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US Territories Water Operator Training Series

Session 10: Disinfection 3: Distribution System Application, Residual Measurement, Evaluation & Adjustment (part 3 of 4)

10/30/25

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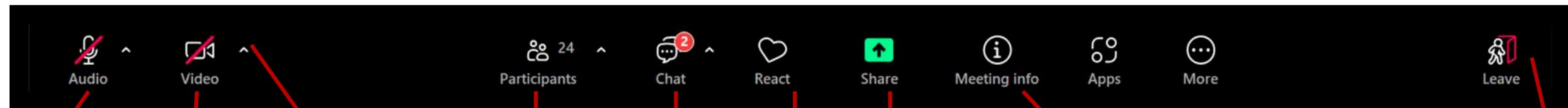
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This training series is funded by the US EPA

Attendee Meeting Controls

- Locate your control bar
- All attendees will see a black horizontal bar on their screen
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1. Mute/unmute

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your video

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4. View Meeting
Participants

5. Chat

6. Reactions/raise hand

7. Share
screen

8. Meeting
info

9. Leave meeting

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: _____

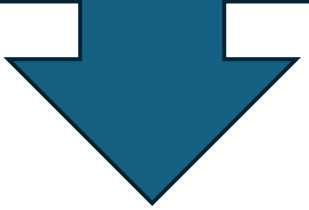
Date: _____

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"

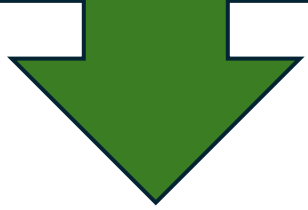
Today's Agenda

- CT
- Distribution System Application
- Residual Measurement
- Residual Evaluation
- Dosage Adjustment
- Repairing Mains

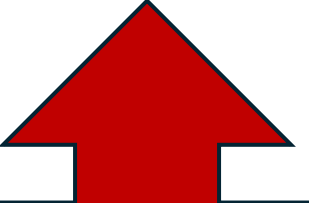
Total amount of
chlorine fed into a
volume of water
(mg/L)



Chlorine remaining
after demand is
satisfied (mg/L)
IS available for
disinfection



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



Chlorine consumed by
material in the water (mg/L)
NOT available for
disinfection
NO residual chlorine



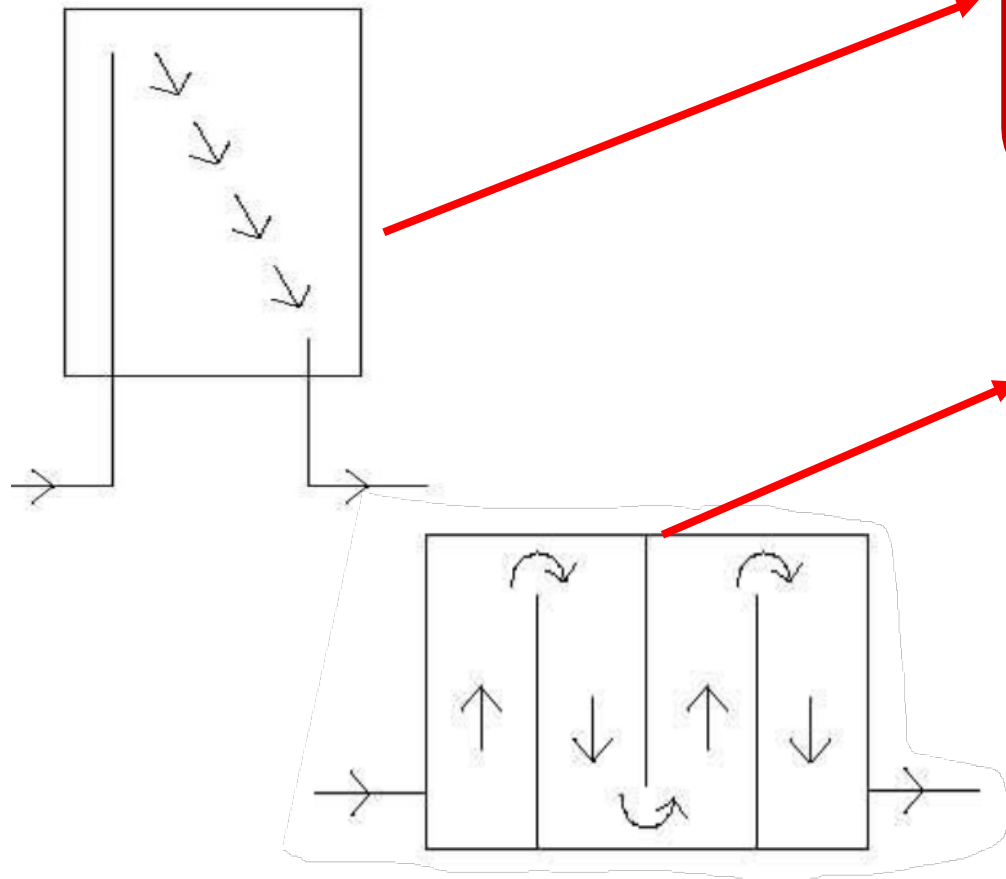
$$CT = \text{Concentration} \times \text{Time}$$

Chlorine takes time to interact with and inactivate organisms. CT must be met to ensure effective inactivation.

- The higher the concentration the less time needed.
- The more time available the lower the required concentration.

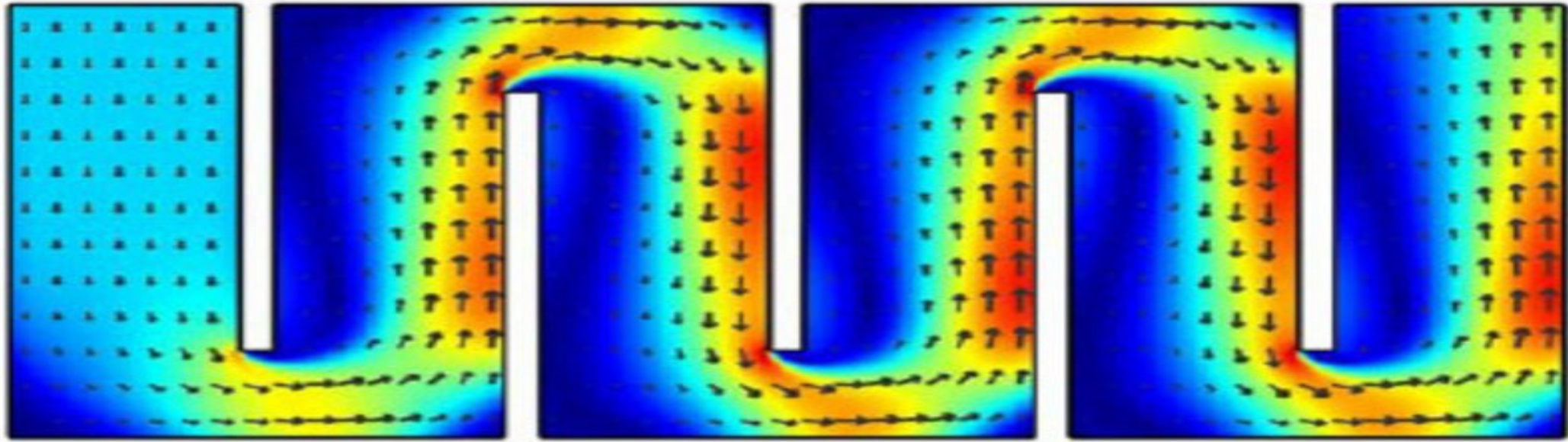


Baffling factor indicates the degree of short circuiting.

