DISINFECTION TECHNOLOGIES FOR SMALL WATER SYSTEMS

Silver Falls

24 May 2006

Some Presentation Topics

(not necessarily in order or complete)

- **Why** do we Disinfect?
- **What, When** & **Where** do we disinfect: Chlorine & Other Common Disinfectants
  - Types of Chlorine
  - Chemistry
  - Application / Dosages
  - Contact Time v. Residual Cl
- **How** to disinfect well – e.g. calculating CTs, & **How** to disinfect **a** well.

Purpose of Disinfection

- Inactivation of Pathogens
  - Bacteria – Coliforms, Campylobacter
  - Viruses – Norwalk, Hepatitis A/B
  - *Giardia* (parasitic protozoa)
  - *Cryptosporidium* (parasitic protozoa)
- Regulatory Requirements
- Residual Maintenance vs. Disinfection
- Why does your system use disinfectant??

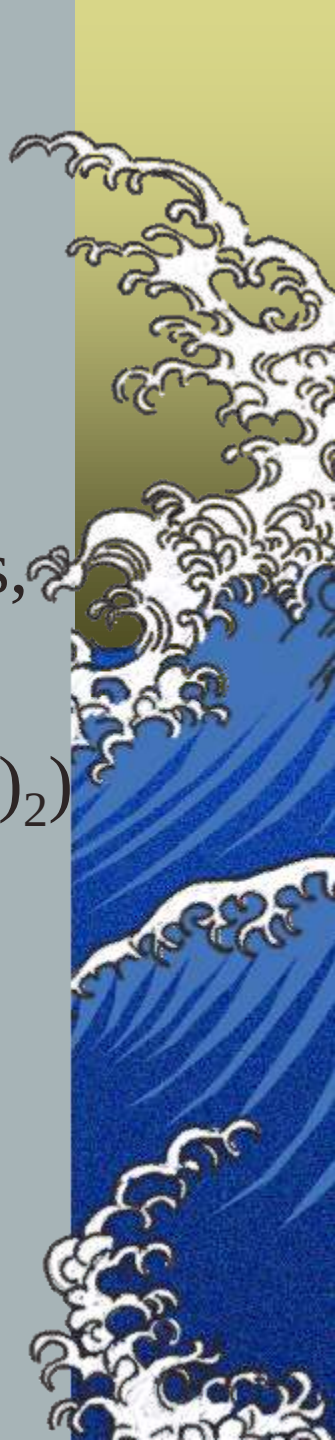
Common Disinfectants

(*In order of prevalence*)

- CHLORINE
- Ultraviolet Light (UV)
- Ozone (O_3)
- Mixed Oxidants (MIOX)
- Chloramines (Cl_2 plus ammonia)

Chlorine

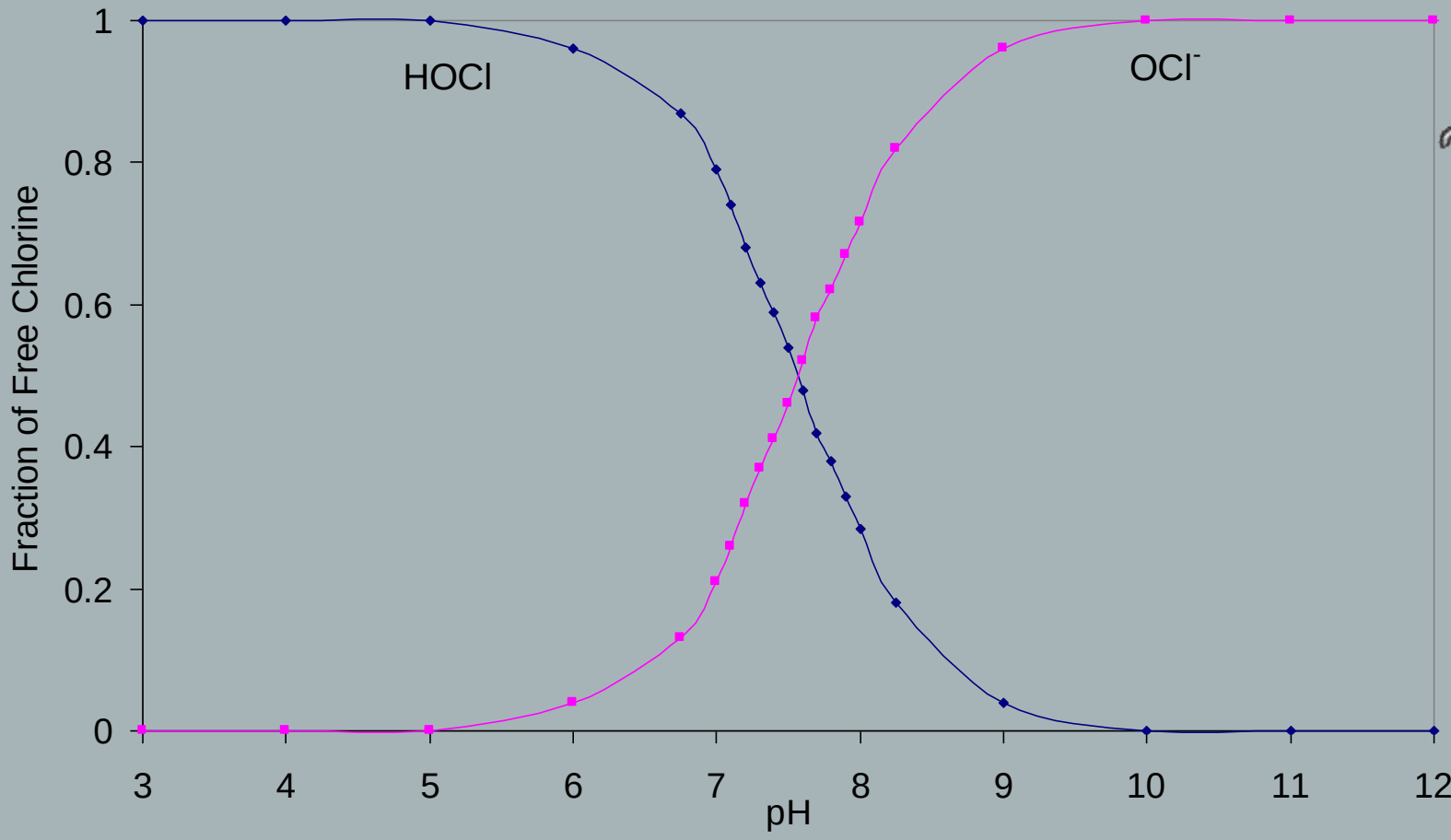
- Types (All must be NSF approved):
  - **Gas**: Larger systems, safety concerns, 99.5 % available chlorine
  - **Solid**: Calcium Hypochlorite ($Ca(OCl)_2$) 15% to 70% available chlorine
  - **Liquid**: Sodium Hypochlorite (NaOCl) 5% to 15 % available chlorine
    Common bleach = 5.25%
    (Shorter half-life at higher concentrations)



