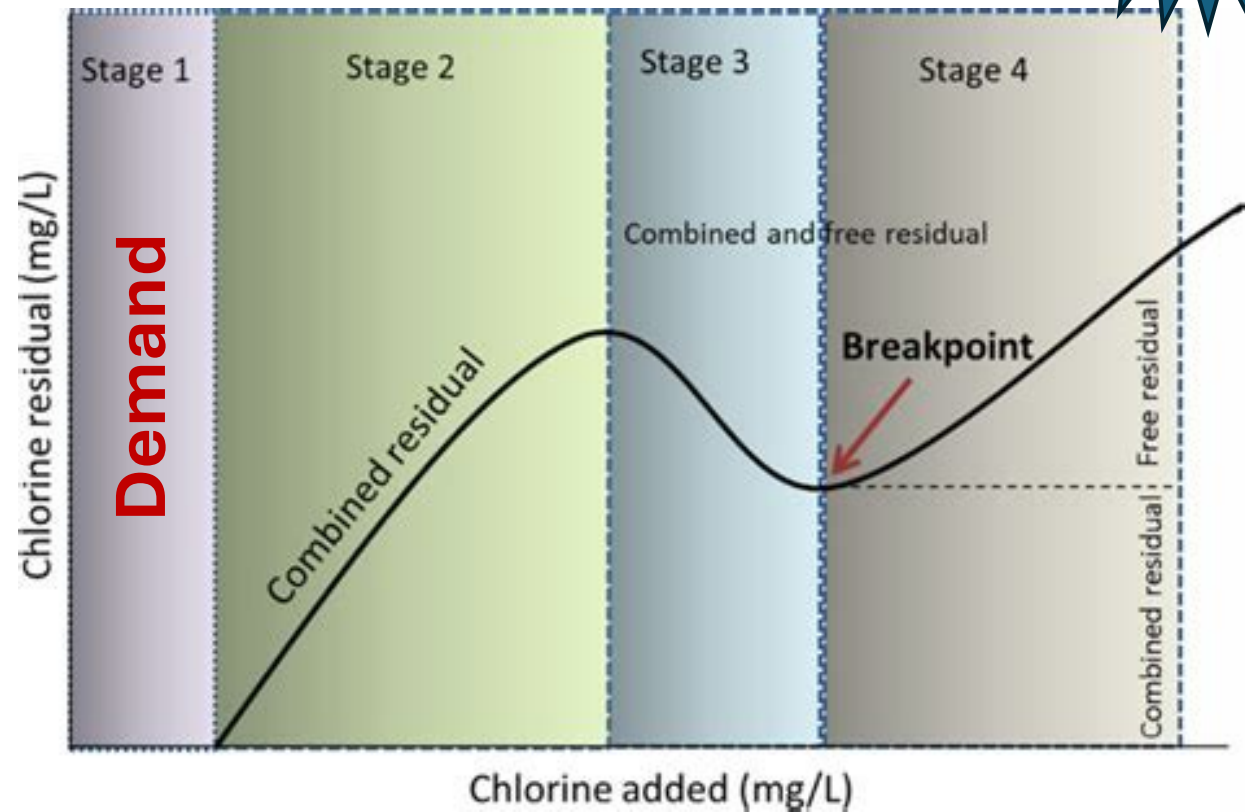
Chlorine Disinfection SDWA Regulations

**Same As
Chloramines**

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 - Monitor for Total Trihalomethanes (MCL = 80 ug/L)
 - Monitor for Haloacetic Acids (MCL = 60 ug/L)

Chlorine Disinfection Objectives

- Reach breakpoint
- Minimize chloramines and combined chlorine



From Nature.com

Oooh... That Smell!