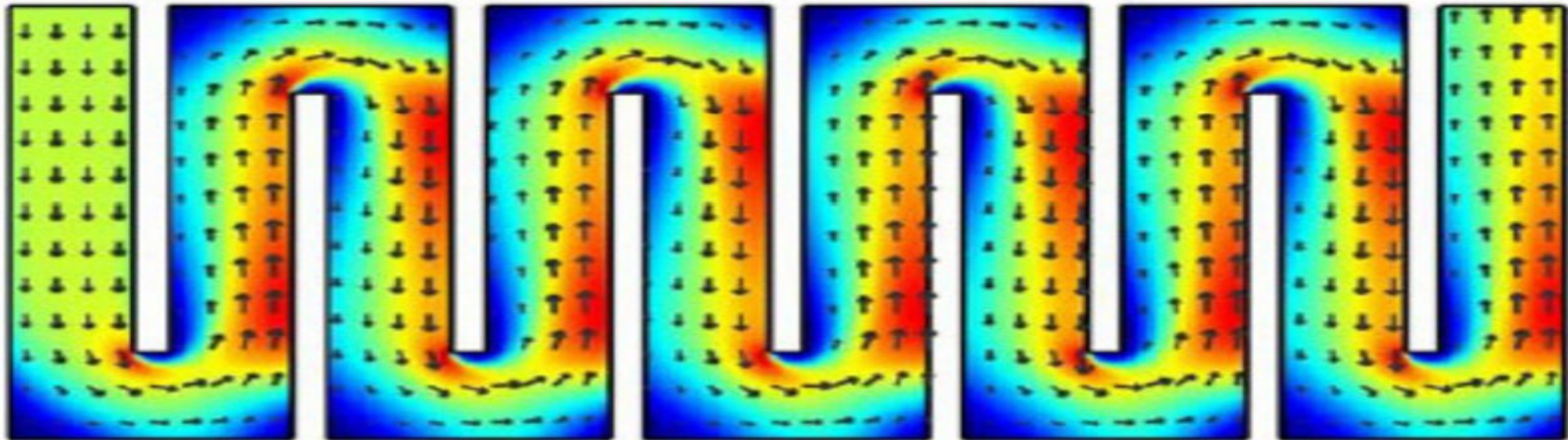


Baffling Condition	Baffling Factor	Baffling Description
Unbaffled (mixed flow)	0.1	None, agitated basin, very low length to width ratio, high inlet and outlet flow velocities.
Poor	0.3	Single or multiple unbaffled inlets and outlets, no intra-basin baffles.
Average	0.5	Baffled inlet or outlet with some intra-basin baffles.
Superior	0.7	Perforated inlet baffle, serpentine or perforated intra-basin baffles, outlet weir or perforated launders.
Perfect (plug flow)	1.0	Very high length to width ratio (pipeline flow), perforated inlet, outlet, and intra-basin baffles.

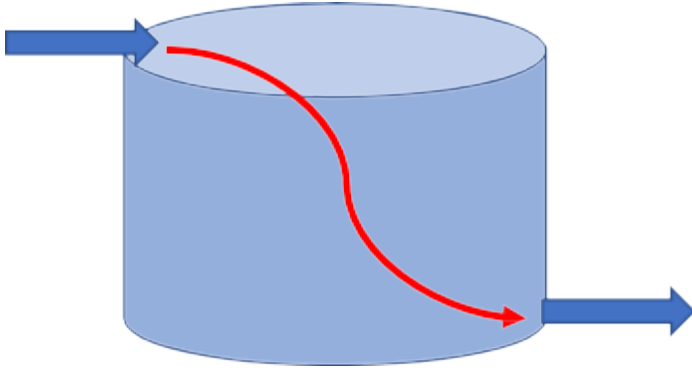
Average baffling



Superior baffling



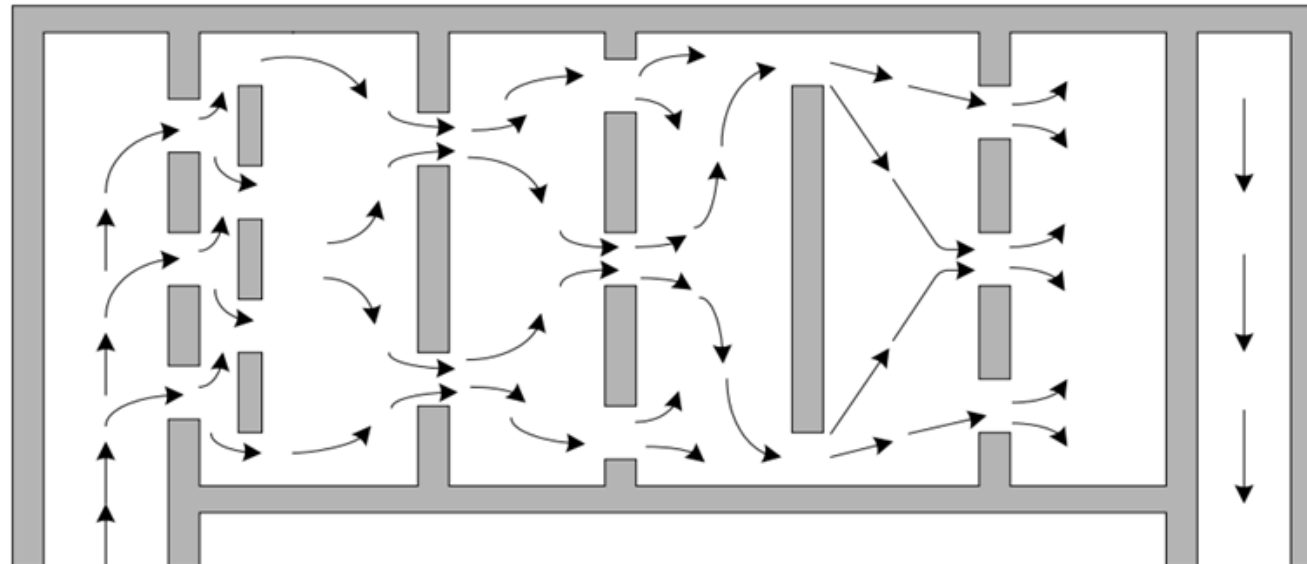
Unbaffled tank **B.F. = 0.1 to 0.3**



Pipeline flow: **B.F. = 1.0**



2. Tank with baffles **B.F. = 0.5 to 0.7**



What is the CT of a system with the following information?

- Chlorine concentration at EP of 0.5 mg/L
- 28 minutes in clearwell between chlorination and EP
- Clearwell baffling factor of 0.3

CT = Concentration x (time x baffling factor)

CT = 0.5 mg/L x (28 minutes x 0.3)

CT = 0.5 mg/L x 8.4 minutes

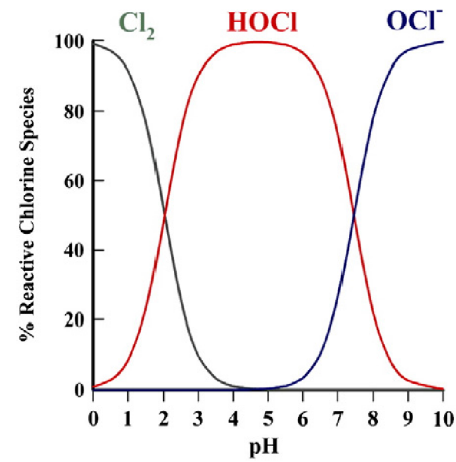
CT = 4.2 mg-min/L

Is this CT sufficient?

CT table - Virus inactivation with chlorine

In our example:

- CT = 4.2 mg-min/L
- Temperature = 15°C
- pH = 8.4



4 log removal of viruses was achieved

	Log Inactivation					
	2.0		3.0		4.0	
pH	6 - 9	10	6 - 9	10	6 - 9	10
Temperature (°C)						
0.5	6	45	9	66	12	90
5	4	30	6	44	8	60
10	3	22	4	33	6	45
15	2	15	3	22	4	30
20	1	11	2	16	3	22
25	1	7	1	11	2	15

Understanding Log Treatment Levels

- 3 log treatment means 99.9% removal or inactivation.
- 4 log treatment means 99.99% removal or inactivation
- The term log refers to an exponent of 10

Illustrative Example

A quantity of raw water contains 1,000,000 microbes and receives 4-log treatment to remove 99.99%.

$$1,000,000 \text{ microbes} - [1,000,000 \times 0.9999] = 100 \text{ microbes remaining}$$

Take aways:

- The quantity of 10^6 microbes was reduced to 10^2 .
- The reduction factor is 10,000 [$10,000 \times 100 = 1,000,000$]
- This reduction factor can be expressed as 10^4 , or 4-log

Table 2-3. CT Values for Inactivation of Viruses in Water at 10°C with pH 6.0–9.0

Disinfectant	CT values (in mg-min/L)		
	2-log Inactivation (99.0%)	3-log Inactivation (99.9%)	4-log Inactivation (99.99%)
Chlorine	3	4	6
Chloramine	643	1,067	1,491
Chlorine Dioxide	4.2	12.8	25.1
Ozone	0.5	0.8	1.0

CT values were obtained from Appendix E (AWWA, 1991).

Table 2-4. CT Values for Inactivation of Giardia Cysts in Water at 10°C with pH 6.0–9.0

Disinfectant	CT values (mg-min/L)					
	0.5-log Inactivation (68.0%)	1-log Inactivation (90.0%)	1.5-log Inactivation (96.8%)	2-log Inactivation (99.0%)	2.5-log Inactivation (99.7%)	3-log Inactivation (99.9%)
Chlorine ¹	17	35	52	69	87	104
Chloramine	310	615	930	1,230	1,540	1,850
Chlorine Dioxide	4	7.7	12	15	19	23
Ozone	0.23	0.48	0.72	0.95	1.2	1.43

CT values were obtained from Appendix E (AWWA, 1991).

