Calculating and Reporting CT for Ground Water Systems under GWR

Concerns in GW Treatment Systems

- Fecal Contamination from contaminated water sources
- Fecal contamination from tanks open to the atmosphere during the treatment process

Resistance of Water Borne Viral Pathogens (Groundwater)

- Viruses are one of the the most common and resistant disease-causing pathogen
- Systems that remove viruses are removing other pathogens as well
- Standard laboratory tests do not identify virus Inactivation, thus treatment requirements are employed

CT Requirements for Ground Water Systems

#	FAC 62-	Required to Perform CT
1	555.315(6)b 555.315(6) f	Wells that cannot pass the well survey requirements or they have a positive raw water sample for E-coli
2	555.350(5)	GW Systems that must treat for Viral Inactivation
3	555.320 (12)(b)	GW systems that are considered contaminated/Susceptible Microbially
4	555.320 (12)b	GW systems with units exposed to the open during atmosphere treatment

CT Protection May be Provided Under the GWR

- Must be determined by a PE
- Must apply to DEP for Monitoring Exemption by Dec 1 2009.
- Must provide CT for each water source

4-Log WTP Requirements

< 3,300

- **Must meet 0.2 mg/l or higher at first customer**
- **Must monitor on a daily basis and collect grab sample at peak hour flow**
- **If less than 0.2 mg/l residual before first customer must take grab sample every 4 hours until residual residual is met**

> 3,300

- **Must meet 0.2 mg/l or higher at first customer**
- **Must Conduct Continuous Residual Monitoring**
- **Must Record minimum Residual each day**
- **Must monitor at state approved location**

Sanitary Significance of Routine Source Well Monitoring, 62-555.320.12b

Pos. (+) Sample For E. coli	> 2 Mo'ly/Q'rtly Pos. (+) TC but no E. coli
Well is considered microbially contaminated.	Disinfect Well & Bacteriologically Survey Well*
Must provide 4-Log Viral Inactivation	

* As Directed by DEP after 3 + TC in any 12 mo. Period.

Well with Positive E. Coli Sample

- 20 repeat sample
- Consecutive days
- At least 6 hours apart

Note:

- If more than 10% come back TC+ 4-Log Viral Inactivation Required
- If any sample shows fecal indicators then Viral Inactivation Required

Most Frequent (22) Well Contamination Causes

Locating the Cause of Contamination is a requirement in all cases where Wells are deemed microbially contaminated!

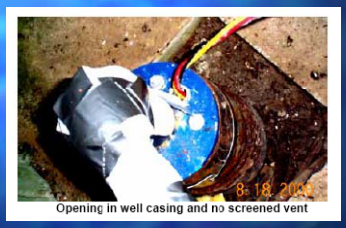
Poor Housekeeping

Poor housekeeping of the well house

Improper Abandonment

Lack of Well Seal

Improper Venting & Screening



Opening in well casing and no screened vent

Corroded Casing Pipe

Roaming Animals in Close Proximity

Intermittent Well Operations

Performing CT Calculations to Provide Microbial Inactivation

CT Value is a WTP Performance Measure

- The CT value is a measure of the performance of the water treatment system
- Meeting or exceeding a required Value is an indicator that Viruses have been removed or Inactivated.
- Viral Inactivation Requirements for Contaminated or Susceptible GW Systems are found in CT tables provided by DEP.

Microbial Inactivation

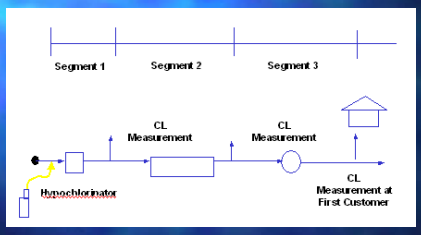
Microbial Inactivation is derived from a table based on the disinfection concentration and the actual contact time in a plant process segment*.

The sum of these microbial inactivation values are used to determine the log reduction for viruses for the Ground Water Treatment System.