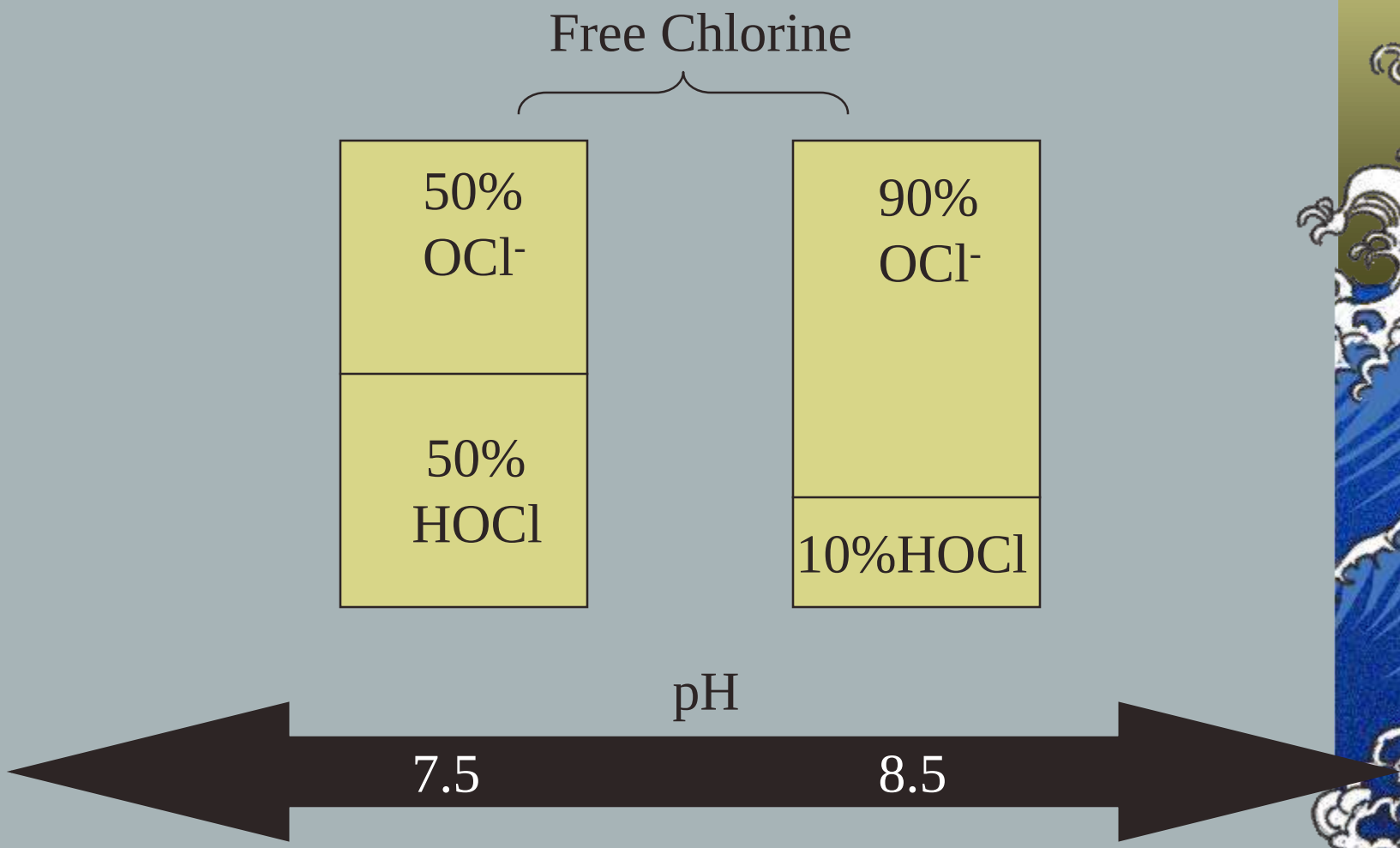
Chlorine Chemistry Tips

- Chlorine + Water = Hypochlorous **acid** (HOCl), a strong disinfectant.
- Depending on water temperature and pH, this **acid** may disassociate to hypochlorite **ion** (OCl^-), a less effective disinfectant.
  - (HOCl is eighty times more potent than OCl^-)
- At pH of 7.5, **acid** to **ion** ratio is 50/50
- Colder water temps and high pH make disinfection less efficient.