¹ at pH 7.0 and chlorine residual ≤ 0.4 mg/L.

Poll: What types of disinfectant do you use at your plant?

- A. Chlorination
- B. Chloramination
- C. Chlorine dioxide
- D. Ozone
- E. UV

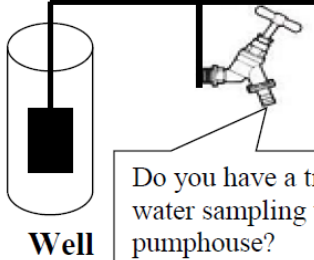
CT Information Worksheet

Complete 1 worksheet for every **Entry Point** for each ground water system you manage.

1 Water System Name: _____ PWS #: _____
 Facility Name: _____ Facility ID: _____ Date Worksheet Completed: _____

4a Name of Tank: _____
 Length of Pipe to Tank: _____ feet
 Diameter of Pipe to Tank: _____ inches
 Flow Rate to Tank: _____ gpm

4b Does the storage tank have:
 a shared inlet/outlet (floating)?
 separate inlet and outlet (direct)?

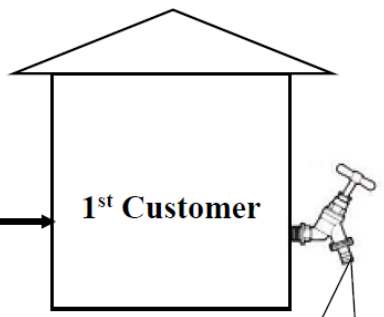
2 **Chlorine**

 Do you have a treated water sampling tap in the pumphouse?
 Free Chlorine Residual: _____ mg/L

3 Do you have a storage tank before the first customer?
 Yes (go to step 4a)
 No (skip to step 5)

4c How big is the storage tank?
 Volume: _____ gallons
 Height: _____ feet
 Diameter: _____ feet

4d What is the tank's lowest operating volume under normal conditions?
 Volume: _____ gallons
 OR
 Level: _____ feet

5 Length of Pipe to 1st Customer: _____ feet
 Diameter of Pipe to 1st Customer: _____ inches
 Flow Rate to 1st Customer: _____ gpm

1st Customer

 Free Chlorine Residual: _____ mg/L
 pH: _____
 Water Temp: _____ °F



Parameter	Value
Diameter of pipe to First Customer (inches)	6
Length of pipe to First Customer (feet)	900
Volume of pipe to First Customer (gallons)	1321.16
Peak flow to First Customer (gpm)	150
Total contact time to First Customer (minutes)	8.8
Temperature at First Customer (°F)	77
Temperature at First Customer (°C)	25
pH at First Customer	7.9
CT from table - based on water temperature & pH (mg-min/L)	2

Minimum Free Chlorine Residual Concentration Required at First Customer (mg/L)	0.23
--	------

Poll: Are you a ground water or surface water system?

- A. Groundwater
- B. Surface water

Poll: Have you ever calculated your CT?

- A. Yes
- B. No

What is the log removal of a system with the following information?

- Chlorine concentration at first customer of 0.41 mg/L
- At peak flow, 40 minutes in clearwell with baffling factor of 0.2
- At peak flow, 12 minutes in pipe going to first customer (baffling factor of 1.0)
- Minimum temperature of 5°C
- Maximum pH of 7.9

- A. 1 log removal
- B. 2 log removal
- C. 3 log removal
- D. 4 log removal

	Log Inactivation					
	2.0		3.0		4.0	
pH	6 - 9	10	6 - 9	10	6 - 9	10
Temperature (°C)						
0.5	6	45	9	66	12	90
5	4	30	6	44	8	60
10	3	22	4	33	6	45
15	2	15	3	22	4	30
20	1	11	2	16	3	22
25	1	7	1	11	2	15

What is the log removal of a system with the following information?

- Chlorine concentration at first customer of 0.41 mg/L
- At peak flow, 20 minutes in clearwell with baffling factor of 0.2
- At peak flow, 4 minutes in pipe going to first customer (baffling factor of 1.0)
- Minimum temperature of 11°C
- Maximum pH of 7.9

Time = time in clearwell x baffling factor + time in pipe x baffling factor

Time = 20 minutes x 0.2 + 4 minutes x 1

Time = 4 minutes + 4 minutes

Time = 8 minutes

CT = Concentration x Time

CT = 0.41 mg/L x 8 min

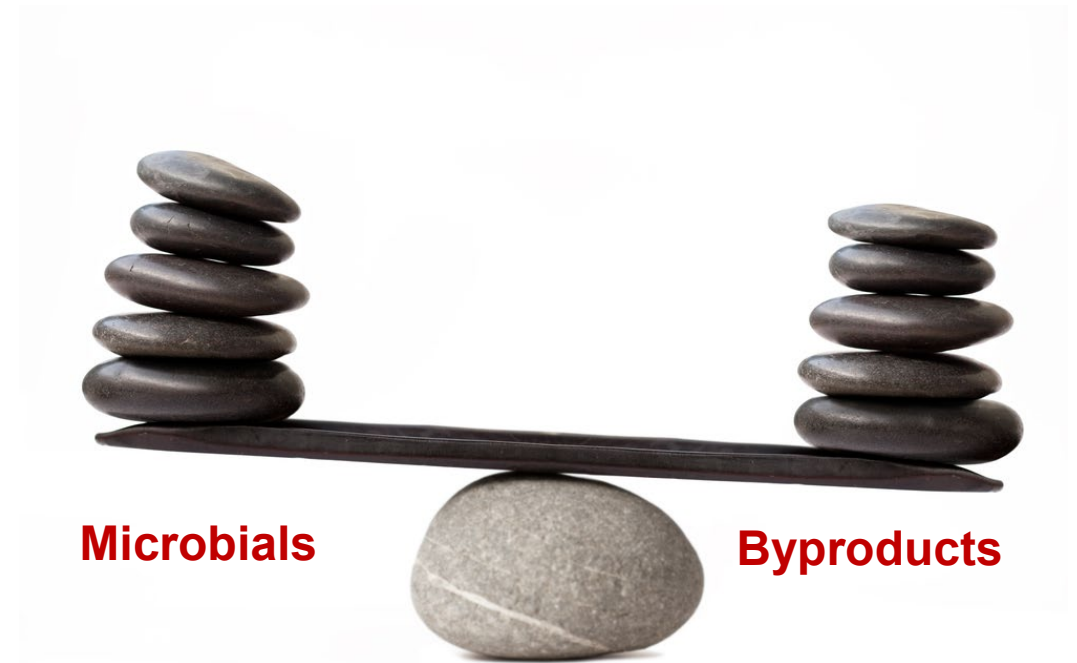
CT = 3.28 mg-min/L

B. 2 log removal achieved

		Log Inactivation					
		2.0		3.0		4.0	
pH	6 - 9	10	6 - 9	10	6 - 9	10	
Temperature (°C)							
0.5	6	45	9	66	12	90	
5	4	30	6	44	8	60	
10	3	22	4	33	6	45	
15	2	15	3	22	4	30	
20	1	11	2	16	3	22	
25	1	7	1	11	2	15	

Disinfection byproducts

- Disinfectant reacts with naturally present substances in the water
 - Fulvic and humic acids
 - Amino acids
 - Organic matter
 - Iodide
 - Bromide
- DBPS include:
 - Trihalomethanes (THMs)
 - Haloacetic acids (HAAs)
 - Bromate
 - Chlorite
 - Other non-regulated DBPs