Chloramine odor (Often confused w/ strong “chlorine” odor)



Pungent to acrid smell

Slight **chlorine** odor



Clean, fresh smell

It's the difference that causes burning eyes and skin rashes after using a pool or hot tub

How Chlorine Disinfection Works



Chlorine & Water

First Reaction



Cl_2 = Chlorine

H_2O = Water

HOCl = Hypochlorous Acid

HCl = Hydrochloric Acid

Chlorine & Water

Second Reaction



HOCl = Hypochlorous Acid

H⁺ = hydrogen ion

OCl⁻ = hypochlorite ion

HOCl is more effective as a disinfectant than OCl⁻ (100-300 times greater)

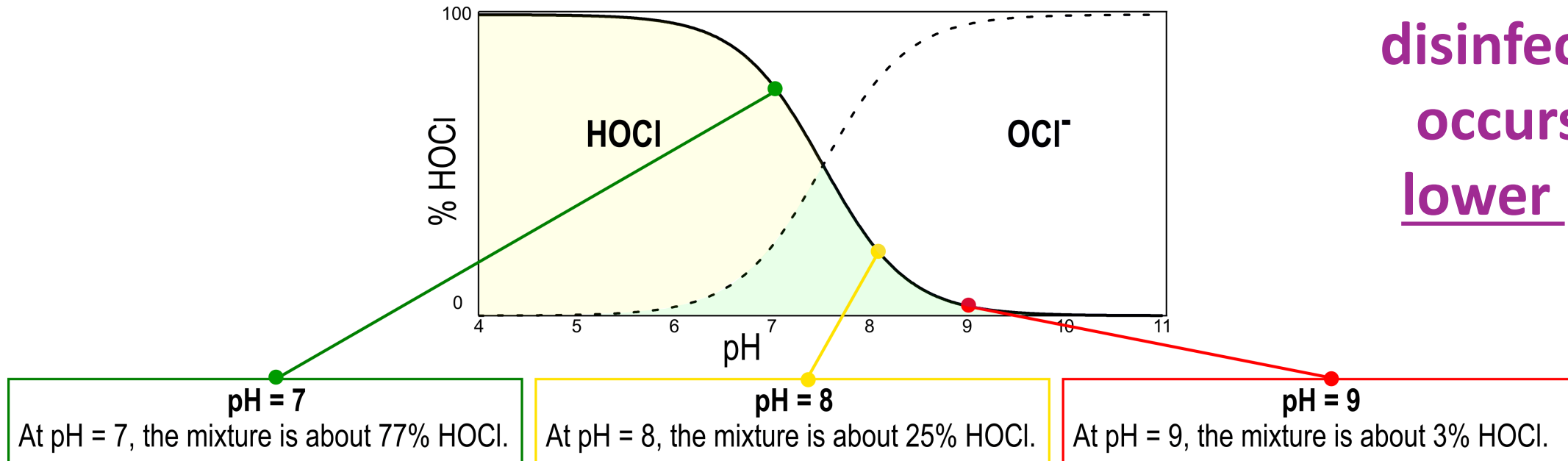
Factors that Affect Chlorine Disinfection



Factors That Affect Chlorine Disinfection

pH

Better
disinfection
occurs at
lower pHs



Factors That Affect Chlorine Disinfection

Water Temperature

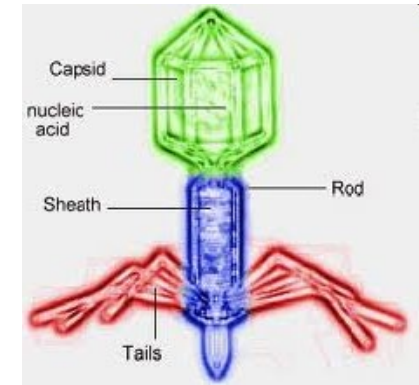
- The **colder** the water, the **longer** the contact time
- The **warmer** the water, the **shorter** the contact time
- The **warmer** the water and the surrounding environment, the **more** chlorine dissipates into the atmosphere



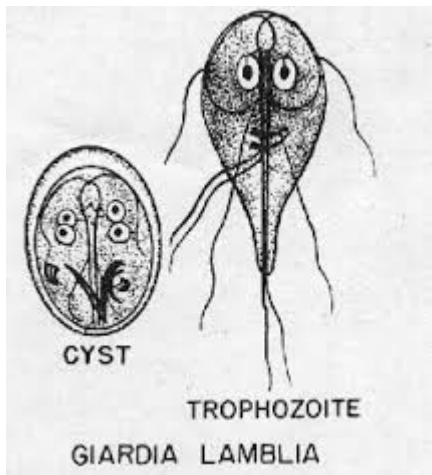
Factors That Affect Chlorine Disinfection

