Teaching an Old Dog New Tricks

Troubleshooting & Optimizing Chlorine Disinfection Systems

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NEWEA
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AGENDA

1. Chlorine Overview
2. Breakpoint Curves
3. Troubleshooting
4. Optimization Approaches

AGENDA

1 **Chlorine Overview**

2 Breakpoint Curves

3 Troubleshooting

4 Optimization Approaches

Chlorine Overview

- Used in Disinfection since 1850
- Chlorine oxidizes cellular material
- Common types
  - Chlorine gas
  - Bulk liquid hypochlorite solutions
  - On-site generated sodium hypochlorite
- Chlorine as a Disinfectant
  - Free chlorine
  - Chloramines

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Chlorine Overview

- 58% use chlorine disinfection – 2017/2018 WEF Survey
- Typical strategy uses chloramines, chlorine plus ammonia:
  - Monochloramine – *Fast reaction, formed first*
  - Dichloramine – *Much slower, forms after monochloramine*
  - Trichloramine – *Formed last, not a well understood reaction*
- Reasons for low effluent ammonia:
  - Lower nutrient limits
  - Nitrification (partial or full)
- Breakpoint chlorination → free chlorine
- Free chlorine strong oxidizer
- Free chlorine may require higher chlorine dose

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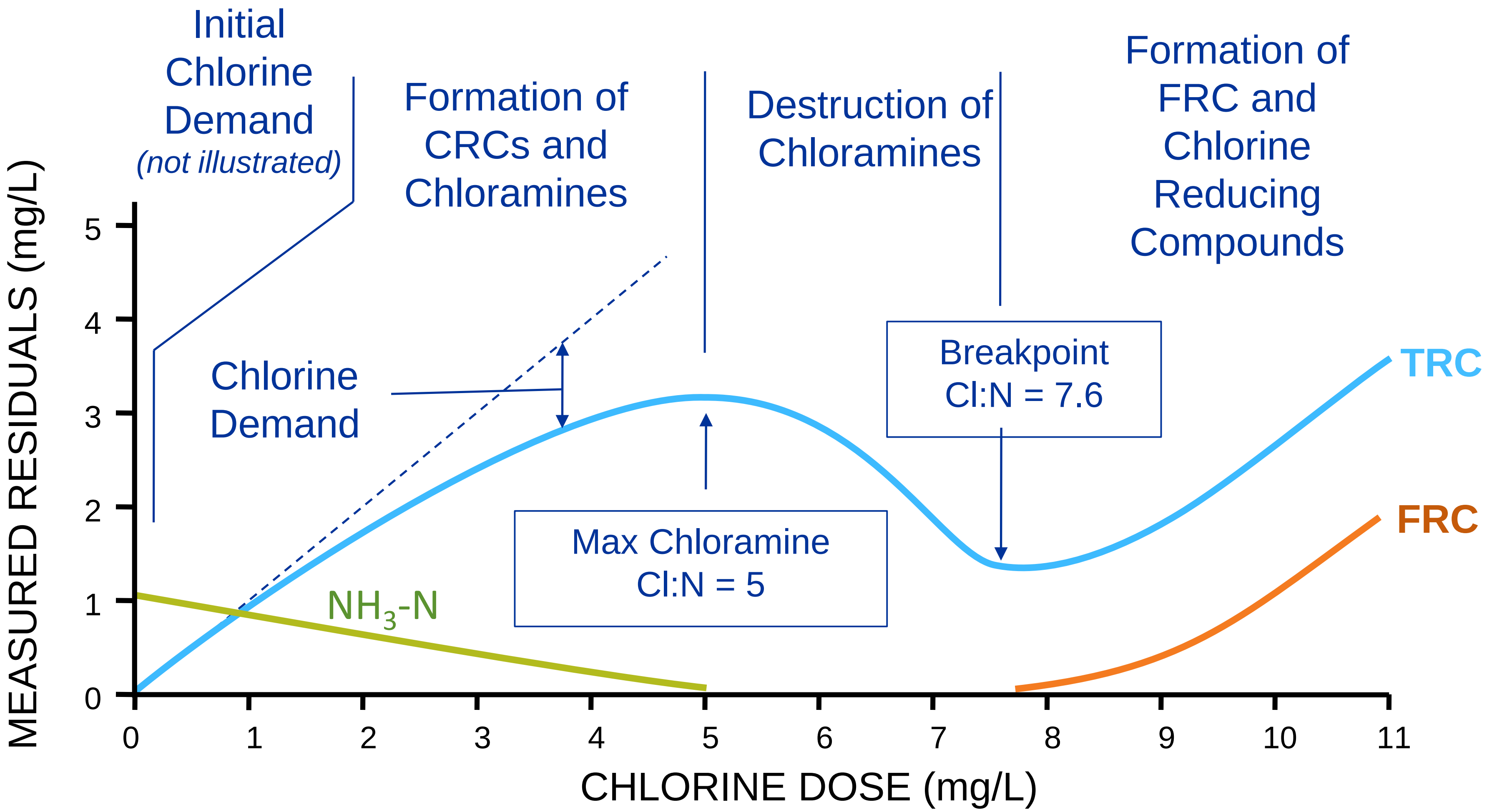
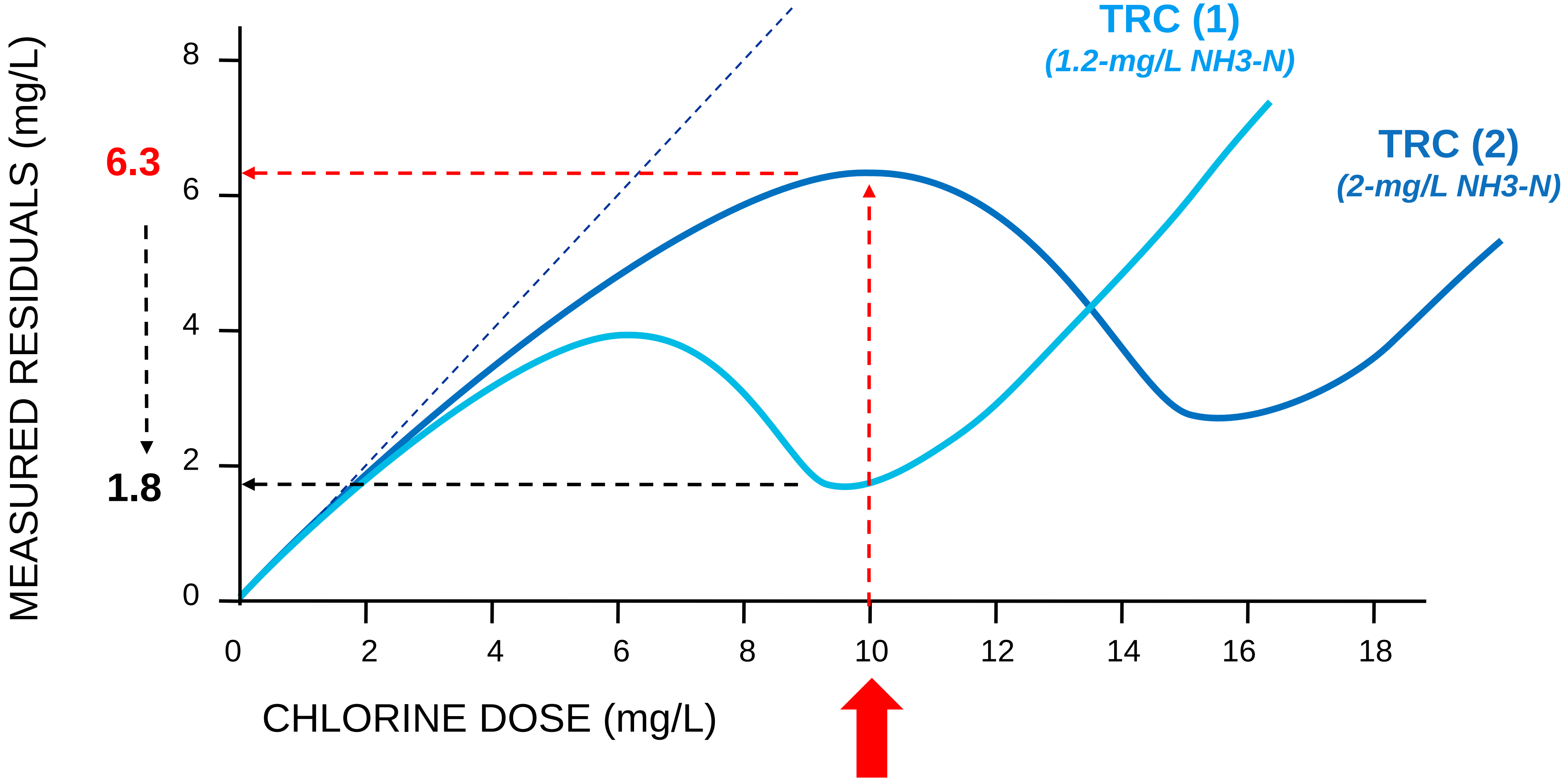
Breakpoint Curve