Relative Amount of Hypochlorous Acid & Hypochlorite Ion

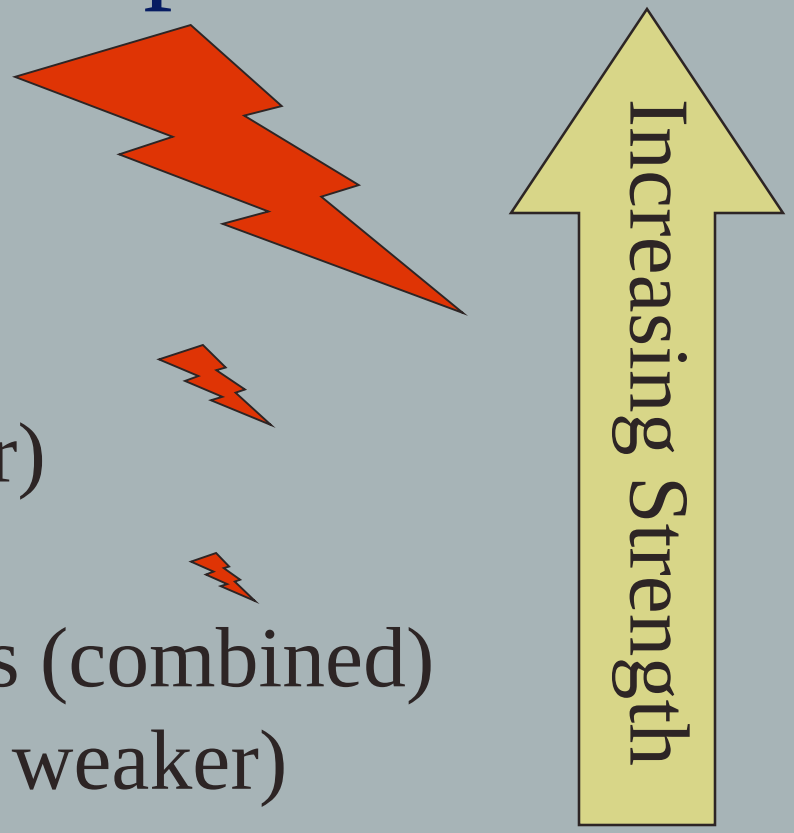


Effects of pH on Residual Type

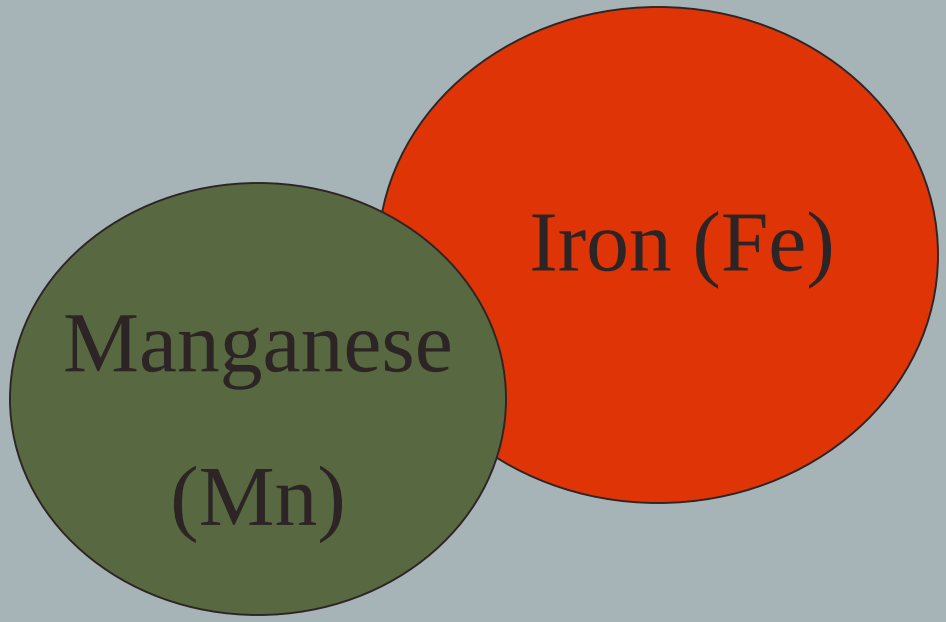


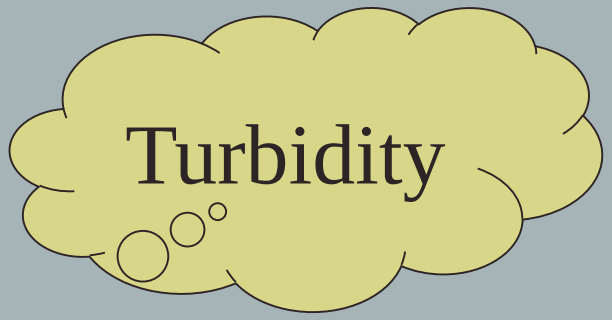
Strengths of Residual Chlorine Compounds