* A segment is from a disinfectant dosing point to a residual disinfectant sampling point

Example Schematic

Showing Segments, Disinfectant Injection and Monitoring Points



CT Formula

CT = Concentration X Contact Time X BF

Conc. = residual disinfectant in mg/l

Cont. Time = Time in Contact in specific zone

Baffling Factor = Factor based on Process Unit configuration

Viral Inactivation Requirements for Free Chlorine

Table 2: CT Values for Inactivation of Viruses by Free Chlorine, pH 6-9

Water Temperature **Note: Max DEP Temperature = 18° C**

°F	50	52	54	55	57	58	60	62	64	66	68	70	72	73	74	76
°C	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Log Inactivation	**CT Required (mg-min. / liter)**															
2	3.0	2.8	2.6	2.4	2.2	2.0	1.8	1.6	1.4	1.2	1.0	1.0	1.0	1.0	1.0	1.0
3	4.0	3.8	3.6	3.4	3.2	3.0	2.8	2.6	2.4	2.2	2.0	1.8	1.6	1.4	1.2	1.0
4	6.0	5.6	5.2	4.8	4.4	4.0	3.8	3.6	3.4	3.2	3.0	2.8	2.6	2.4	2.2	2.0

Comparison of CT Values (in mg-min/L) Viral Inactivation @ 10°C, pH 6-9 for Commonly Used Disinfectants

Disinfectant	2-Log Inactivation	3-Log Inactivation	4-Log Inactivation
Free CL	3	4	6
Chloramine*	643	1,067	1,491
CL Dioxide	4.2	12.8	25.1
Ozone	0.5	0.8	1.0

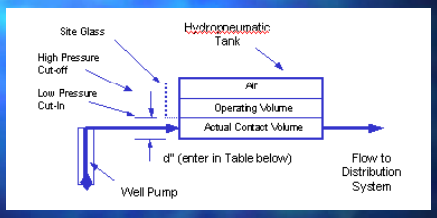
* Chlorine must be added prior to NH_4

Basin Considerations

Basin Capacity Determination

#	Basin Type/Condition	Value to Use
1	All Covered Basins	Minimum Water Level
2	Hydro-Tank	10% of Volume or Min. Recorded Siteglass Level at Cut-in Pressure
3	Water Tank	Min. Water Level minus dead storage
4	Uncovered Filter	Depth of Water below Media minus 60% vol.

Hydropneumatic Tank Configuration



Without Documentation Volume = 10%

Basin Capacity Determination (continued)

#	Basin Type/Condition	Value to Use
5	Covered Sed. Basins	Min. Water above sludge surface
6	Cover Slurry Basin	Min. Depth above highest blanket
7	Clearwell	Min. Water Level
8	Pipelines	Full Volume if submerged

Contact Volumes for Pipelines

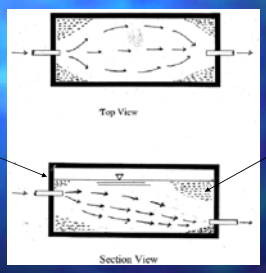
Pipe Diameter (inches)	Volume (gallons per foot)
2	0.16
3	0.37
4	0.65
6	1.47
8	2.61
12	5.88
16	10.44
20	16.3
24	23.5

Baffling Factor Considerations

Baffling Factor Consideration

- Based on Length to Width Ratio and,
- Degree of baffling within the unit and,
- Effect of Inlet Outlet Configuration
- Description and Basin Configuration examples are Provided for Comparison to accurately determine BF Values

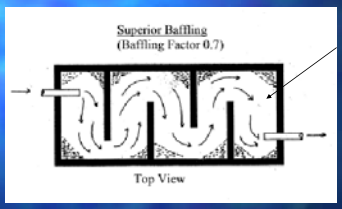
Baffling Example for Worst Tank "Unbaffled Condition"



Note Short Circuiting

Note Dead Spots

Baffling Example for Best Tank "Superior Condition"

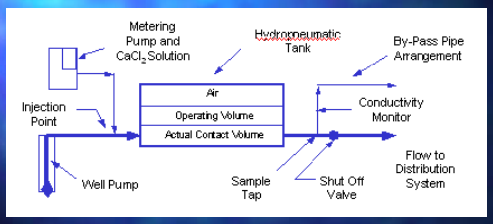


Note Plug Flow Pattern

Baffling Classifications

Condition	Factor T_{10}/T	Description
Unbaffled	0.1	None, agitated basin, very low length to width ratio, high inlet/outlet Velocity
Poor	0.3	Single/multi unbaffled inlet/outlets no intra-baffles
Average	0.5	Baffled inlet or outlet w/ intra baffles
Superior	0.7	Perforated Inlet baffle, serpentine or perf. Intra baffles, outlet weir or perf launders
Perfect	1.0	Very high length to width ratio (pipe flow), perf.. Inlet/outlet, intra-baffles