Testing for chlorine residuals

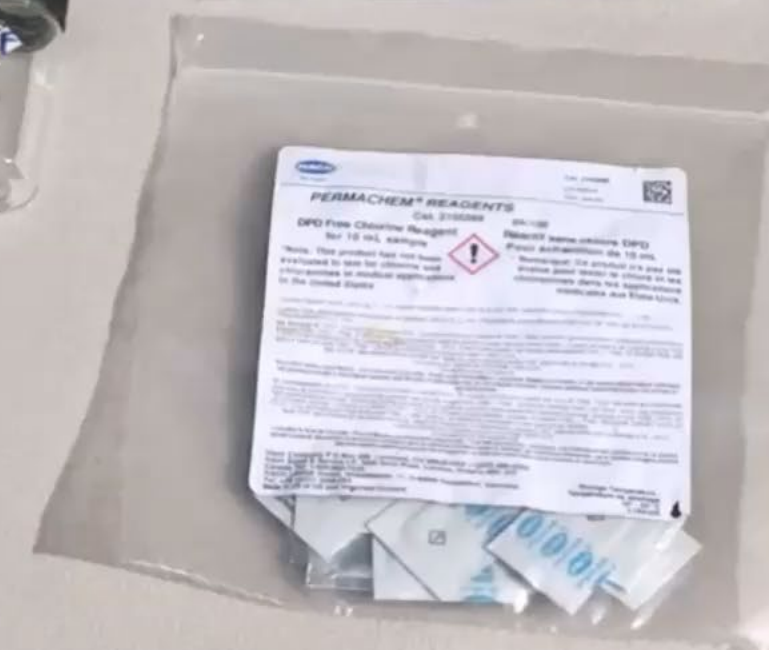
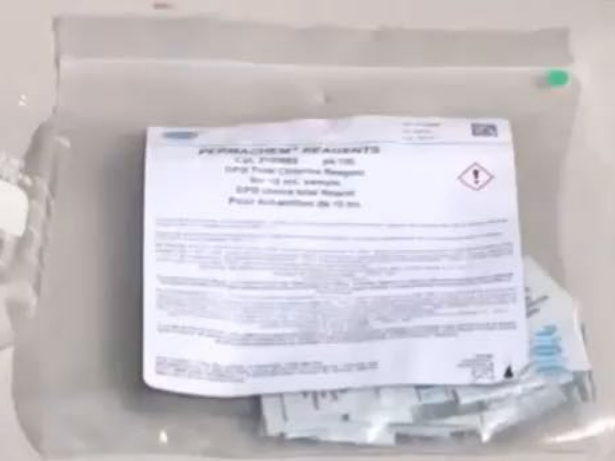
Testing For Chlorine Residuals



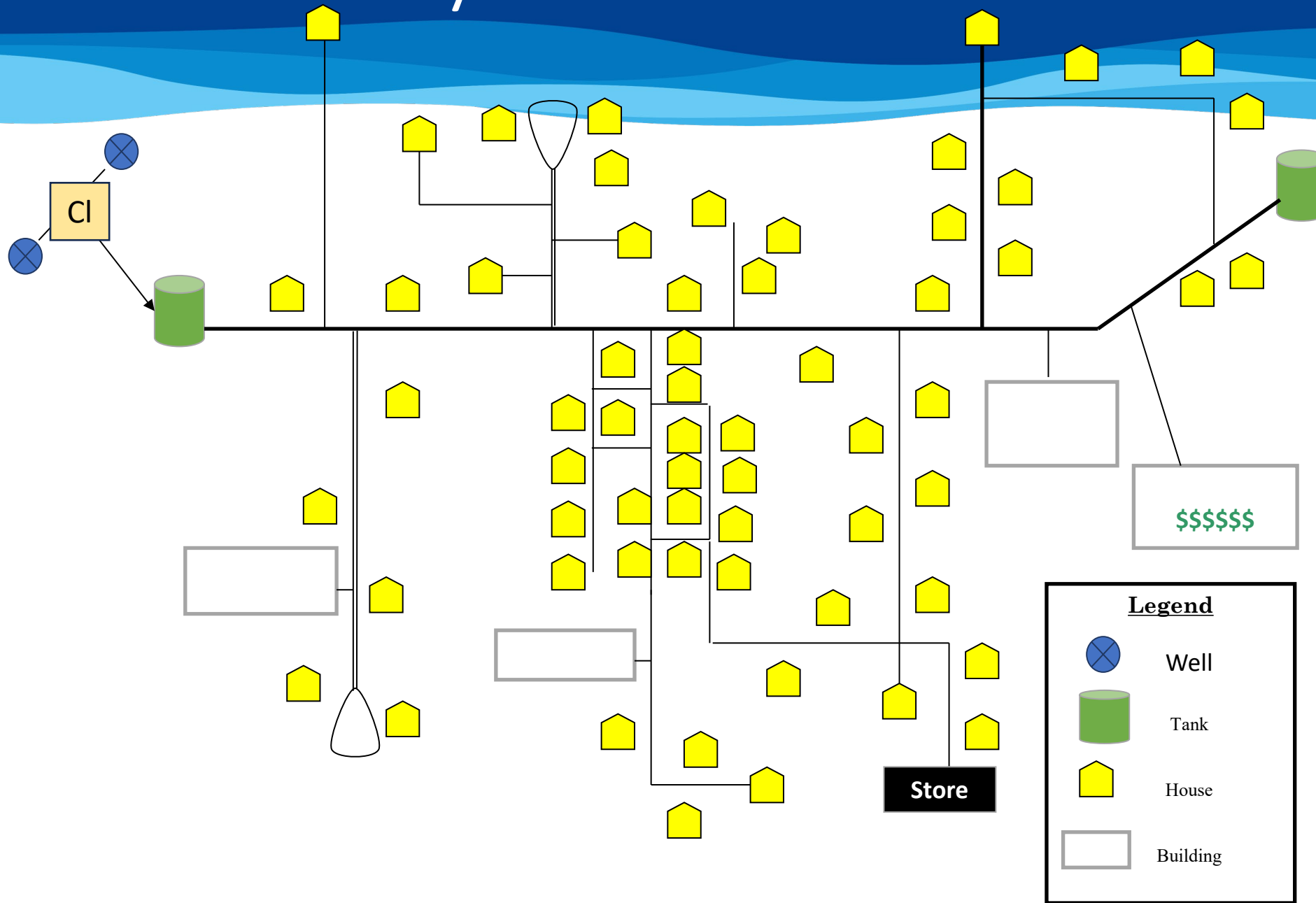
Testing For Chlorine Residuals

- DPD test
- Must be tested within 15 minutes of sampling
- Reagent is added and compared to the blank with a color wheel or a spectrometer/colorimeter
- Reagent for free and total residual