- HOCl
- OCl^- (80x weaker)
- Chloramines (combined) (60x – 200x weaker)



Interfering Agents





When to Increase Chlorine Dosage

Increase Chlorine Dose When You Have:

Increase in:
- pH
- Turbidity
- Fe & Mn

Decrease in:

- Temperature

Calculating Chlorine Residual

Chlorine Dose

- Chlorine Demand

Chlorine Residual

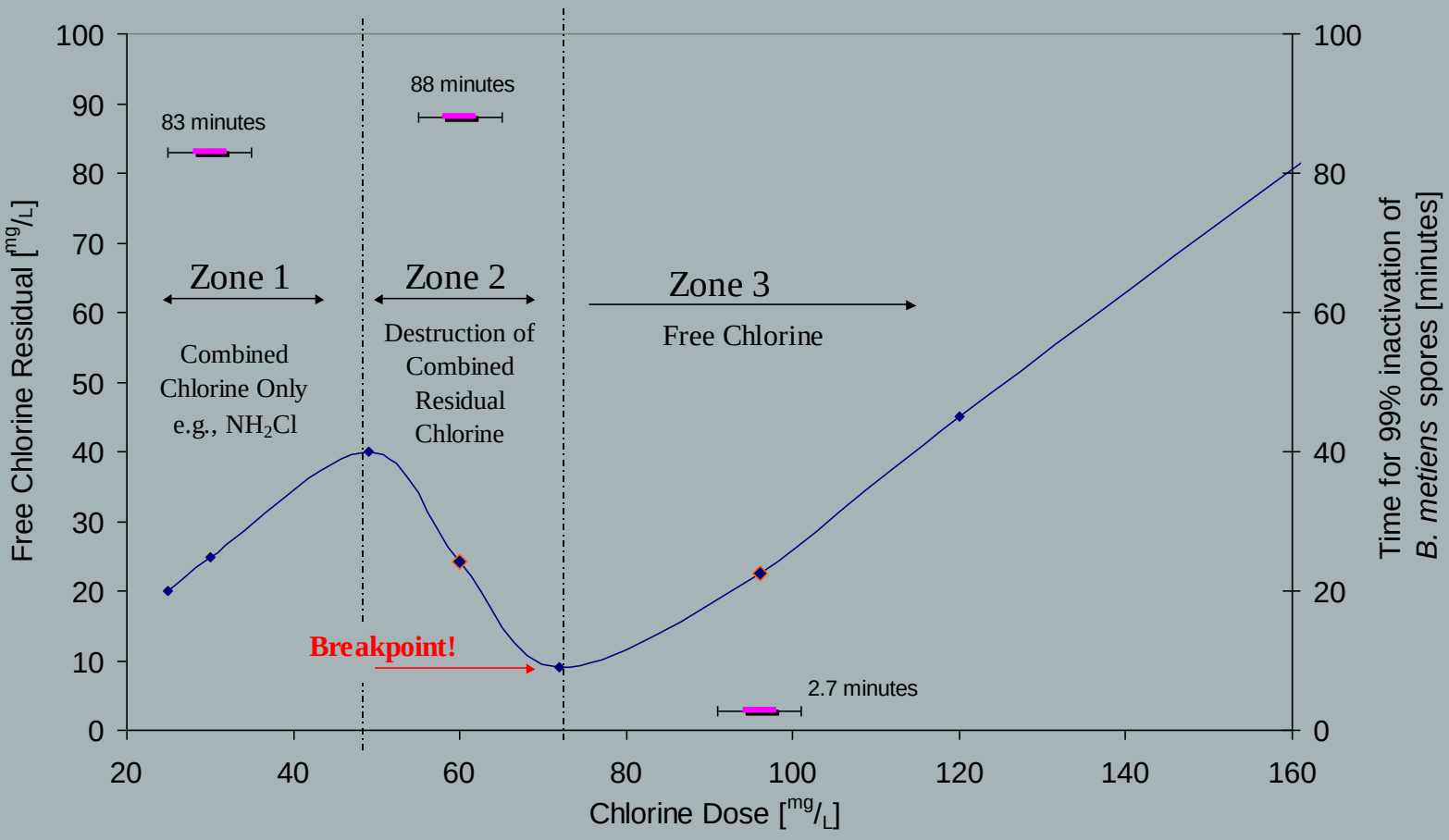
Calculating Chlorine Residual (continued)