Determining Baffling Factor Using a Tracer Study



Computing 4-Log Viral Inactivation Using CT Values

Requirements for 4-Log Viral Inactivation

For Contaminated or Susceptible Ground Water Treatment Systems

- 4 Log or 99.99% inactivation of Viruses is Required
- There are Two Inactivation Components:

  1. Log Inactivation Portion
  2. Log Reduction or Credit Portion

CT Credit Calculation for Properly Operated Conventional Filters

Pathogen	GW Requirement	Removal Credit	Inactivation Needed
Viruses	4-Log	2-Log	2-Log

For Other 4-Log Credits, see the following DEP demonstration requirements

Summary of Technologies Used for Virus Treatment; and Virus Inactivation or Removal Credit Claimed for Each Technology

Technology	Virus Inactivation or Removal Credit Claimed, logs
☐ Chemical disinfection using free chlorine	
☐ Chemical disinfection using chloramines	
☐ Chemical disinfection using chlorine dioxide	
☐ Chemical disinfection using ozone	
☐ Ultrafiltration (UF)	
☐ Nanofiltration (NF); or reverse osmosis (RO)	
☐ Ultraviolet (UV) disinfection	
☐ Conventional filtration treatment, including lime softening	
☐ Slow sand filtration	
☐ Direct filtration; or microfiltration preceded by coagulation	
☐ Diatomaceous earth filtration	
☐ Other (describe):	
Total	

Checklist of Information Attached and Included in this Demonstration

Log Reductions or Credit Portion

Only Systems That Use Conventional Filtration (Sand, Dual or Multimedia)

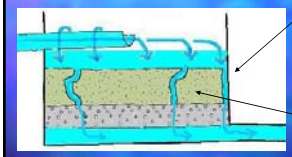
- If yes, then a "Removal Credit" may be applied.
- Combined Filter Turbidity of settled water must be consistently near 1 NTU
- Filter Problems must be absent

Filter Problems

- Mudballs – Formed by chemical deposits of solids during backwashing (leads to coating of media surfaces)
- Surface Cracking – Caused by compressible matter around media at surface
- Media Boils – Caused by too rapid of backwash and displaces gravel support below
- Air Binding – Caused by excessive headloss (infrequent backwashing) allowing air to enter media from below

Large Mudball Typical Size ¼" to 2+" dia.

Surface Cracking in a Filter



Retraction:

Filter Media Separation along wall.

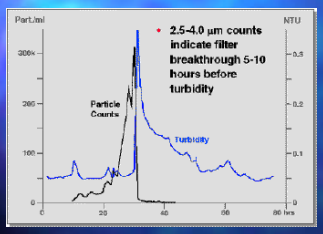
Filter Cracking:

Cracks on the Filter Surface.

- 12 inches long **or**
- ¼-inch wide **or**
- ½-inch deep.

Media Boils in a Filtration System

Filter Operational Problems Breakthrough and Air Binding



Filter Process Control

- Head Pressure
- Timed Run
- Increase in Turbidity

CT Examples

Variables Used in Determining Viral Inactivation (CT) from Tables

- Disinfectant Type
- Disinfectant Concentration
- Temperature
- pH (for Free Chlorine)