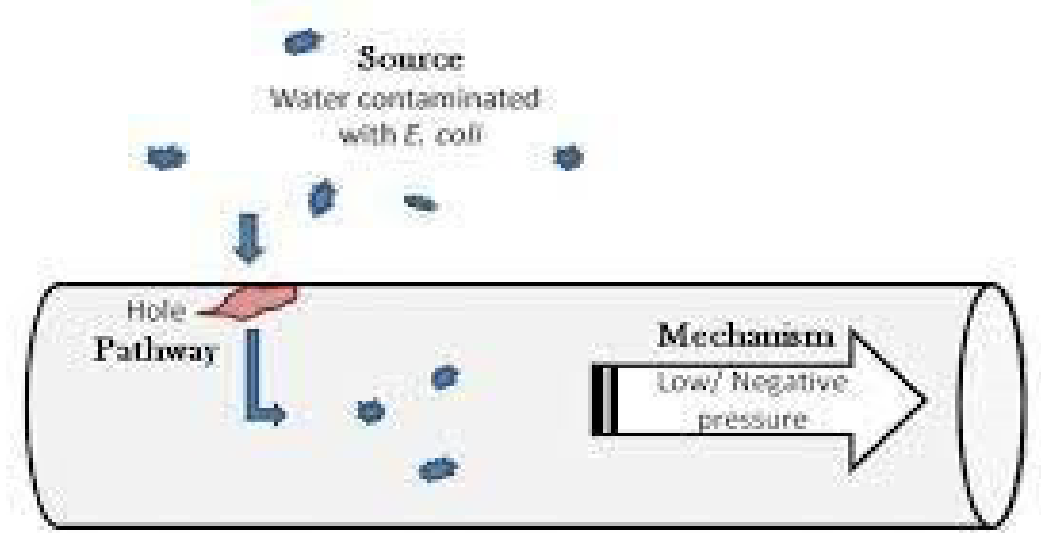




Distribution system

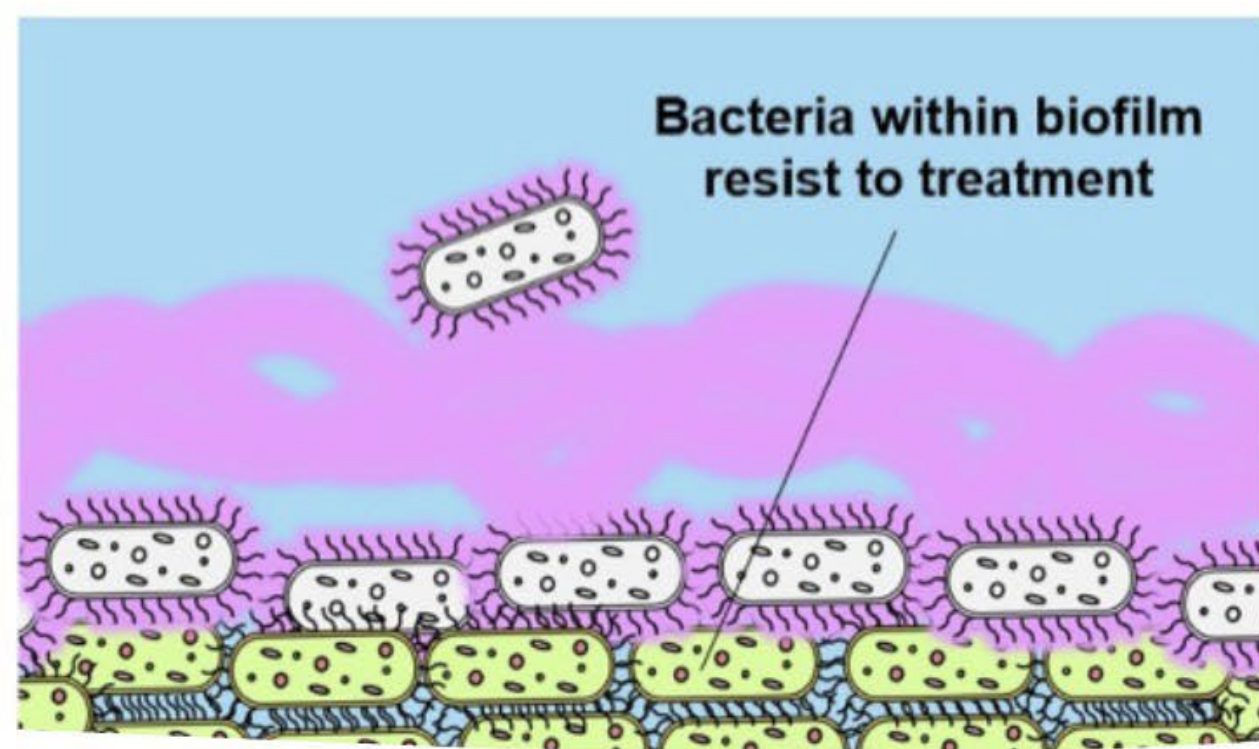
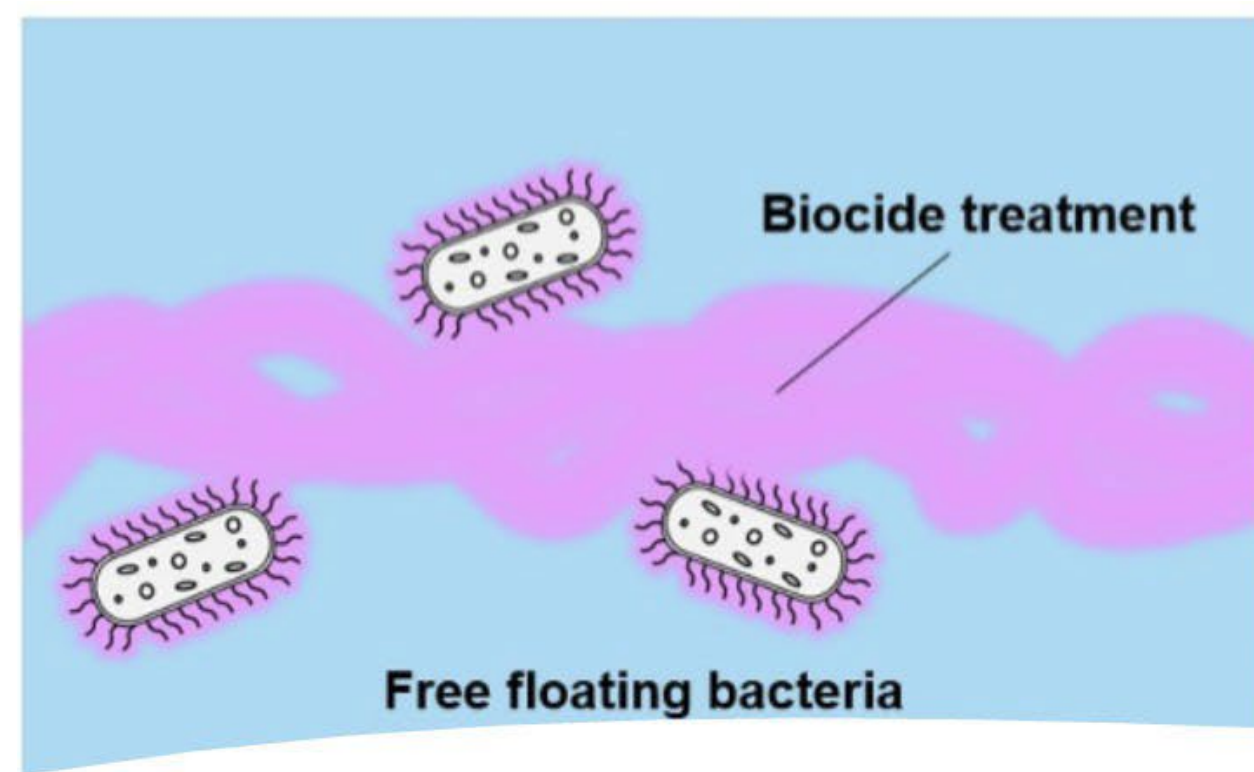


Distribution protection



Important distribution control measures

1. Physical integrity of the distribution system
 2. Continuous positive water pressure (between 20 and 100 psi)
 3. Maintain a chlorine residual (at least 0.20 mg/L)
- Contamination events require a source (contaminated groundwater), a pathway (pipe crack), and a mechanism (low pressure event).
 - After initial disinfection, maintaining a free chlorine residual in the distribution system is a final barrier to protect against contamination, but once the residual is used up, there is no more disinfecting power.
 - Multiple studies correlate water borne disease occurrences with main breaks, main repairs, and low pressure events.

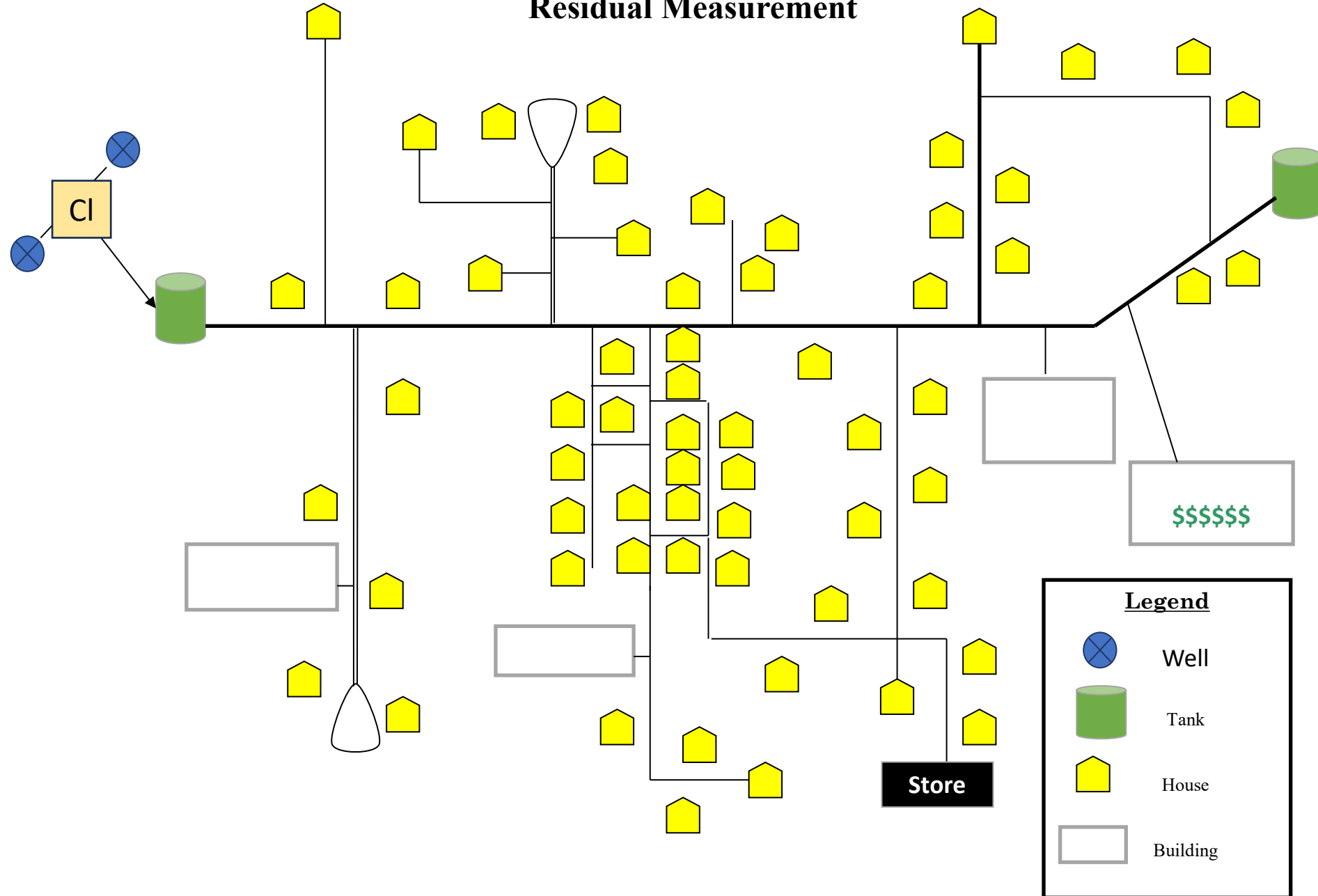


Biofilms protect pathogenic microbes from harsh environmental factors, including **chlorine**, shear stress, heat, inhibitors, and detergents, allowing them to survive (Hemdan et al., 2021).