Breakpoint Curve



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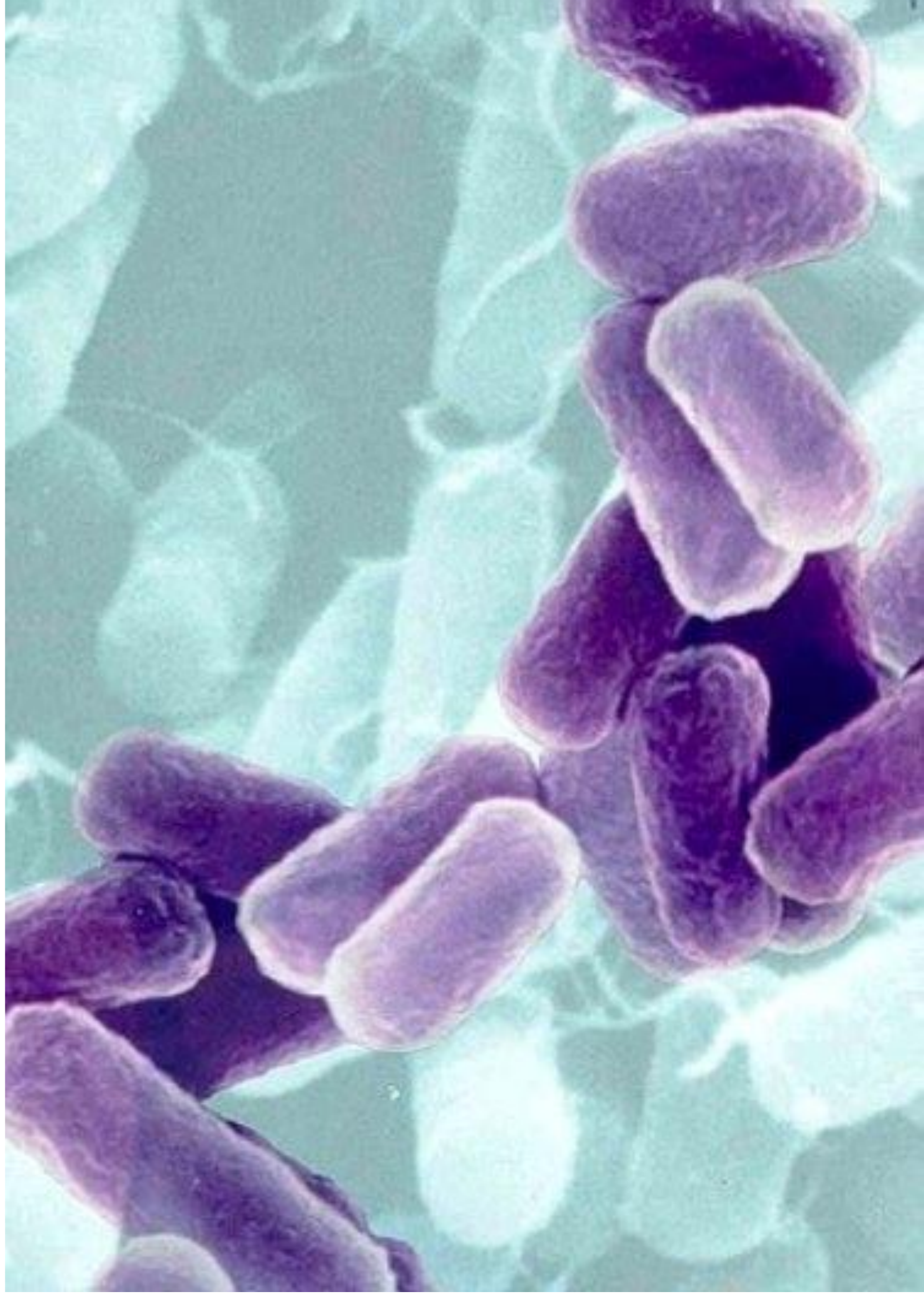
Troubleshooting