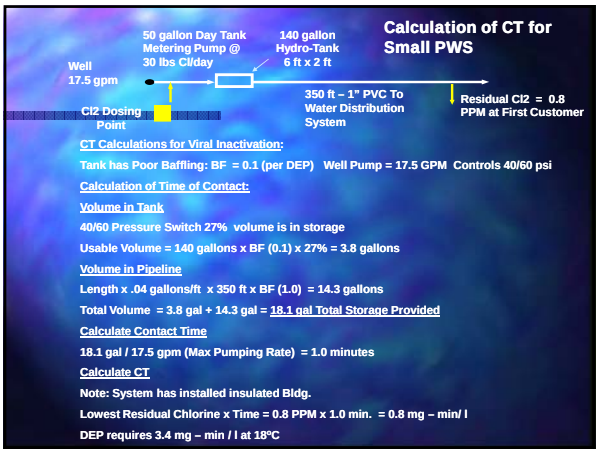
Use Worst Case Conditions

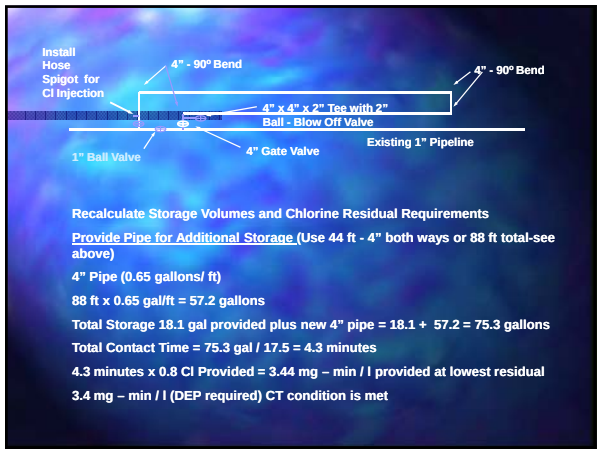
- Maximum Pump Rates
- Minimum Basin Levels
- Minimum Disinfection Residual

Unless Actual Conditions have been Recorded

Components of a Treatment Plant Schematic

- Label the known parameters such as pipe diameters, flow lengths and tank dimensions.
- Label Locations of Disinfection injection points and disinfection residual sampling points
- Develop a daily worksheet based on the plant schematic to simplify calculations.





Collecting Needed Data for CT Calculation

- Measure disinfectant residual concentration, pH and temperature (C°), each day in operation at each disinfection sampling point, i.e. if there are four disinfection feed points there will be four disinfection sampling points.
- There may be more sampling points than feed points.
- The measurements must be taken at peak hourly flow taken from records or from maximum pumping ratings.

Calculating CT Values Procedural Steps

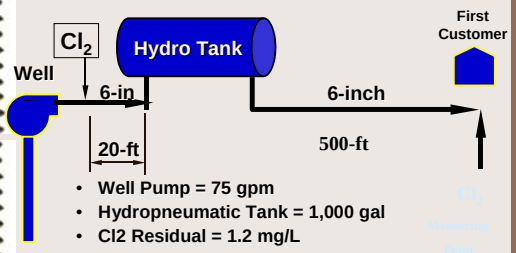
- Use lowest water level for the Basins
- Apply any De-rating factors, i.e. media, sludge, dead storage (for water tanks)
- Always use the lower of measured residual chlorine values
- Calculate tank capacities and apply BF's.
- Calculate CTs for each segment
- Determine Required Log Reductions and subtract filtration removal credits, if any
- Determine Viral Log Inactivation from Table based on pH and Temperature
- Compute Viral Inactivation for each segment
- Add the CTs for each segment and compare to Log-Inactivation Requirement

Examples for Various Water Treatment System Configurations

Six Example Templates are Provided

Find Water Treatment Plant Configuration that most closely matches Your WTP

Step 1 - Prepare Schematic



- Well Pump = 75 gpm
- Hydropneumatic Tank = 1,000 gal
- Cl2 Residual = 1.2 mg/L
- Water = 21ºC, 7.8 pH

Step 2 - Compute Tc for Pipe Segment

- Pipe CT = Conc x T_C x BF

- Well Pump = 75 gpm (Peak Flow)
- 6-inch Pipe = 1.47 gal/foot
- BF for pipe = 1 (MOR Table 1, page 6)
- T_C = (Pipe Length x Pipe Vol) / Peak Flow
- T_C = 520-ft x 1.47 gal/ft / 75 gpm = 10.2 min
- T_C x BF = 10.2 min x 1 = 10.2 min

Step 3 - Calculate Tc for Hydro-Tank Segment

- Tank CT = Conc x T_C x BF

- Well Pump = 75 gpm (Peak Flow)
- 1,000 gal Hydro-Tank @ 10% operating volume*
- BF for Tank = 0.3 (MOR Table 1, page 6)
- T_C = Tank Volume / Peak Flow
- T_C = 10% x 1,000 gal / 75 gpm = 1.3 min
- T_C x BF = 1.3 min x 0.3 = 0.4 min

*Use Tank Volume at minimum water level and minimum operating pressure. Without operating records, this will be 10-20% of the gross tank volume for a hydropneumatic tank pre-pressurized to 5 –10 psig, respectively, below a minimum operating pressure of 35 psig.