Free Chlorine Residual

+ **Combined** Chlorine Residual

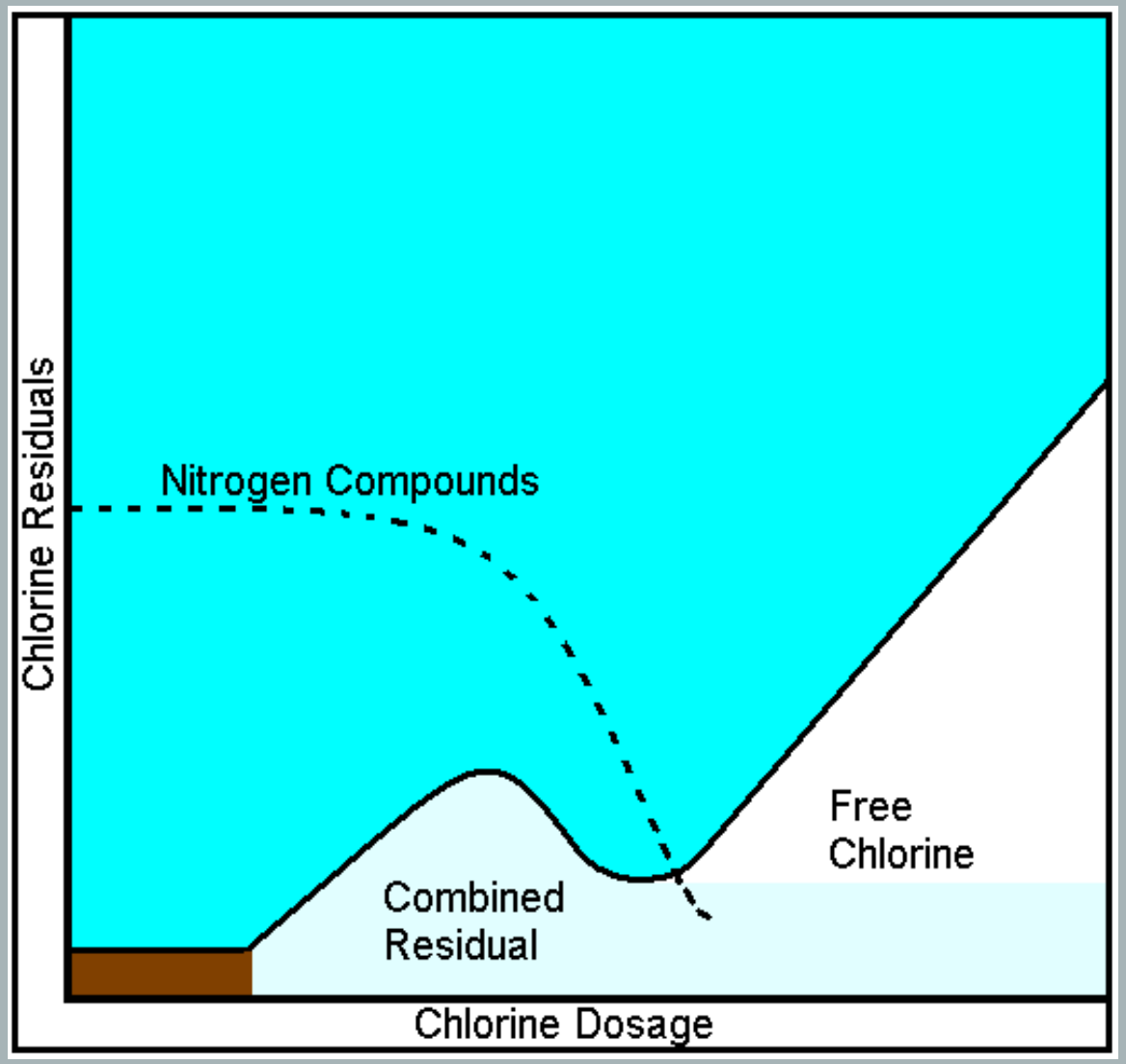
Total Chlorine Residual

Breakpoint Chlorination Curve



Same Breakpoint Curve

(with Nitrogen Compounds)



Disinfection Contact Time v. Residual Maintenance

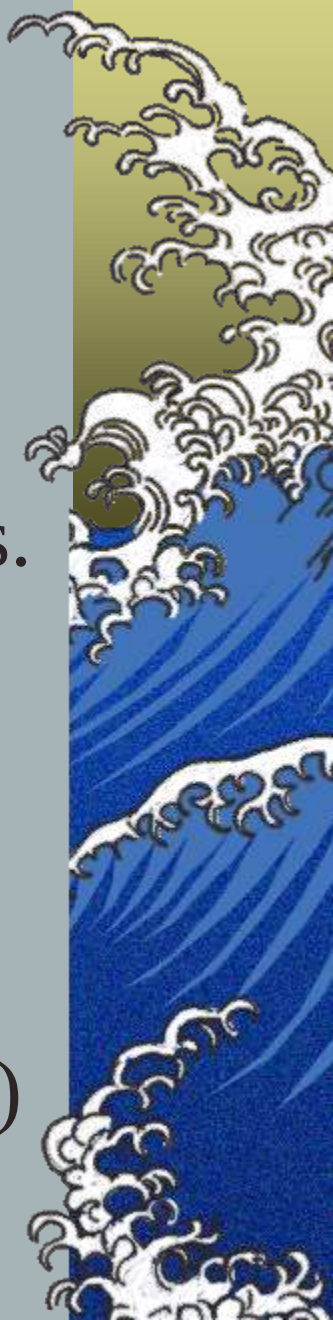
What's the Difference??

Generally speaking, we require:

- Disinfection with **Contact Time** for contaminated **Sources**.
- **Residual Maintenance** for **Distribution**.