- Nitrification

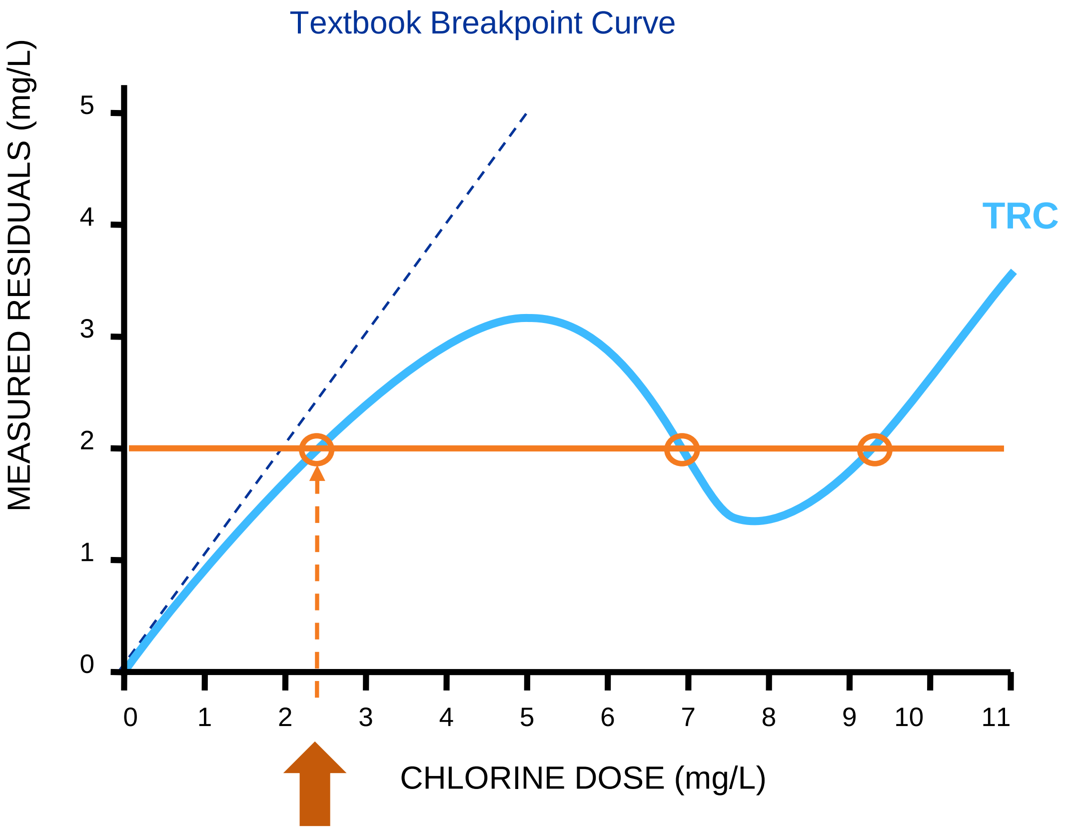
  $NH_3\text{-}N + 1.5\ O_2$ + Nitrosomonas → $NO_2^- + H_2O + H^+$

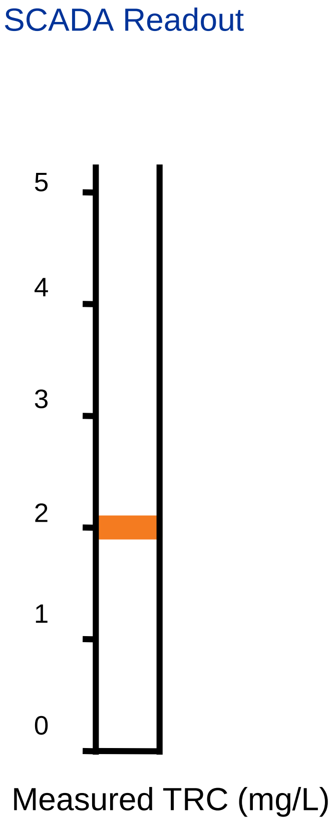
  $NO_2^- + 0.5\ O_2$ + Nitrobacter → NO_3^-
- NH_3-N between 1 to 3-mg/L
  - Can chloraminate
  - Use lower chlorine dose
  - Requires careful attention to dosing control system
- NH_3-N less than 1-mg/L
  - Challenging to chloraminate
  - Form FRC
  - CRCs may exert high chlorine demand



Troubleshooting

- Revisit instruments
  - TRC analyzers
  - FRC analyzers
  - Oxidative Reduction Potential (ORP)
  - Ammonia analyzers
  - Keep them calibrated





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Troubleshooting

- Sample upstream of disinfection for :
  - pH
  - NH_3-N
  - Nitrite (1 mg/L reacts with 10 mg/L of chlorine)
  - Nitrate
  - Organic-N = TKN – NH_3-N
  - Concentration of indicator organisms
- Biological process adjustments
  - Reduce solids retention time
  - Control dissolved oxygen