EPS – Extracellular polymeric substances – gel like substances secreted by bacteria

Waterville

Residual Measurement

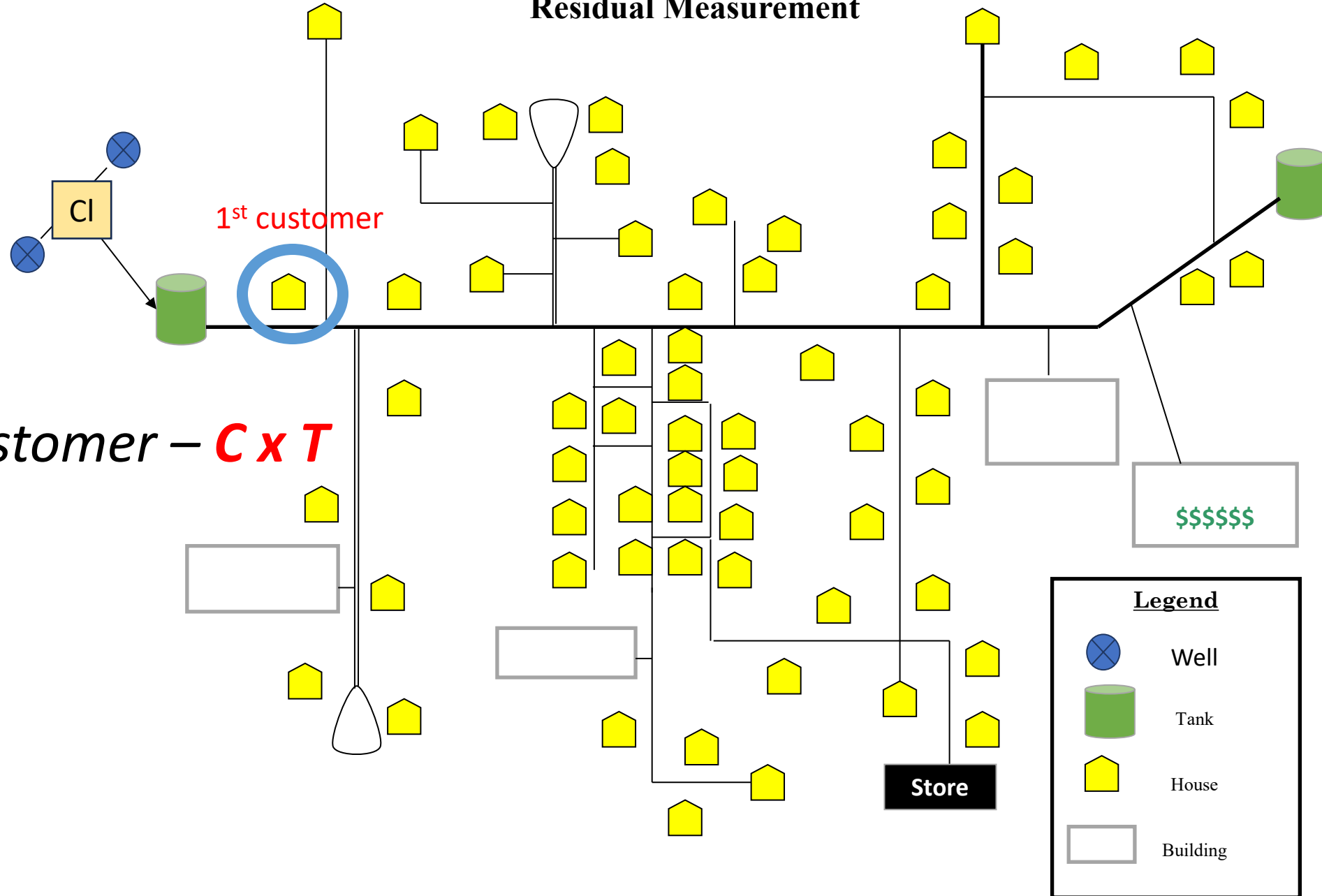


Which customers do we need to consider?

- First customer (CxT)
- Dead ends
- Far ends of the distribution system
- Susceptible populations
 - Hospitals, dialysis clinics, schools