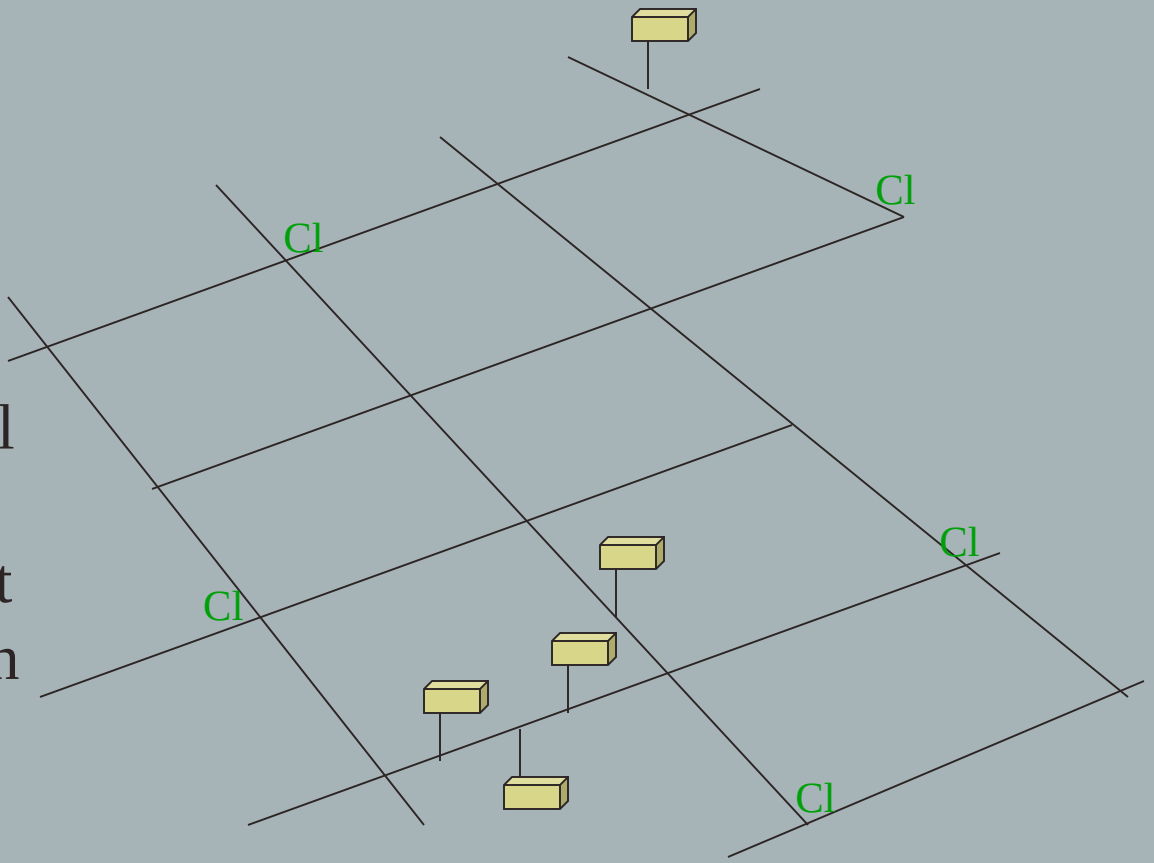
Chlorine Residual

- Measure **free** chlorine residual daily.
- Must be detectable *everywhere* at all times.
- High levels of iron, manganese, or turbidity will increase chlorine demand.
- Use DPD-type test kit (colorimeter/digital)



Why Is Residual Maintenance *NOT* "Disinfection"?

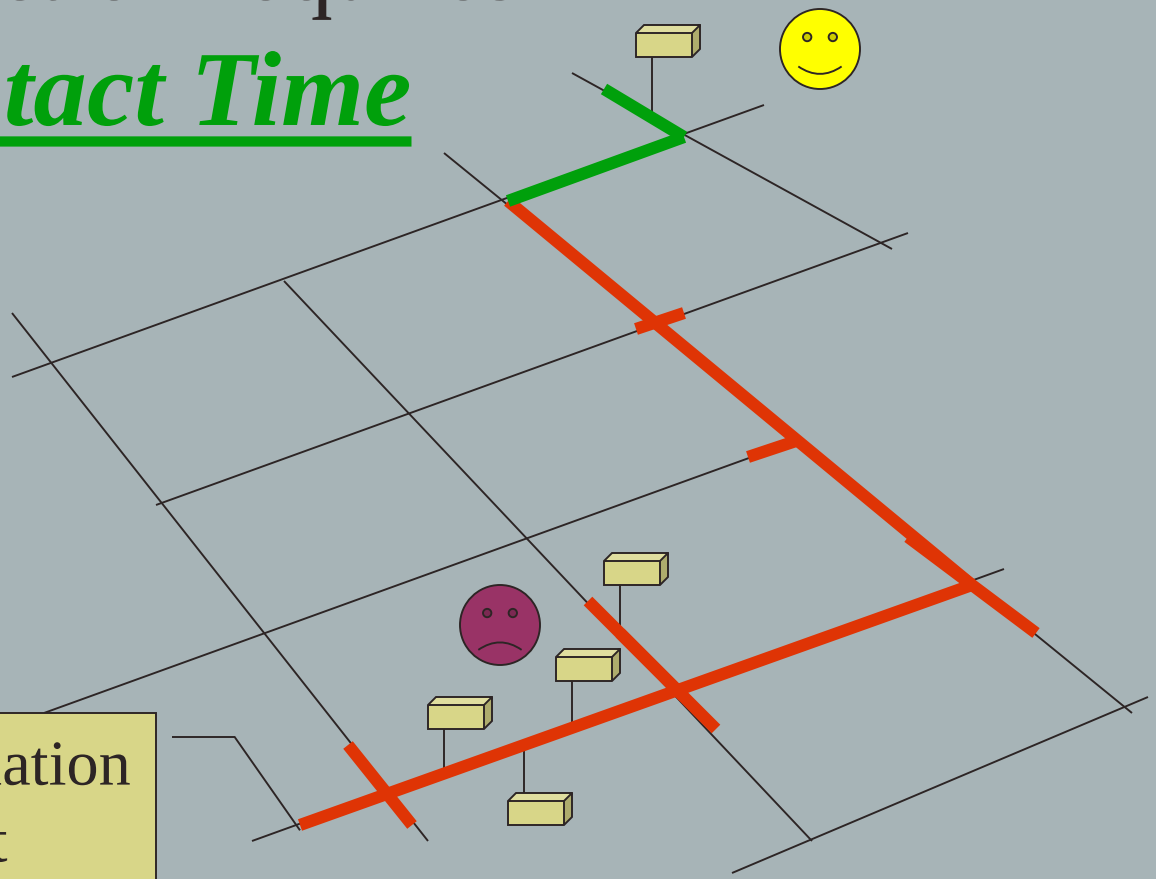
0.2 ppm Cl residual throughout distribution system