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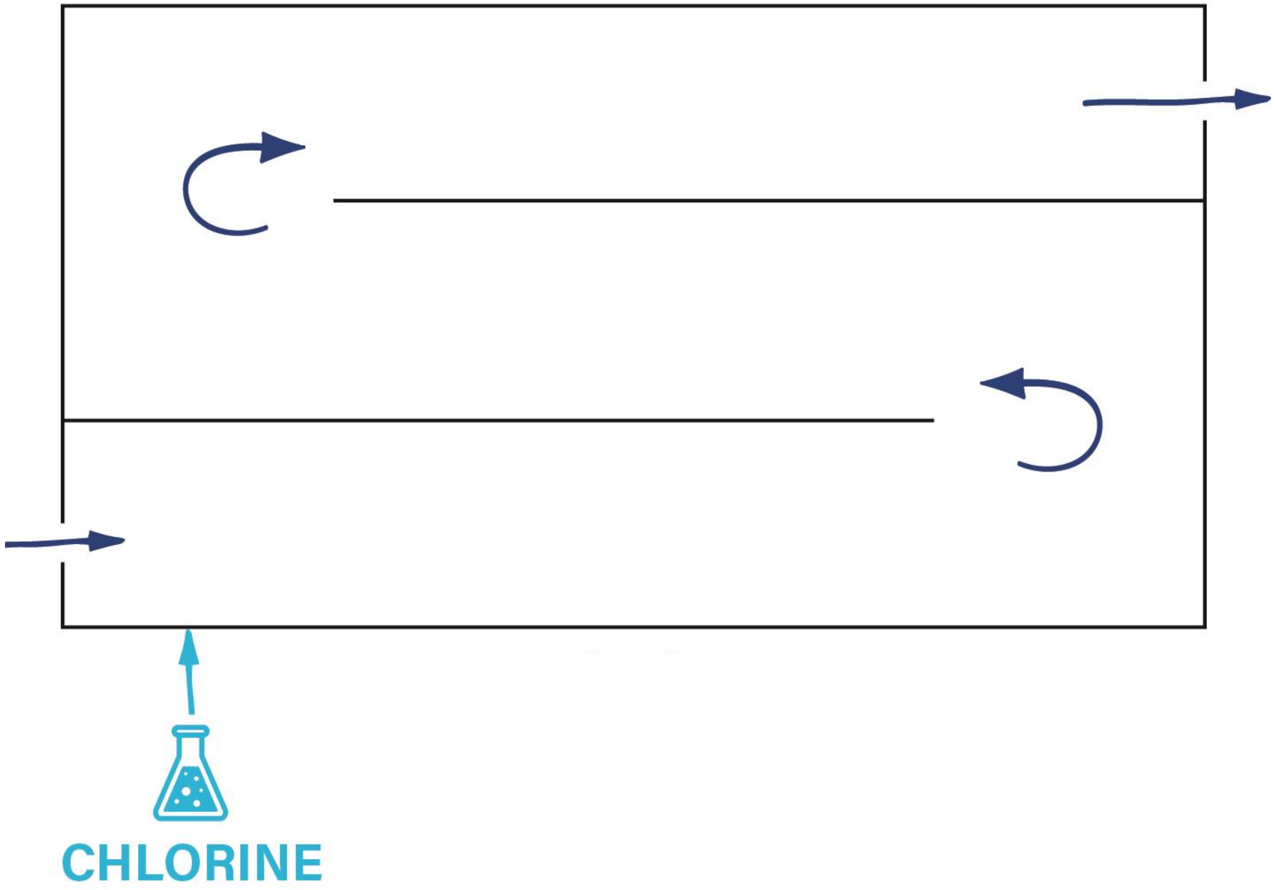
Optimization

- Manual control
- Flow pacing
- Compound control loop
- CT based approach
  - Disinfection efficacy tied to CT
  - Integrated CT more accurate repr
  - Three components of disinfection
    - Disinfectant kinetics
    - Inactivation kinetics
    - Hydraulic efficiency of contact ve



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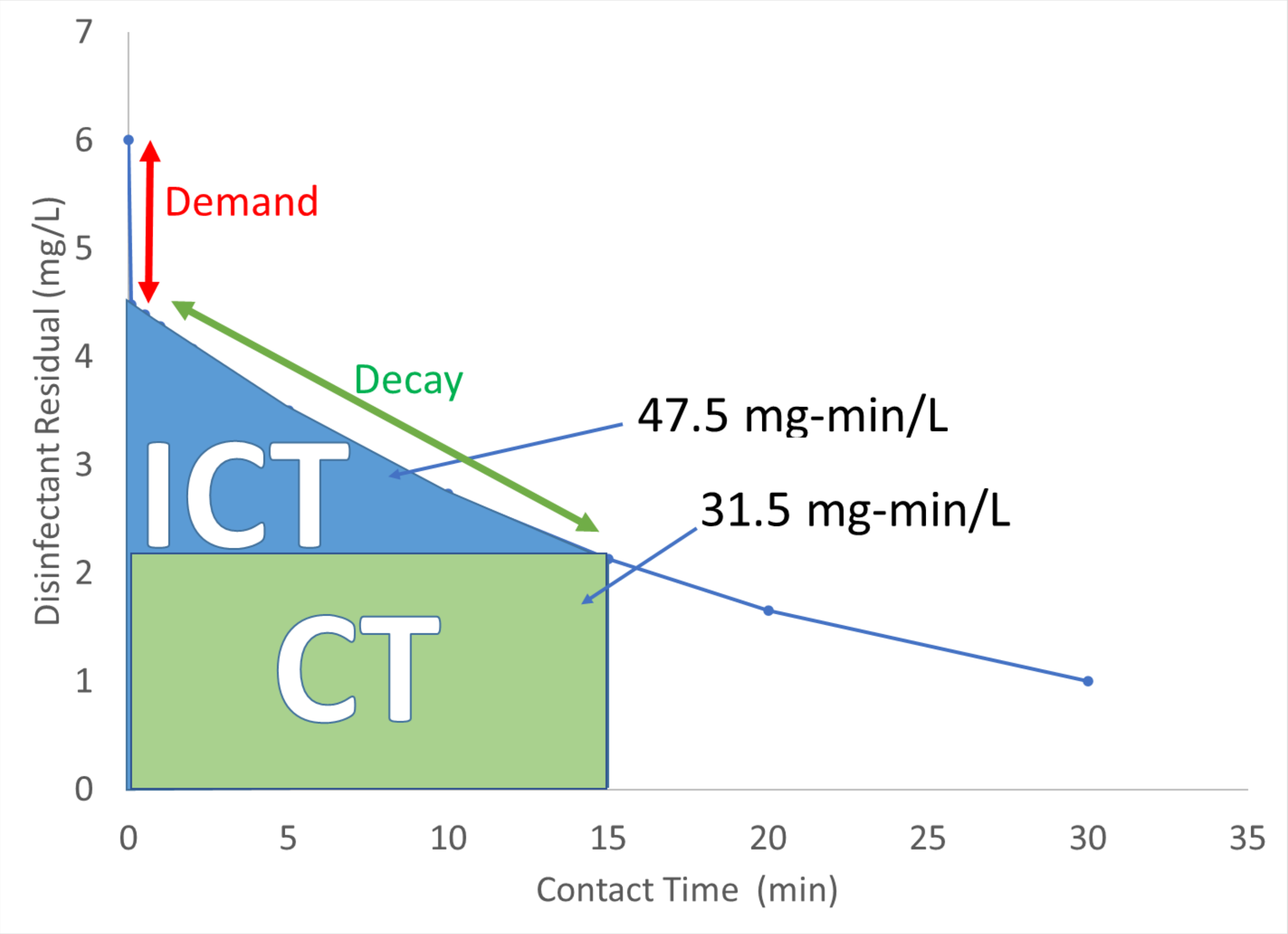
Optimization – Disinfectant Kinetics



$$ICT = \frac{C_o - D}{k} * (1 - e^{-kt})$$

- Where:
  - C_o = Initial disinfectant dose
  - D = Disinfectant demand
  - k = Decay of disinfectant over time
  - t = Contact time