Type of Organism

- **Viruses** are much harder to kill than **bacteria** and require higher chlorine dosages
- Some **protozoans** are extremely resistant to chlorine and may not be affected at all
 - Cryptosporidium
 - Giardia



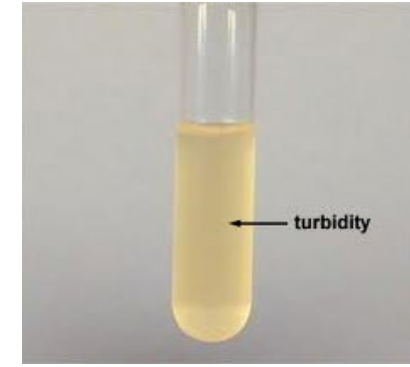
That's why surface water systems and GWUDI systems must also provide filtration in addition to disinfection



Factors That Affect Chlorine Disinfection

Interfering Agents

- Organic Materials
- Minerals
- Turbidity

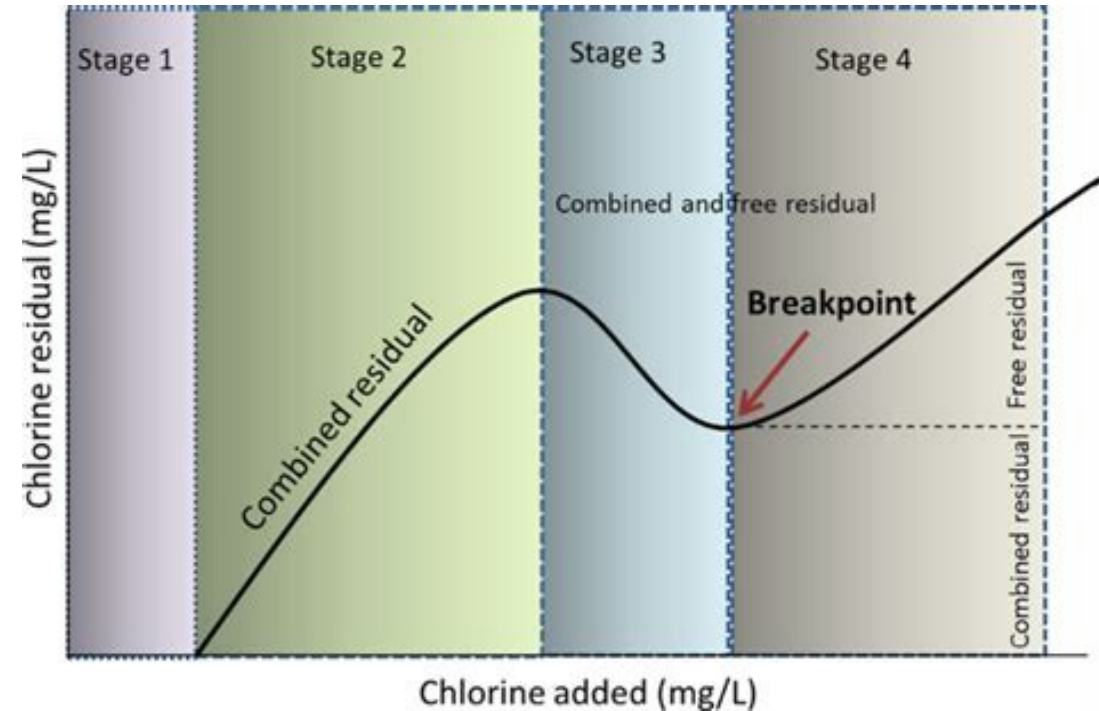


**Interfering agents
increase the chlorine
demand in the
distribution system**

Factors That Affect Chlorine Disinfection

Type of Residual

- **Nitrogen** compounds present in the water combine with **HOCl** and form chloramines
 - Inorganic ammonia
 - Organic proteins and amino acids
- Chloramines are **Combined Residual Chlorine**