Why Isn't Residual Maintenance "Disinfection"?

Disinfection requires

Contact Time



Contamination Point

Chlorine Applications

- Continuous Disinfection
  - Must be proportional to flow
- Shock Disinfection
  - One-time dose
  - Well or reservoir disinfection
  - Repairs

Common Chlorine Doses

- 0.2 to 1.0 $^{mg}/_{L}$ in distribution system
- Max allowable = 4.0 $^{mg}/_{L}$
- Using bleach (5.25% chlorine):
  - $^{1\text{ cup bleach}}/_{100\text{ gal water}}$ = 25 ppm
  - $^{1/3\text{ cup bleach}}/_{1000\text{ gal water}}$ = 1 ppm
- Reservoir cleaning:
  - 10 ppm for 24 hours or
  - 50 ppm for 6 hours

Well Disinfection - Shock

- 50 ppm for **24** hours
- Mix chlorine with water before introducing into well
- Re-circulate if possible

Well Disinfection Dose (cont')

- 6" diameter well = 1.5 $^{\text{gallons}}/_{\text{foot of depth}}$
- Need well depth & static water level **(SWL)**
- 2 cups 5% bleach / 100 gallons water = 50 ppm
- Pump to waste.

Shock Chlorination Example

Well = 200 feet deep; SWL = 120 feet

- 80’ of water in 6” casing = 120 gallons of water in the well
- Since 2 cups of 5% bleach per 100 gallons of water will produce 50 ppm, use slightly over 2 cups.
- Flush after 24 hours.

Disinfection of Storage Tanks

- May be necessary if sampling indicates
- Access to tank (sight only, arm's length, or physical entry)
- Tank drainage
  - Where to?
  - Discharge may be regulated
  - Pump out if no drain

Disinfection Doses for Storage Tanks

(per AWWA Std. C652 and OAR 333)

- 10 ppm for 24 hours (with tank full)
- 50 ppm for 6 hours " "
- 200 ppm sprayed or brushed on interior surfaces of empty tank

Chlorine Equipment

- Gas cylinders (and safety equipment)
- Chemical feed pumps
- Tablet dispensers / Erosion chlorinators
- Test kit
  - DPD-type, color wheel or digital
  - Orthotolodine (OTD) method or test strips *not* acceptable

Chemical Feed Pumps

- Positive-displacement type (LMI, BlueWhite)
- Peristaltic (Stenner)
- Meter-driven (no electricity)

LMI Feed Pump

Wallace & Tiernen Feed Pump

SCBA

Proper Storage

On-site Hypochlorite Generator

“Electrocution” Chamber

Disinfection "**CT Values**"

- *Definition*:

CT values are a measurement of the effectiveness of chlorine disinfection against bacteria, viruses, and protozoa.

Concentration * Time = C*T

CT Calculation

- CT = Cl_2 residual multiplied by contact time

- CT = [$^{mg}/_{L}$] X [minutes]
  = a number (no units expressed)

- *Example*: 0.2 $^{mg}/_{L}$ times 30 minutes
  CT = 6

The Magic Number 6

CT required = 6

30 minutes * 0.2 ppm Cl

<u>Assumptions</u>: Water Temperature ≥ 10°C (50°F)

Required CT Values GW vs. SW

- Groundwater –
  - Minimum CT = 6
  - Adequate for bacteria / virus kill

- Surface Water –
  - Required CT varies with:
    pH, temp, and log-inactivation requirement

Disinfection Contact Time
(not to be confused with CT Calculation)

- Determined by Tracer Study or *interim* estimate
- Time = "effective" volume of contact chamber / flow
- Time = [minutes] = [gal] / [gpm]
- Pipe flow is ideal
  - I.e., 100% credit for pipe volume
- Storage tanks likely have short-circuiting

How Do You *Really* Measure Contact Time? $T = {}^{V}/_{Q}$

1. Determine peak **demand** flowrate
   - Does system have an *effluent* flowmeter?
2. Look at the configuration of system.
3. Make estimate based on tank configuration & length of pipe
   - Assume 10% of tank volume if unknown.
4. Calculate contact time using *effective* tank volume and *effluent* flowrate.