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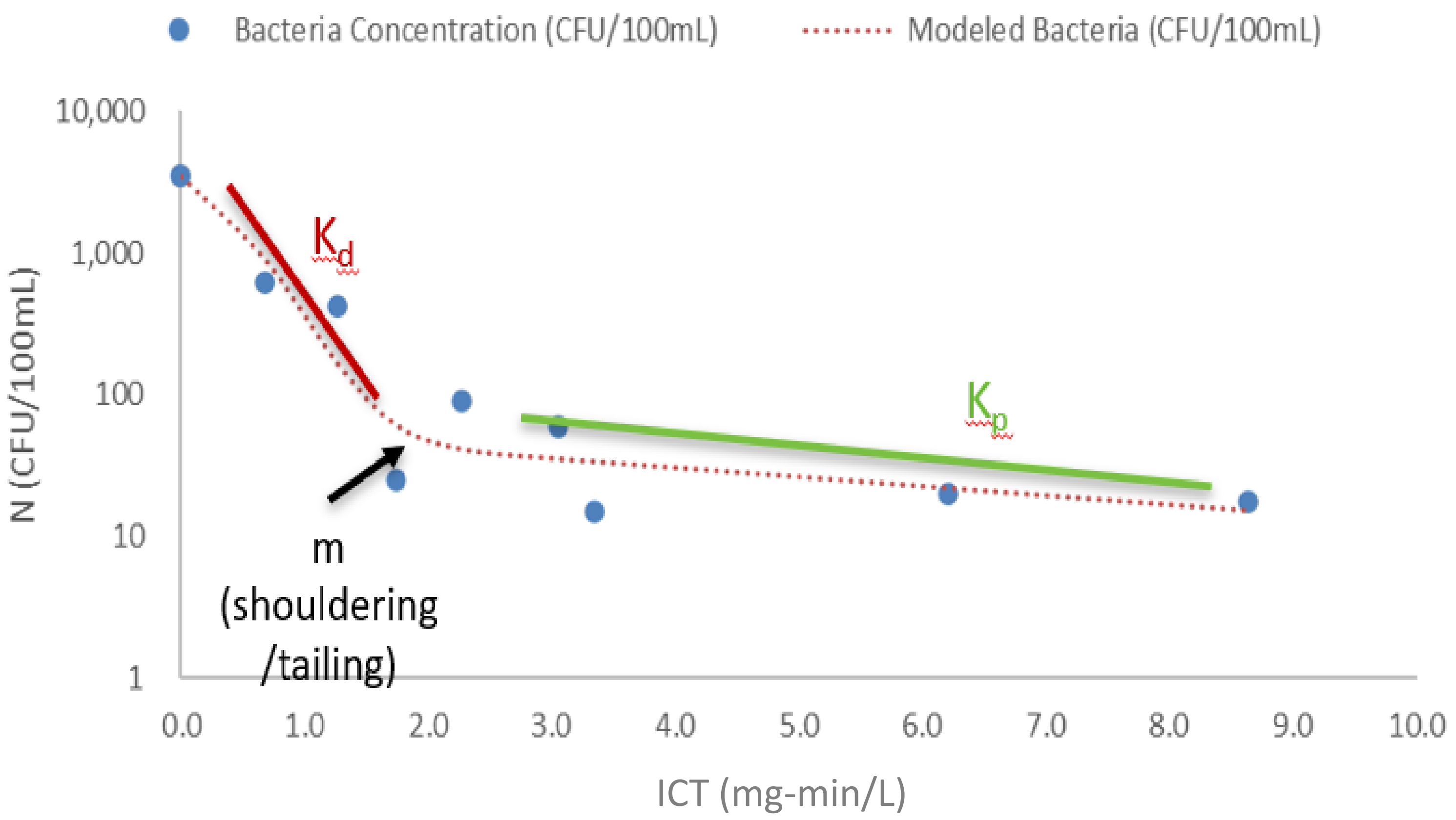
Optimization – Inactivation Kinetics

$$N = N_o(1 - B)e^{(-K_d * ICT^m)} + (N_o \times B)e^{(-K_p * ICT)}$$

- Where:
  - N = Bacteria count after applied ICT
  - N_o = Initial bacteria count
  - B = Coeff for particle based bacteria
  - k_d = Decay rate for dispersed bacteria
  - k_p = Decay rate for particle-based bacteria
  - m = Coeff for magnitude of k_d