Waterville

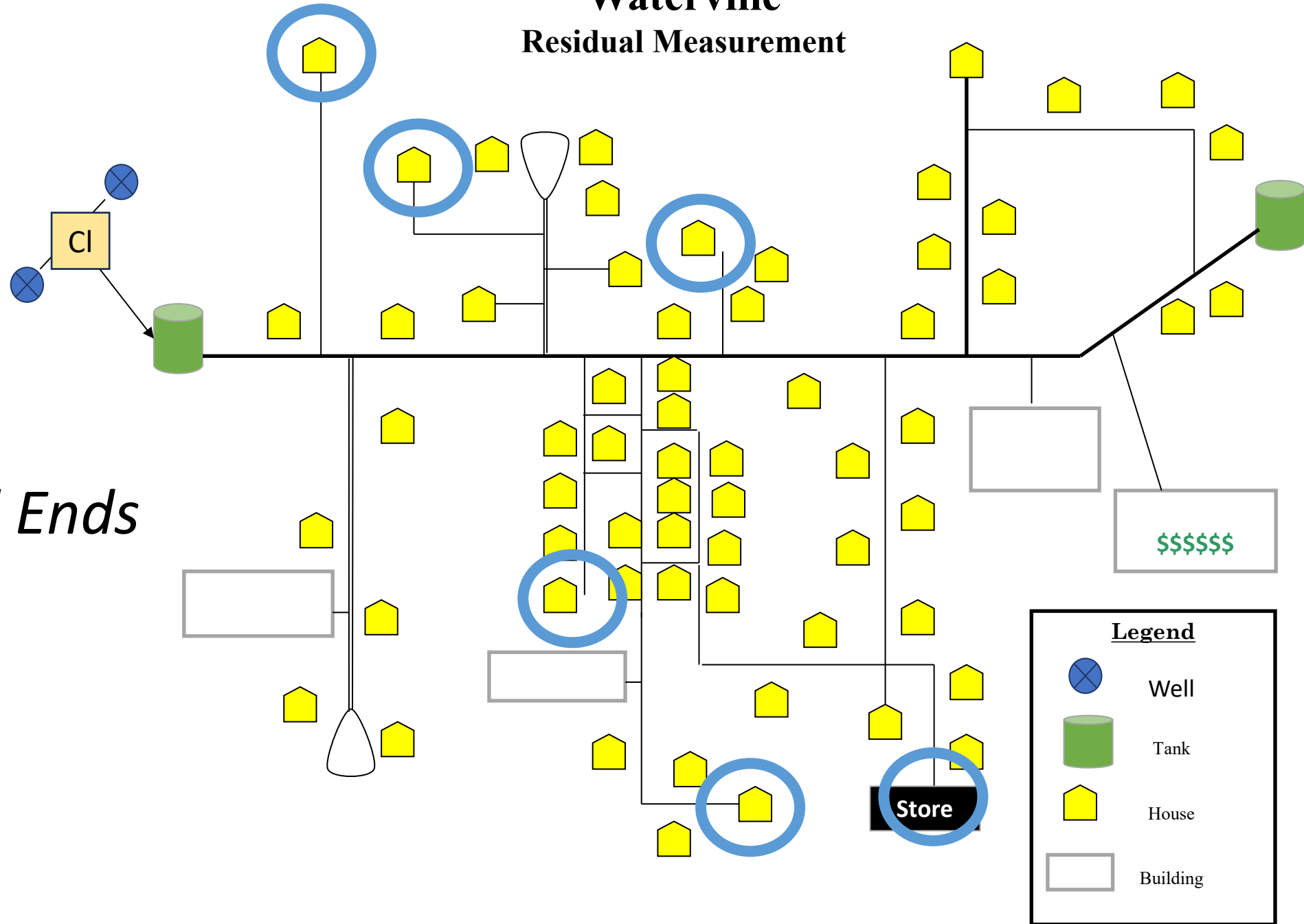
Residual Measurement



Waterville

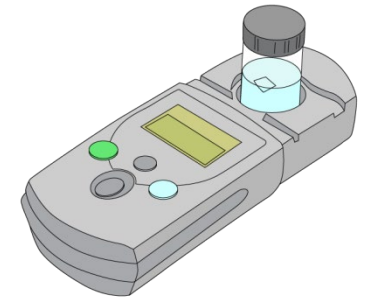
Residual Measurement

Dead Ends

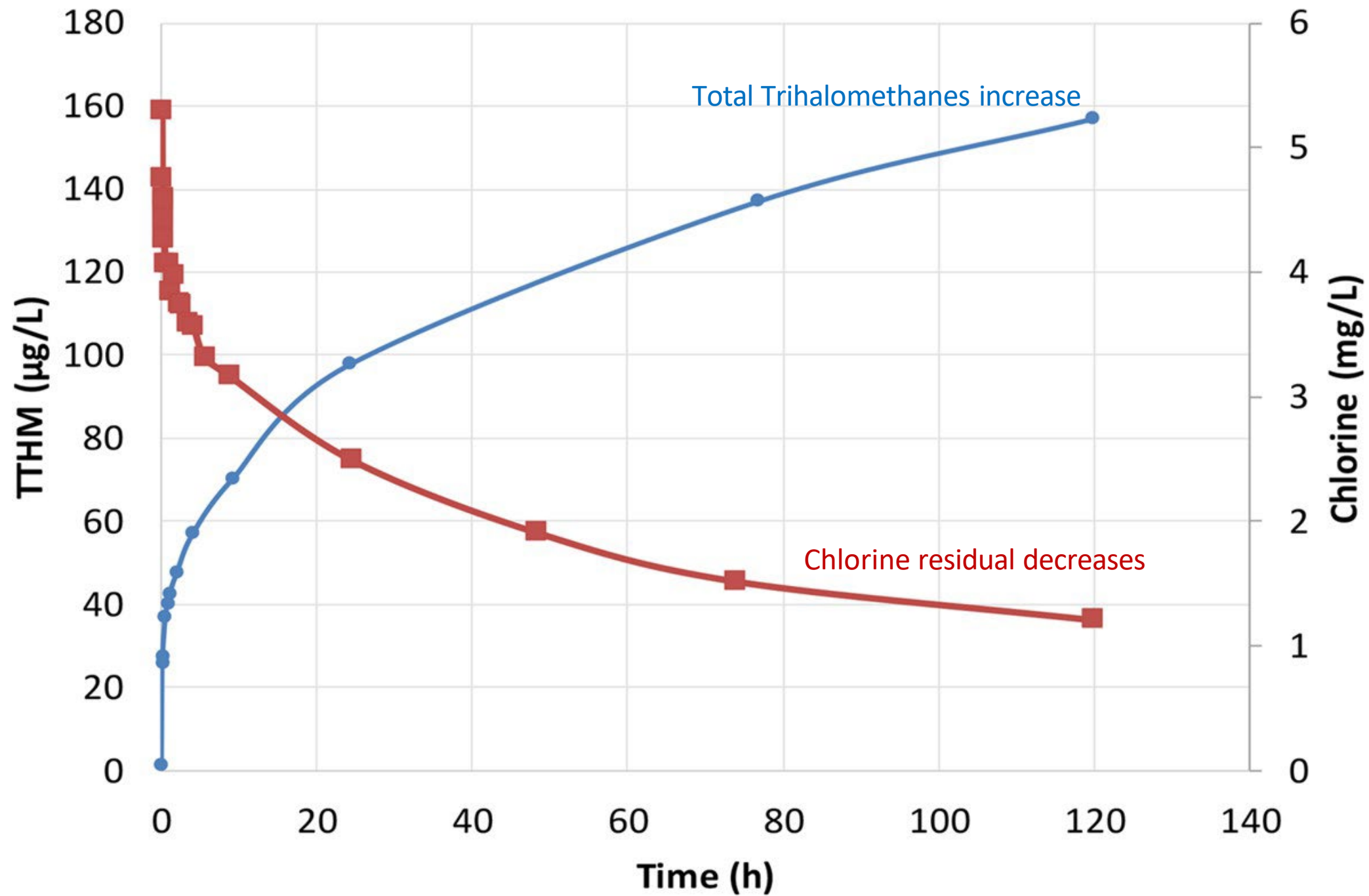


Dead Ends

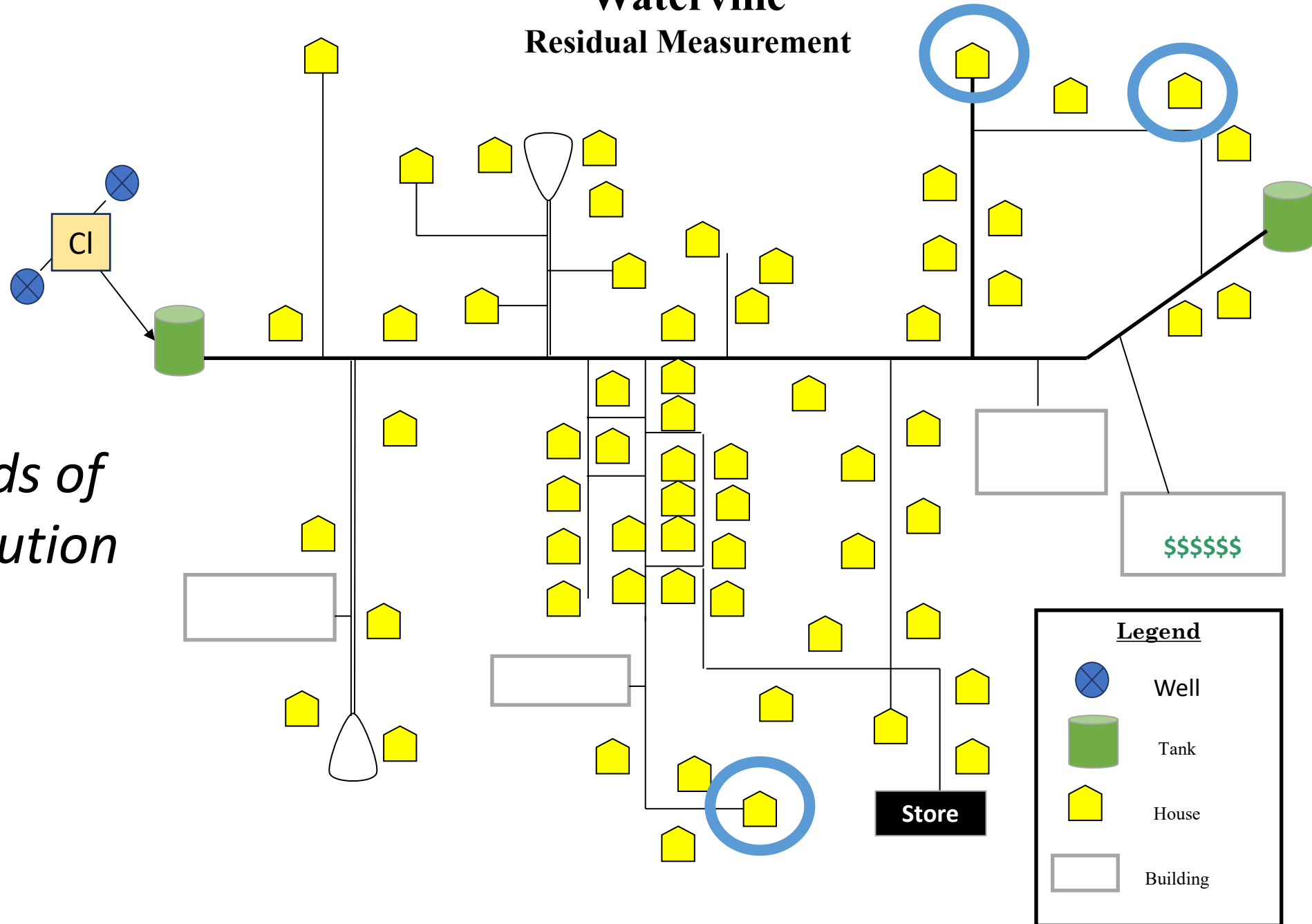
- Chlorine concentrations will be variable compared to the rest of distribution
- Flush dead ends to ensure good chlorine levels - amount and timing depends on system
- Increased biofilm growth
- Increased disinfection byproduct formation (DBPs)



LeChevallier et al. (1996) found that distribution systems that have dead-ends with free chlorine residuals less than 0.2 mg/L or chloramine levels less than 0.5 mg/L had substantially more coliform occurrences (system-wide) than systems maintaining higher residuals.