Chlorination Concerns

- Disinfection by-products (DBPs)
  - THMs and HAA5s
- DBP production encouraged by:
  - High chlorine levels
  - Long contact time
  - Warm weather
  - High source water TOC

UV

Ultraviolet Light

- Effective non-chemical disinfectant
- Suitable for small systems with few distribution lines
- Must meet plan review requirements:
  - Minimum dosage 38 $^{mWsec}/_{cm^2}$
  - Intensity monitor
  - Automatic shut-off

UV Pros & Cons

- Advantages:
  - No chemicals, therefore no DBP's
  - No contact time required
  - Simple
  - Low operation & maintenance cost

- Disadvantages:
  - No residual that protects distribution system

Ozone (O_3)

- Disinfection and taste/odor control
- Produced by electricity and air or pure O_2
- Inactivates *Cryptosporidium*
- Must be generated on-site
- Leaves minimal disinfectant residual
- Costs 4 times more than conventional disinfection, yet cheapest LT2 option

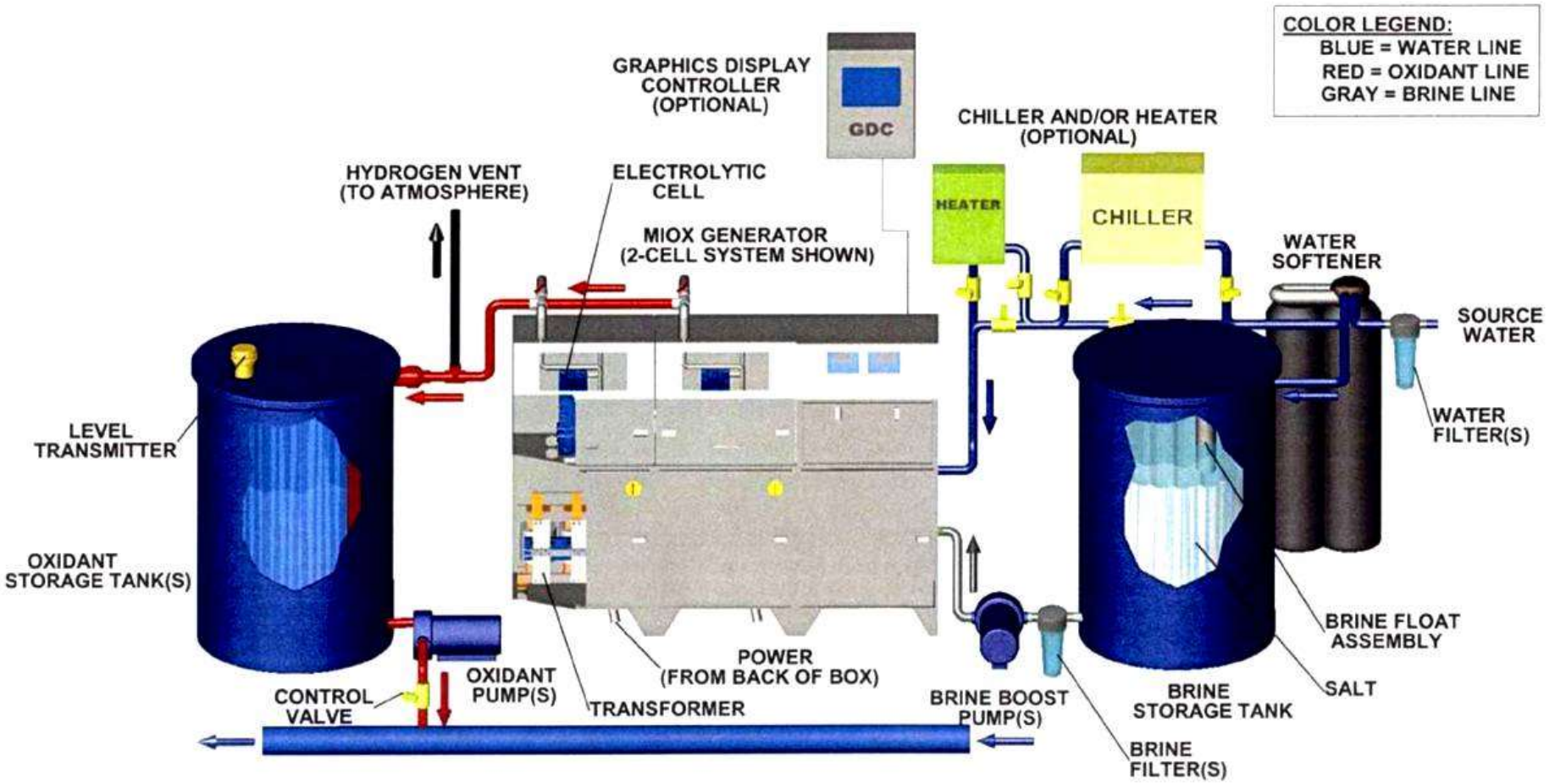
Onsite O_3 Generation

Demo SS Injection w/ Nozzles

MIOX

- "Mixed Oxidants" – mostly hypochlorite, ozone, and peroxides
- Produced on-site
- Requires electricity, rock salt, and water
- Special equipment needed, difficult for small systems
- Produces less DBPs

MIOX Process



MIOX Salt for Brine Solution

MIOX Manifold

PLAN REVIEW

- Required for **ALL** disinfection projects.
- NSF certification
- Contact regional engineer for specifics
- If don't know whether PR was done: *Ask!*

Questions???
Start Talking.