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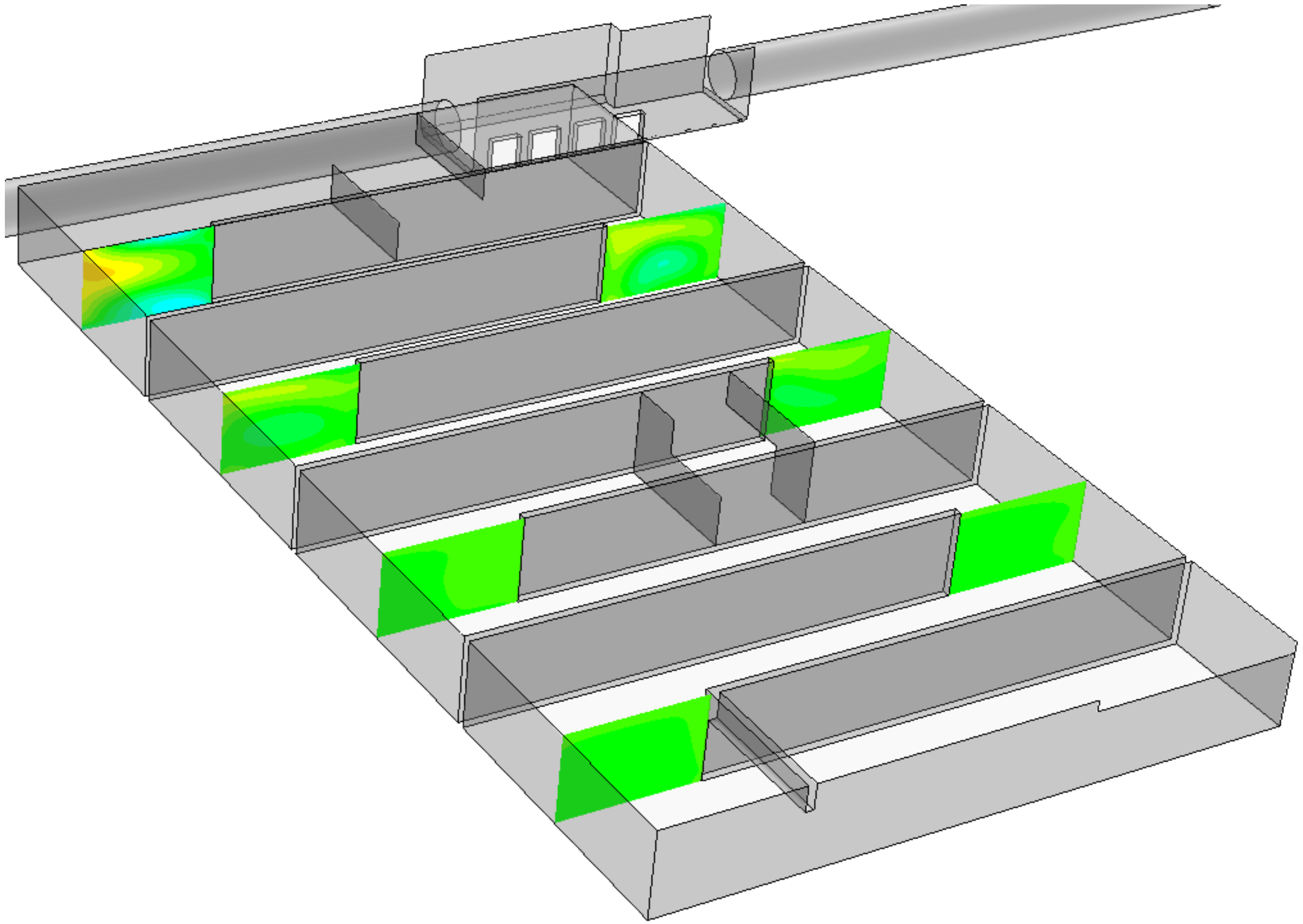
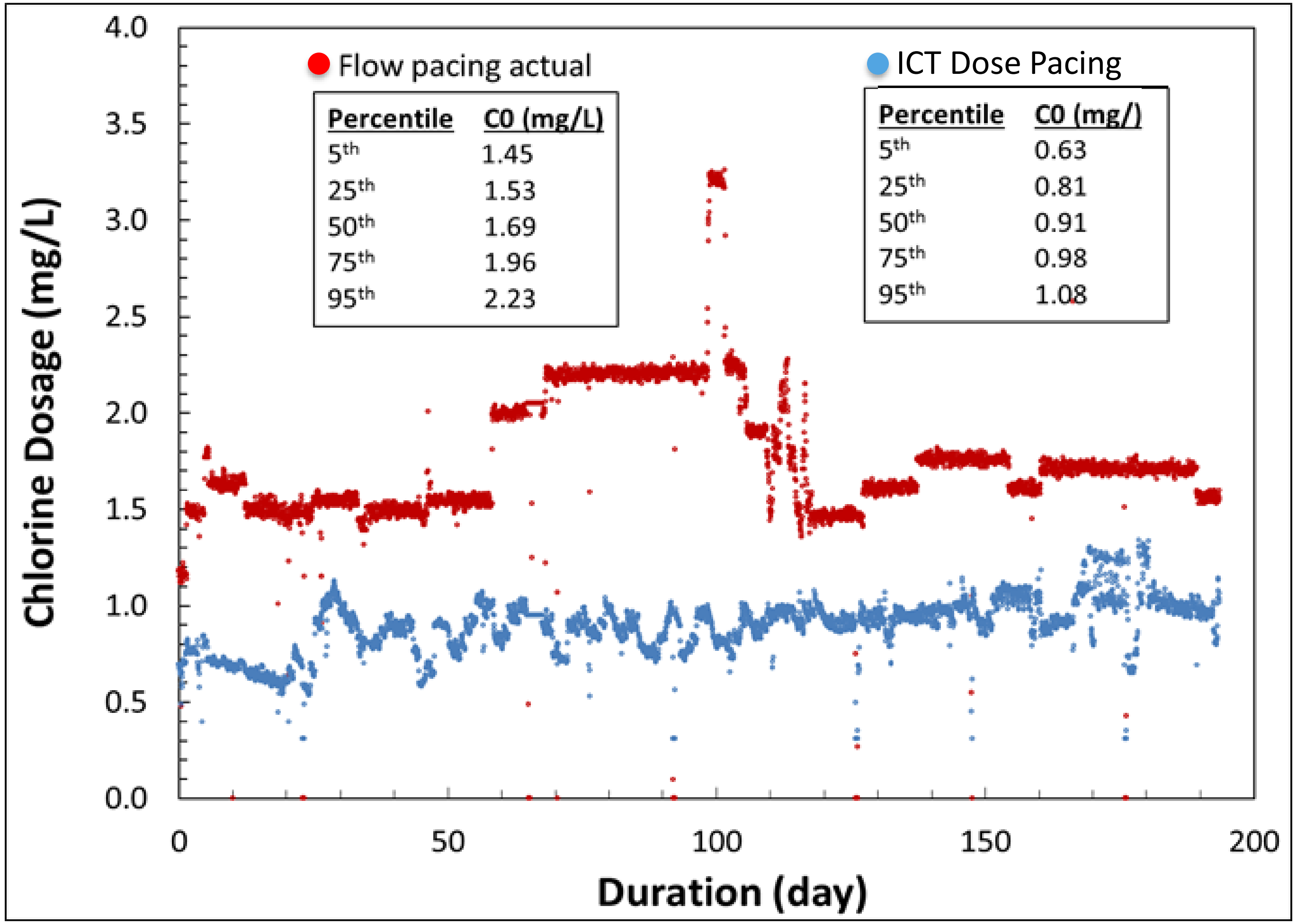
Optimization – Hydraulic Impacts

- Theoretical contact time
  - $\frac{Tank\ Volume}{Flow\ Rate}$
- Determine true hydraulic efficiency
  - Computational fluid dynamics
  - Physical modeling
  - Tracer study
- True contact volume
- Accurate flow measurement
- Baffling factor range – 0.3 up to 0.7
- Mixing zone needs to be considered



