WSA 510 Contact Time (CT) Calculation

Disinfection is a key component to the multi-barrier approach to provide safe drinking water. The effectiveness of disinfection is demonstrated through the concept of contact time (CT), which is defined as a product of a disinfectant residual concentration(C), in mg/L and the effective disinfectant contact time (T), in minutes. The CT value is developed to relate the levels of inactivation under different operational conditions. For all true groundwater systems, a CT value must be achieved that provides a minimum of a 4-log virus reduction/inactivation; while all surface water or Groundwater Under Direct Influence (GUDI) systems, a CT value must be achieved that provides a minimum of a 0.5 log Giardia and 2-log virus reduction/inactivation. Depending on the treatment process, additional Crypto and Giardia removal/inactivation may be required for a surface water source. Significant deterioration of water quality may require further removal or inactivation of viruses, Cryptosporidium and Giardia.

How to perform a CT calculation?

In completing CT calculations, the following operating or design conditions must be applied to determine the effective contact time provided at a water treatment plant:

1) The peak hourly flow rate (typically the pump peak flow);
2) Minimum normal operating level of the storage reservoir, clearwell or tank;
3) The baffling factor for the chlorine contact tank;
4) Minimum disinfectant residual measured at the end of each disinfection segment, or the minimum disinfectant residual allowed in the Permit to Operate;
5) Minimum temperature of the water undergoing disinfection; and
6) Maximum pH of the water undergoing.

The baffling factor (BF) of a contact tank is used to adjust the theoretical detention time to a more realistic value of the CT and reduces the effective storage volume to account for potential short-circuiting. It is expressed as T_{10}/T, where T_{10} refers to the effective contact time, which is the time it takes 10% of the volume of a unit to pass through that unit and T is referred as theoretical detection time. A reliable and accurate method to determine the BF (T_{10}/T) of a disinfection system is through the use of a tracer study or computational fluid dynamics modeling. Otherwise, the baffling factors in Table 1 should be applied based on the geometry and configuration of the chlorine contact tank.

Table 1. Baffle Factor for Different Storage Configurations

Baffling Conditions	Baffling Factor (T10/T)
No contact time: Atmospheric or Hydropneumatic tank with a single combined inlet/outlet	0
Unbaffled : No intrabasin baffles, mixed flow, agitated basin, very low length to wideth ration, high inlet and outlet flow velocities	0.1
Poor: Single or multiple unbaffled inlets and outlets, no intrabasin baffles	0.3
Average: Bafflled inlet or outlet with at least 2 or more intrabasin baffles	0.5
Superior: Perforated inlet baffle with at least 2 or more serpentine or perforated intrabasin baffles. An outlet weir or perforated launders	0.7
Near –Plugflow: High length to width ration of 5:1 or greater pipeline flow	0.9
Plug flow: very high length to width ratio of 40:1 or greater pipeline flow	1.0

Note: Table taken form EPA LT1ESWTR Disinfection Profiling and Benchmarking Technical Guidance Manual

For daily operation at facilities where CT calculation is an on-going operating requirement, CT may be calculated using actual values for reservoir volume, flow, temperature, pH, chlorine residual and other required factors. However, for design purpose, conservative CT calculation must be used to determine if the system will meet CT requirements at all times. For a seasonal operation system, CT calculation for winter and summer conditions may be required to cover the worst case scenario.

In case where more than one disinfectant is used, or where there are multiple disinfectant injection points, disinfection segments should be identified. In the case of multiple disinfection segments, the CT calculation is performed for each individual disinfection segment and then summed to get for the total CT value for the entire system.

Example 1: Groundwater WTP with Chlorine Disinfection

Assuming: A groundwater treatment plant employs chlorine as disinfectant prior to the storage with following operational conditions:

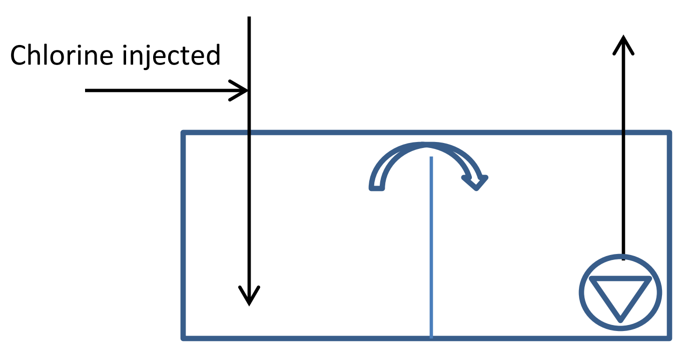

Figure 1. Single Disinfection Segment

Step 1: Collect data and calculate actual CT

Peak hourly flow rate Q = 3500 LPM
Reservoir volume= 700 m^3
Minimum normal operating volume V= 50% of the full reservoir capacity= 350 m^3
Reservoir is rectangular, one baffle, BF=0.3
Minimum Residual chlorine concentration = 0.6 mg/L leaving reservoir
Minimum water temperature = 5 ^oC
Maximum pH = 8.0

Where Effective detection time (T_{10}) = Theoretical detection time (T) × BF

$T = \frac{V}{Q}$ = 100 minutes

T_{10} = 30 minutes

Actual CT= minimum residual chlorine concentration × Effective detection time
= 0.6 mg/L × 30 minutes
= 18 mg-min/L

Step 2: Compare actual CT to required CT

The required CT value for different disinfectant and operational conditions can be obtained from Appendix A, Table 1 -13 of EPB 501 Waterworks Design Standard. In this case, for inactivation of 4-log of viruses at 5 ^oC and pH 8.0 by free chlorine, the required CT value is 8.0 mg-min/L. Actual CT of 18 mg-min/L exceeds the required CT of 8.0 mg-min/L, therefore the CT requirement is met and adequate disinfection is achieved for a groundwater WTP.