Step 4 Calculate CT Combined Segments

- Tc Tank = 0.4 min
- Tc Pipe = 10.2 min
- Tc Total = 10.6 min
- Lowest CT Provided Before or at 1st Customer at Sample Point, During Peak Flow, mg-min/L

- CT = Residual Chlorine Concentration x T_C
- CT = 1.2 mg/L x 10.6 min
- CT = 12.7 mg-min /L

Step 5 – Compare to DEP CT Requirements

- Water Temperature = 21ºC; pH = 7.8
- MOR Table 2, page 6
- CT Values for Inactivation of Viruses by Free Chlorine, pH 6-9 (mg-min/L)

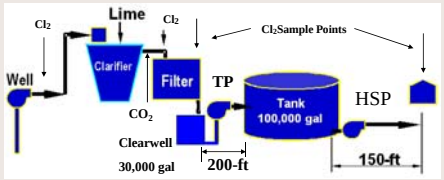
Inactivation (Log)	10ºC	15ºC	20ºC	21ºC	22ºC	23ºC
2	3.0	2.0	1.0	1.0	1.0	1.0
3	4.0	3.0	2.0	1.8	1.6	1.4
4	6.0	4.4	3.0	2.8	2.6	2.4

- Minimum CT Required = 2.8 mg-min/L

Step 6 Calculate 4-Log Viral Inactivation Ratio

- CT Required is 2.8
- CT Calculated for System is 12.7
- 4-Log Viral Ratio = 12.7 / 2.8
- 4-Log Viral Ratio = 4.5
- 4-Log Viral Ratio Required = 1
- For this system the chlorine dose being added at the plant may be higher than necessary to achieve disinfection. High levels of free chlorine can contribute to formation of disinfection by-products.

Basin Exposed to Open Atmosphere During Treatment



- **Pump Peak Flows**
  - Well Pumps, 2 ea 500 GPM
  - Transfer Pump, 500 GPM and 250 GPM
  - High Service Pumps, 2 ea. 1000 GPM and 500 GPM
- **Basins & Pipelines**
  - Filters 3ea. At 10,000 gallons each
  - Clearwell at 30,000 gallons
  - Storage Tank at 100,000 gallons
  - Pipe #1 200'- 12" dia.
  - Pipe #2 150' - 12" dia.

Step #1 - Identify Segments

Chlorine Dosing Point is at entry to Filters

Chlorine Residual measurements are taken at Filter Effluent (sampling point #1) and just before first customer (sampling point #2).

Segment #1 - Through Filters
Segment #2 - Through Clearwell
Segment #3 - Transfer Pump to Tank (pipeline #1)
Segment #4 - Through Storage Tank
Segment #5 - High Service Pump to Sample Point (pipeline #2)

Step #2 – Determine Peak Flow Through Basins & Pipelines

Segment #1 - Through Filters
Combined Wells Capacities
= 2 x 500 GPM = 1000 GPM

Segment #2 - Through Clearwell
Combined Transfer Pump Capacities
= 500 GPM + 250 GPM = 750 GPM

Segment #3 - Transfer Pump to Tank (pipeline #1)
Combined Transfer Pump Capacities
= 500 GPM + 250 GPM = 750 GPM

Segment #4 - Through Storage Tank
Combined High Service Pump Capacities
= 1000 GPM + 500 GPM = 1500 GPM

Segment #5 - High Service Pump to Sample Point (pipeline #2)
Combined High Service Pump Capacities
= 1000 GPM + 500 GPM = 1500 GPM

Step #3 – Assemble Needed Data

Chlorine Residual Measurements
Sample Point #1 = 0.8 mg/l pH = 8.3 Temp. = 21ºC
Sample Point #2 = 0.7 mg/l pH = 8.3 Temp. = 21ºC

Peak Flow Rates
Segment #1 - Through Filters = 1000 GPM
Segment #2 - Through Clearwell = 750 GPM
Segment #3 – Tr. Pump to Tank (pipeline #1) = 750 GPM
Segment #4 - Through Storage Tank = 1,500 GPM
Segment #5 - High Service Pump to Sample Point (pipeline #2) = 1,500 GPM

Refer to Examples to Determine How to Calculate Flow Rates

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