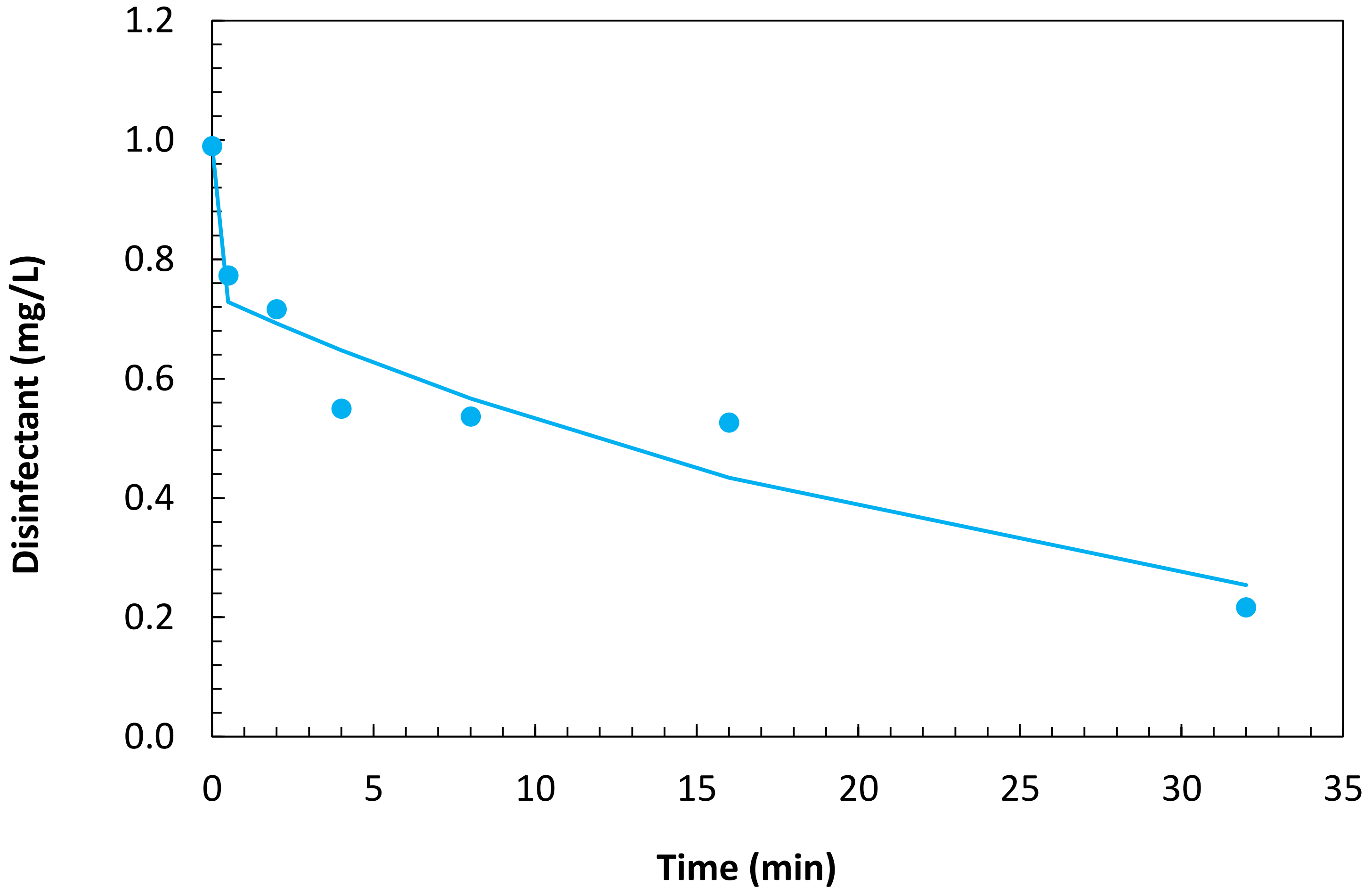
ICT Dose Pacing Performance



ICT Dose Pacing reduces chemical usage by ~50%

Optimization - Example

- Dose Response Testing
  - Undisinfected sample
  - Apply various chlorine doses
  - Collect samples at various contact times
  - Measure:
    - Bacteria counts
    - Total Residual Chlorine
    - Free Residual Chlorine
    - Number of water quality parameter for undisinfected



Optimization – Example

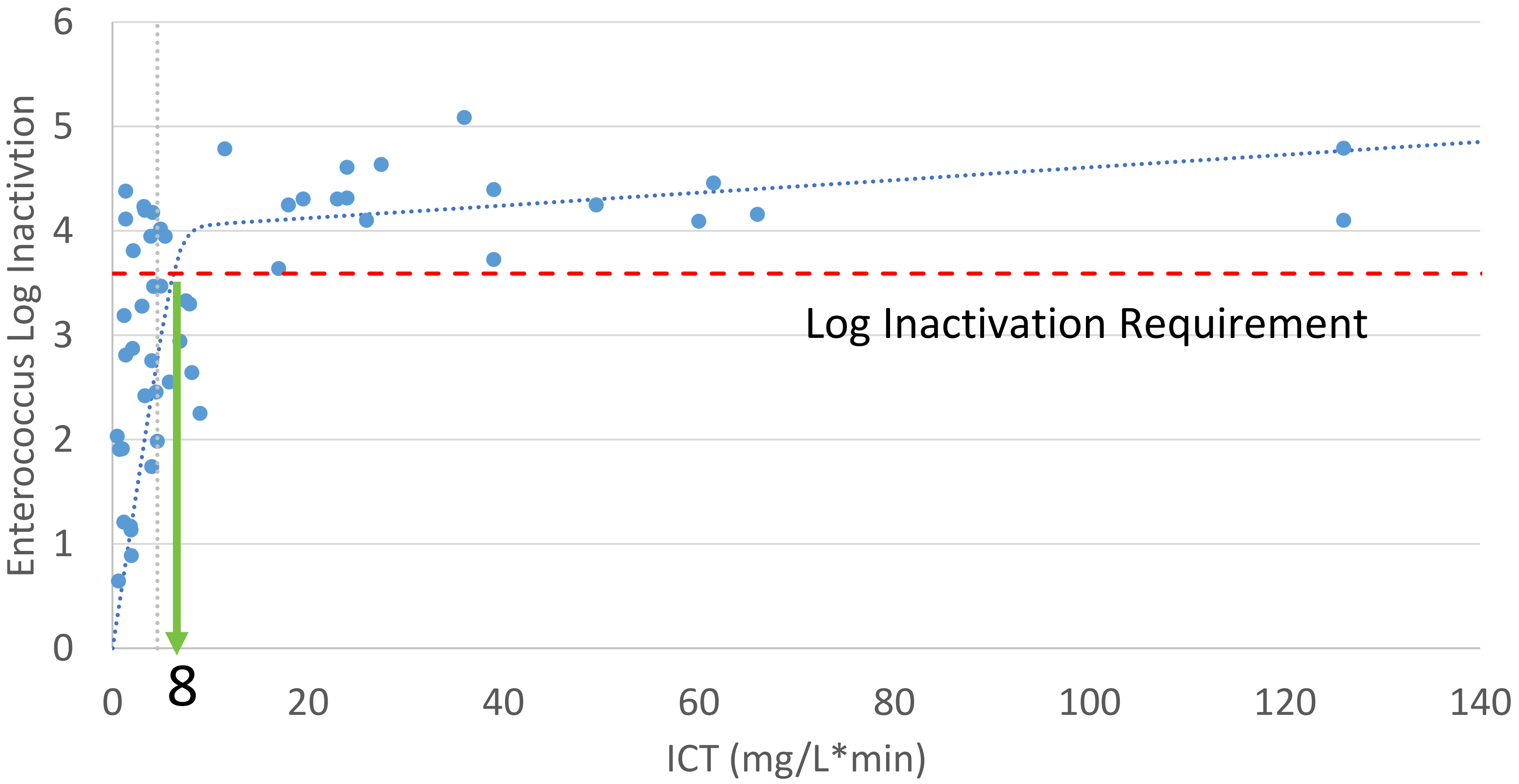
- Determine log inactivation
- Historical data analysis
- Undisinfected bacteria