Since water treatment facilities rarely operate at pH, temperature and disinfectant residual concentrations that exactly match the value listed in the CT tables, linear interpolations can be made between the tables to determine the CT for the actual conditions.

Example 2: Surface Water WTP with Chlorine Disinfection

Assuming: A surface water treatment plant employs conventional chemical-assisted filtration and chlorine disinfection prior to the reservoir storage. The operational conditions remain the same except the minimum water temperature is 1 ^oC.

Step 1: Collect data and calculate actual CT

The actual CT= 18 mg-min/L (refers to Example 1 step 1)

Step 2: Compare actual CT to required CT

The required CT value for inactivation of 0.5 log of Giardia at 1 ^oC at pH 8.0 by free chlorine should be 46.1 mg-min/L. Actual CT is less than the required CT for Giardia inactivation, therefore, adequate disinfection is not achieved at chlorine residual level of 0.6 mg/L for the surface water treatment plant.

In order to achieve the CT value of 46.1mg-min/L with chlorine disinfection only, the required chlorine residual has to maintain 1.54 mg/L leaving the reservoir in this case. The increased chlorine dosage may lead to elevated disinfection by-products formation. For this reason, sometimes alternative disinfection is desirable. These alternate disinfectants for drinking water treatment include ultraviolet (UV), chlorine dioxide, chloramines, and ozone.

Example 3: Multiple Disinfection Segments for Surface Water WTP

Assuming: A surface water treatment plant employs conventional chemical-assisted filtration with ozone disinfection and chlorine disinfection prior to the reservoir. Because there are two disinfectants injected into the filtered water, the CT calculation is divided into two disinfection segments, with segment 1 for ozone disinfection and segment 2 for chlorine disinfection.

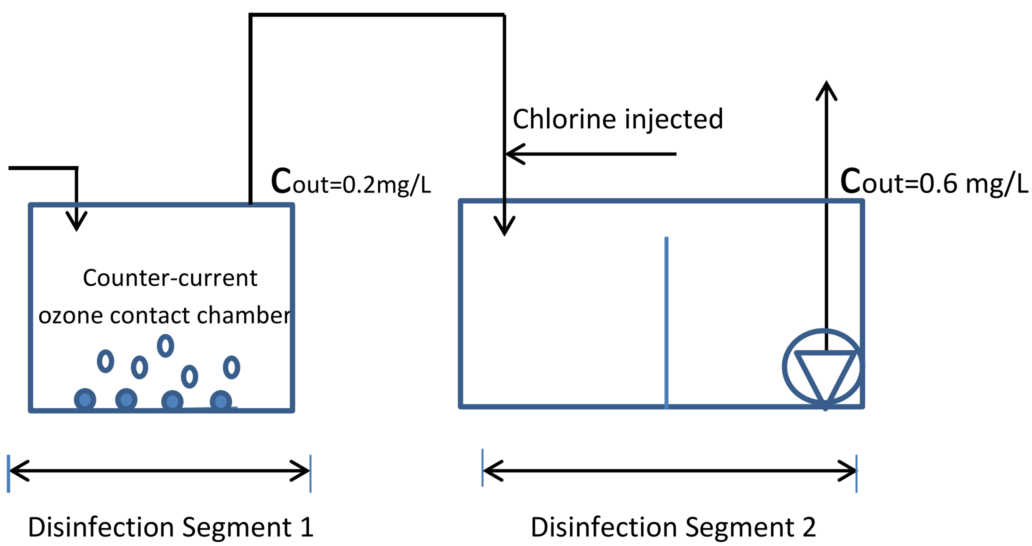

Figure 2. Multiple Disinfection Segment

Step 1: Calculate CT value for Ozone disinfection Segment 1

Given: Results from a tracer study showed that the T_{10} for the ozone contact chamber is 4 minutes; Minimum ozone residual concentration measured at the outlet of the chamber = 0.2mg/L for a counter-current flow chamber. For CT calculation purpose, the ozone residual concentration is C= ½ C_{out}=0.1mg/L in a counter-current flow chamber.

Water temperature = 1 ^{o}C

pH =8.0

Then : Actual CT for ozone segment 1 = 0.1 mg/L × 4 minutes =0. 4 mg-min/L.

Step 2: Calculate the Giardia log credit for Ozone Segment 1

According to Table 12, Appendix A of EPB 501 Waterworks Design Standard, at water temperature 1 ^{o}C, CT value for 2.5 log of Giardia inactivation is 2.4 mg-min/L, therefore, for calculated CT value of 0.4 mg-min /L, the Giardia log removal by ozone segment 1 =(0.4//2.4) × 2.5 log= 0.417 log.

Step 3: Calculate CT value for Chlorine Disinfection Segment 2

Assuming all the operational conditions remain identical to the Example 2 step 1,

Actual CT value for chlorine Segment 2 = 18 mg-min/L.

Step 4: **Calculate Giardia inactivation log for chlorine segment 2**

Because the required CT value for inactivation of 0.5 log of Giardia at 1 ^{o}C at pH 8.0 by free chlorine should be 46.1 mg-min/L, the actual Giardia log inactivation by chlorine = (18 mg-min/L/46.1 mg-min/L) × 0.5 log = 0.195 log.

Step 5: Calculate total log inactivation of Giardia

Total Giardia log inactivation = Ozone Disinfection Segment 1+ Chlorine Disinfection Segment 2

= 0.417log + 0.196 log

= 0.613 log

Thus, by introducing the ozone disinfection ahead of the chlorination, the total Giardia log inactivation exceeds the disinfection requirement for the surface water treatment plant.