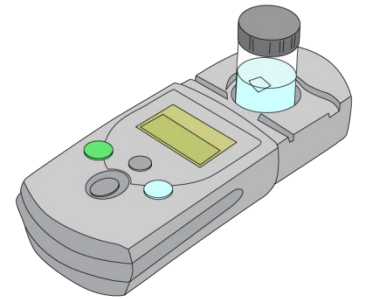


Residual Measurement



Far Ends of Distribution

- Maintain 0.2 mg/L minimum
- May need to increase chlorine at EP to make sure good residual at ends

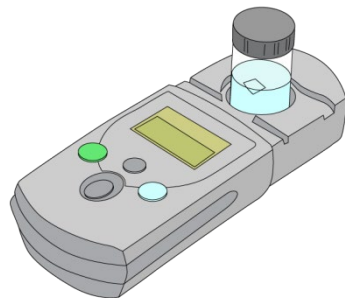


Measuring Residual

Where and When?

After treatment (EP)

- Process Control – **Daily**
- SDWA Compliance Samples – according to compliance schedule



Distribution

- RTCR Sites – Monthly
- DBP Sites –according to compliance schedule
- First Customer – **Daily**
- Dead Ends – **Daily**
- Long Runs – **Daily**
- Far Ends of Distribution – **Daily**
- Susceptible Populations – **Daily**

Chlorine Residual Goals

Chlorine Disinfection & Daily Operations

Written Goals Change How You Operate



Goals Are Not Set in Stone



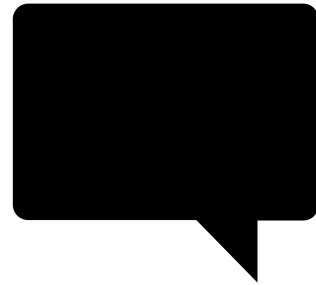
**GOALS
CAN BE
CHANGED**

**OR
ADJUSTED
OVER TIME**

SMART Goals



How much free residual do we
need to protect the customers?



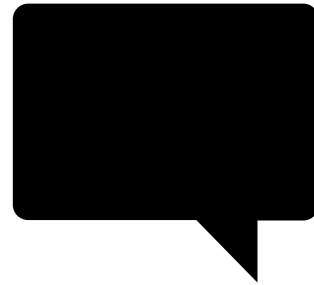
What is your goal for free residual chlorine at the EP?



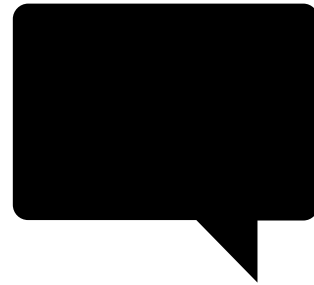
What is your goal for free residual chlorine at the first customer?



What is your goal for free residual chlorine at dead ends?



Under what conditions would you turn up your chlorine feed rate?



Under what conditions would you turn down your chlorine feed rate?



Disinfecting Water Mains

American Water Works Association

ANSI/AWWA C651-99

(Revision of ANSI/AWWA C651-92)



AWWA STANDARD
FOR
DISINFECTING WATER MAINS



The following procedures apply primarily when existing mains are wholly or partially dewatered. After the appropriate procedures have been completed, the existing main may be returned to service prior to the completion of bacteriological testing in order to minimize the time customers are without water. Leaks or breaks that are repaired with clamping devices while the mains remain full of pressurized water may present little danger of contamination and therefore may not require disinfection.

4.7.2 *Swabbing with hypochlorite solution.* The interior of all pipe and fittings (particularly couplings and sleeves) used in making the repair shall be swabbed or sprayed with a 1% hypochlorite solution before they are installed.

4.7.3 *Flushing.* Thorough flushing is the most practical means of removing contamination introduced during repairs. If valve and hydrant locations permit, flushing toward the work location from both directions is recommended. Flushing shall be started as soon as the repairs are completed and shall be continued until discolored water is eliminated.

4.7.4 *Slug chlorination.* Where practical, in addition to the procedures previously described, the section of the main in which the break is located shall be isolated, all service connections shut off, and the section flushed and chlorinated as described in Sec. 4.4.4. The dose may be increased to as much as 300 mg/L and the *CT* reduced to as little as 15 min. After chlorination, flushing shall be resumed and continued until discolored water is eliminated and the chlorine concentration in the water exiting the main is no higher than the prevailing water in the distribution system or that which is acceptable for domestic use.

4.7.5 *Bacteriological samples.* Bacteriological samples shall be taken after repairs are completed to provide a record for determining the procedure's effectiveness. If the direction of flow is unknown, then samples shall be taken on each side of the main break. If positive bacteriological samples are recorded, then the situation shall be evaluated by the purchaser who can determine corrective action. Daily sampling shall be continued until two consecutive negative samples are recorded.

Sec. 4.7 Disinfection Procedures When Cutting Into or Repairing Existing Mains

The following procedures apply primarily when existing mains are wholly or partially dewatered. After the appropriate procedures have been completed, the existing main may be returned to service prior to the completion of bacteriological testing in order to minimize the time customers are without water. Leaks or breaks that are repaired with clamping devices while the mains remain full of pressurized water may present little danger of contamination and therefore may not require disinfection.

4.7.1 Trench treatment. When an existing main is opened, either by accident or by design, the excavation will likely be wet and may be badly contaminated from nearby sewers. Liberal quantities of hypochlorite applied to open trench areas will lessen the danger from this pollution. Tablets have the advantage in this situation, because they dissolve slowly and continue to release hypochlorite as water is pumped from the excavation.

Work shall be started as soon as the repairs are completed and shall be continued until discolored water is eliminated.

4.7.4 Slug chlorination. Where practical, in addition to the procedures previously described, the section of the main in which the break is located shall be isolated, all service connections shut off, and the section flushed and chlorinated as described in Sec. 4.4.4. The dose may be increased to as much as 300 mg/L and the *CT* reduced to as little as 15 min. After chlorination, flushing shall be resumed and continued until discolored water is eliminated and the chlorine concentration in the water exiting the main is no higher than the prevailing water in the distribution system or that which is acceptable for domestic use.

4.7.5 Bacteriological samples. Bacteriological samples shall be taken after repairs are completed to provide a record for determining the procedure's effectiveness. If the direction of flow is unknown, then samples shall be taken on each side of the main break. If positive bacteriological samples are recorded, then the situation shall be evaluated by the purchaser who can determine corrective action. Daily sampling shall be continued until two consecutive negative samples are recorded.

Sec. 4.7 Disinfection Procedures When Cutting Into or Repairing Existing Mains

The following procedures apply primarily when existing mains are wholly or partially dewatered. After the appropriate procedures have been completed, the existing main may be returned to service prior to the completion of bacteriological testing in order to minimize the time customers are without water. Leaks or breaks that are repaired with clamping devices while the mains remain full of pressurized water may present little danger of contamination and therefore may not require disinfection.

4.7.1 *Trench treatment.* When an existing main is opened, either by accident or by design, the excavation will likely be wet and may be badly contaminated from nearby sewers. Liberal quantities of hypochlorite applied to open trench areas will lessen the danger from this pollution. Tablets have the advantage in this situation.

4.7.2 *Swabbing with hypochlorite solution.* The interior of all pipe and fittings (particularly couplings and sleeves) used in making the repair shall be swabbed or sprayed with a 1% hypochlorite solution before they are installed.

contamination introduced during repairs. If valve and hydrant locations permit, flushing toward the work location from both directions is recommended. Flushing shall be started as soon as the repairs are completed and shall be continued until discolored water is eliminated.

4.7.4 *Slug chlorination.* Where practical, in addition to the procedures previously described, the section of the main in which the break is located shall be isolated, all service connections shut off, and the section flushed and chlorinated as described in Sec. 4.4.4. The dose may be increased to as much as 300 mg/L and the *CT* reduced to as little as 15 min. After chlorination, flushing shall be resumed and continued until discolored water is eliminated and the chlorine concentration in the water exiting the main is no higher than the prevailing water in the distribution system or that which is acceptable for domestic use.

4.7.5 *Bacteriological samples.* Bacteriological samples shall be taken after repairs are completed to provide a record for determining the procedure's effectiveness. If the direction of flow is unknown, then samples shall be taken on each side of the main break. If positive bacteriological samples are recorded, then the situation shall be evaluated by the purchaser who can determine corrective action. Daily sampling shall be continued until two consecutive negative samples are recorded.

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Next time:

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/>

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