- Target Bacteria Count

95th percentile: 225,000 CFU/100mL

Target: 55 CFU/100mL

Log inactivation = 3.6



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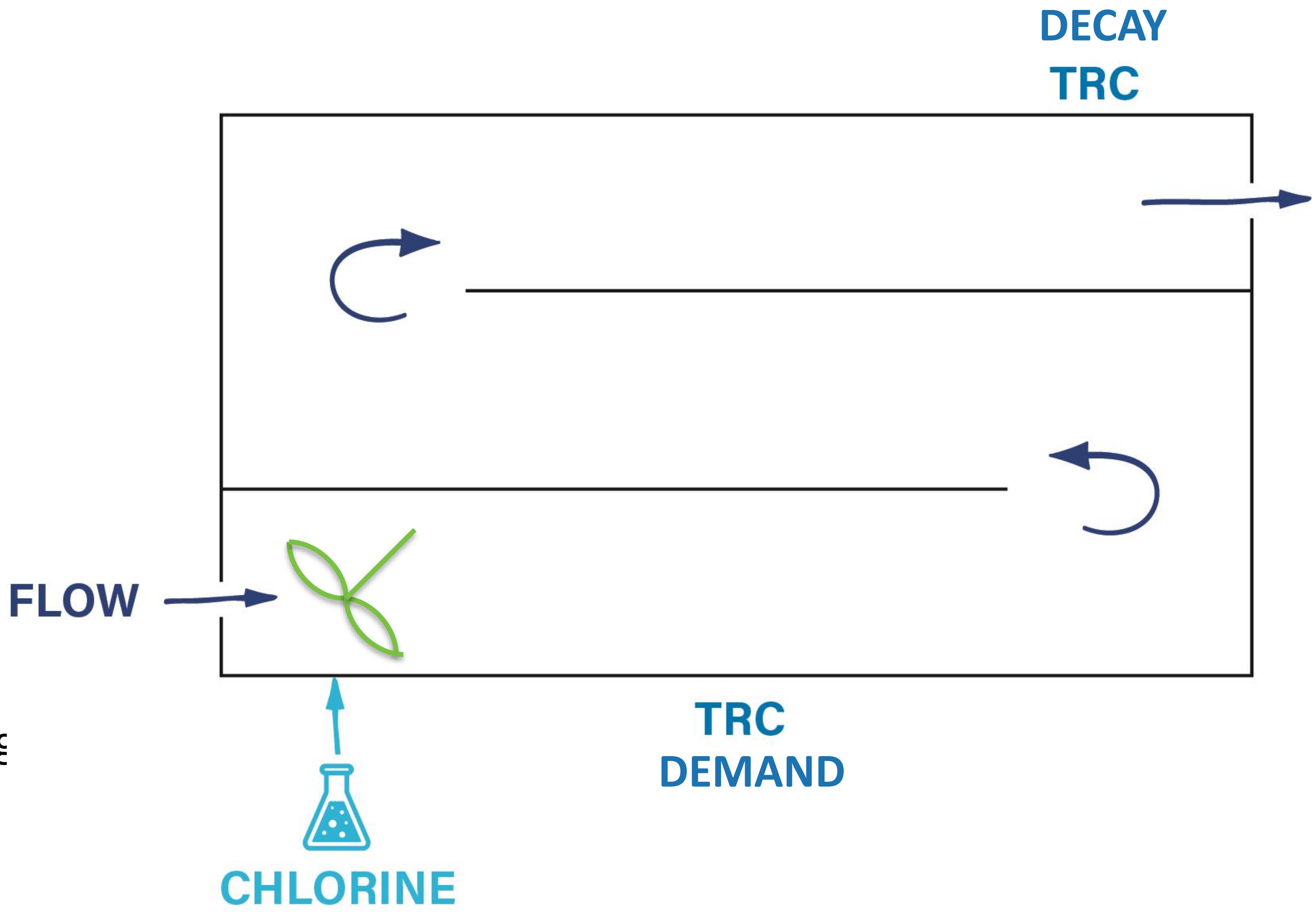
Optimization - Example

ICT to determine dose

		Peak Daily Flow	Max Month	Future Average Day	Current Average Day
	Flow (mgd)	309.9	191.9	135.9	116.9
1	Actual HRT (min)	27	45	55	63
2	Required Residual (mg/L) to Achieve an ICT	3.42	2.06	1.71	1.49
3	Chlorine Demand (mg/L)	1.26	3.1	3.1	3.1
4	Required Dose, Including Chlorine Demand (mg/L)	4.68	5.16	4.81	4.59

Optimization

- ICT with real time control
  - ICT value
  - Actual contact volume
  - 4-20mA flow signal
  - Real Time *D* and *k* from online TRC
- Simplified ICT control
  - ICT value
  - Actual contact volume
  - 4-20mA flow signal
  - *D* and *k* from dose response testing



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In Conclusion

- Chloramination depend upon upstream processes
- Understanding undisinfected water quality is key
- Maintain instruments
- Various control options
- Hydraulic impacts
- Optimizing with ICT

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