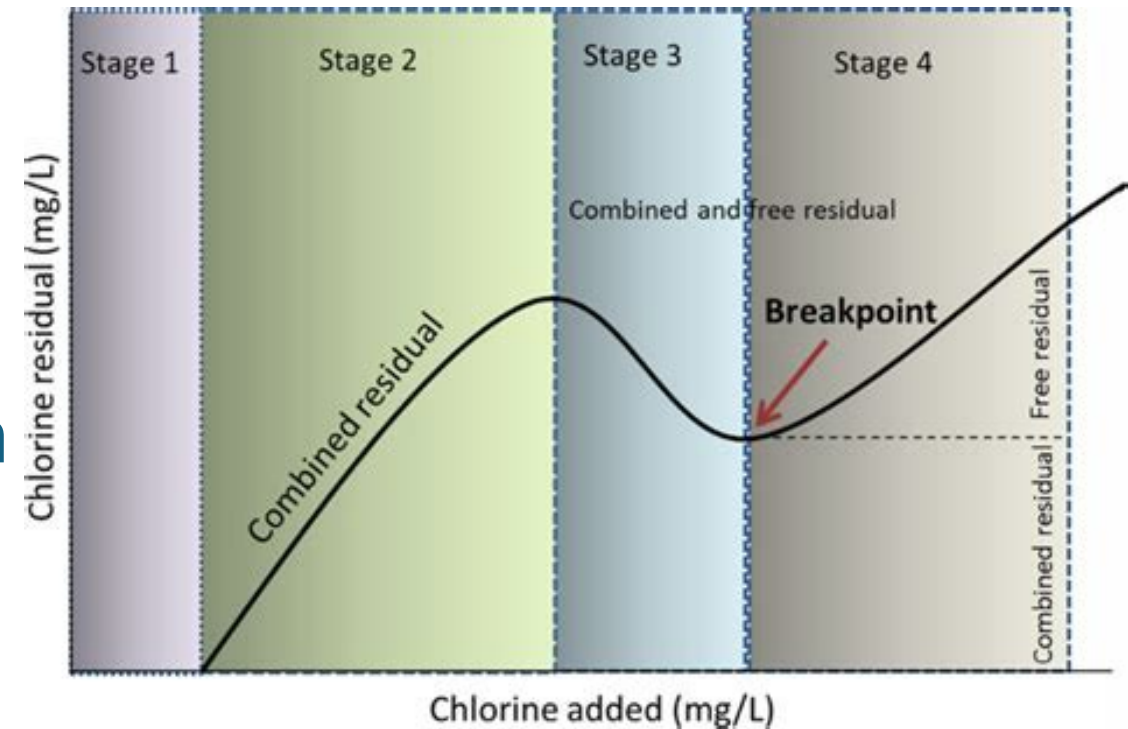
Combined chlorine is available for disinfection

Factors That Affect Chlorine Disinfection

Type of Residual

The amount of **hypochlorous acid (HOCl)** or **hypochlorite ion (OCl⁻)** that has not combined with nitrogen compounds and is still available is measured as:

Free Residual Chlorine



**Free chlorine
is available for
disinfection**

Factors That Affect Chlorine Disinfection

Type of Residual

**FREE RESIDUAL
CHLORINE**

**IS THE BEST
DISINFECTANT**

- Required minimum of 0.2 mg/L everywhere in the distribution system if surface water
- Recommend 0.2 mg/L everywhere if ground water
- Higher at the EP
- This level will vary with different systems

Chlorine Disinfection Terminology Review

Chlorine Dosage

- The total amount of chlorine fed into a volume of water (expressed as mg/L)
- Most operators record pounds or gallons per day. This is the **FEED RATE**, not the dosage.

$$\text{DOSAGE} = \text{DEMAND} + \text{RESIDUAL}$$

Chlorine Demand

- The difference between the amount of chlorine fed (dosage) and the residual chlorine remaining
- The amount of chlorine consumed or bound up by material in the water (expressed as mg/L)
- This chlorine is **NOT** available for residual (free or total)

$$\text{DEMAND} = \text{DOSAGE} - \text{RESIDUAL}$$

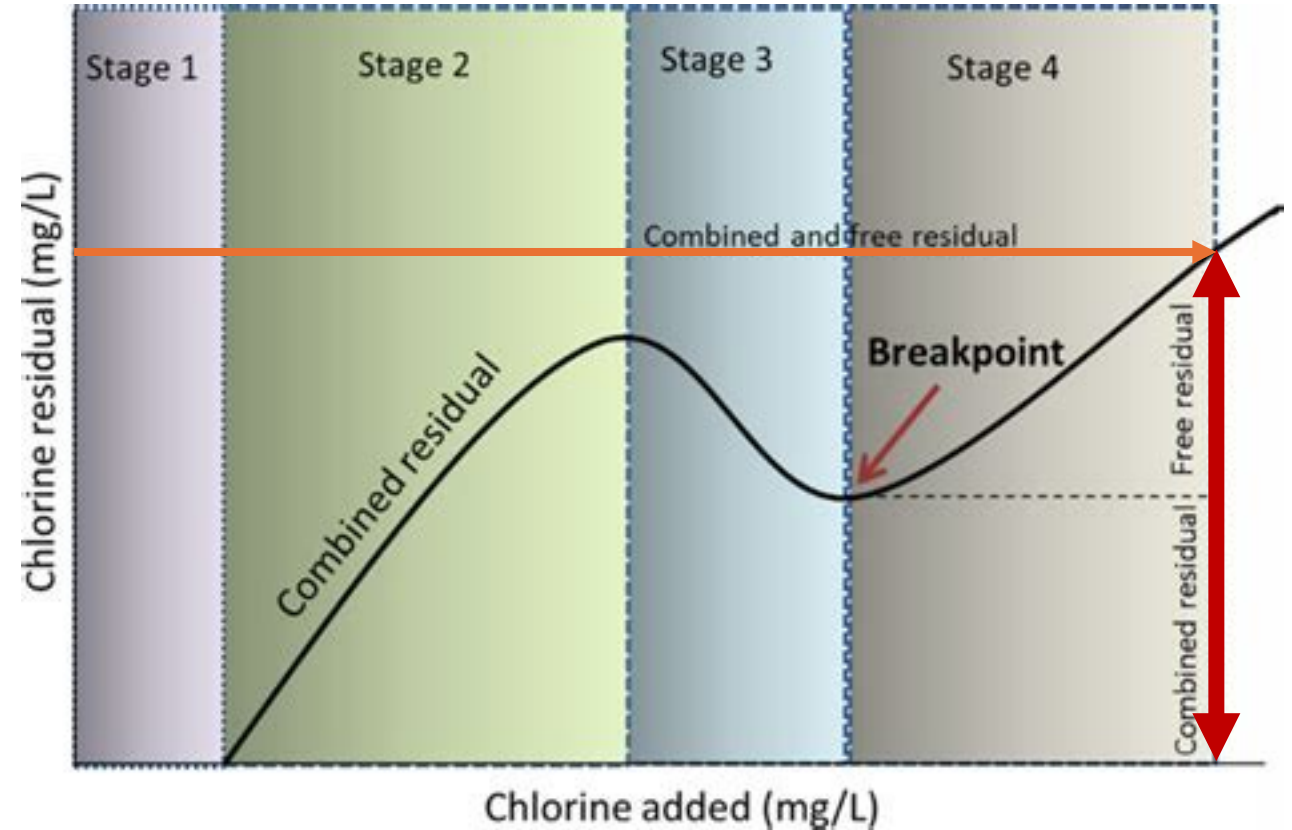
Chlorine Residual

- The amount of chlorine remaining after the chlorine demand is satisfied (expressed as mg/L)
- This chlorine **IS** available for further disinfection

$$\text{RESIDUAL} = \text{DOSAGE} - \text{DEMAND}$$

Three Types of Chlorine Residual

- Total
- Combined
- Free



$$\text{TOTAL} = \text{COMBINED} + \text{FREE}$$

Calculate Chlorine Residual

Calculate the residual chlorine if the demand is 2.0mg/L and the dosage is 2.8 mg/L

What do we know?

$\text{Residual Cl}_2 = \text{Dosage} - \text{Demand}$

$\text{Demand} = 2.0 \text{ mg/L}$

$\text{Dosage} = 2.8 \text{ mg/L}$

$\text{Residual Cl}_2 = \text{Dosage} - \text{Demand}$

$\text{Residual Cl}_2 = 2.8 \text{ mg/L} - 2.0 \text{ mg/L}$

$\text{Residual Cl}_2 = 0.8 \text{ mg/L}$

This equation can be re-arranged to solve for any of the given parameters by isolating the unknown

$\text{Residual} = \text{Dosage} - \text{Demand}$

$\text{Dosage} = \text{Residual} + \text{Demand}$



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CONTACT INFORMATION



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