BASICS -

4-LOG VIRUS INACTIVATION THROUGH CHLORINE DISINFECTION

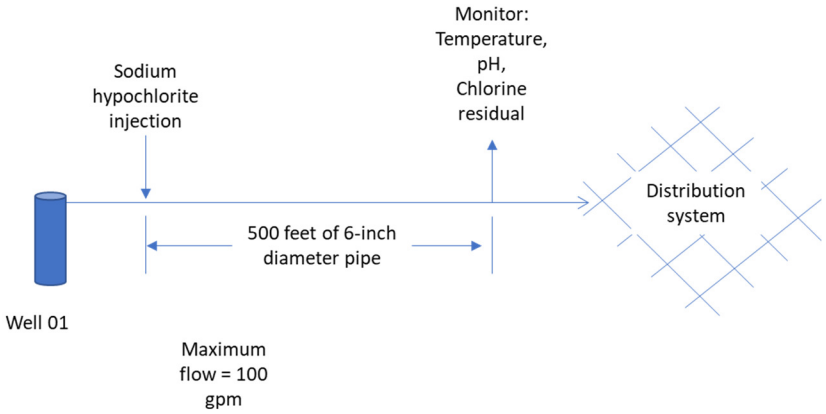
If a water system is required to provide 4-log virus inactivation through chlorine disinfection, the chlorination system must be maintained to provide continuous, reliable disinfection. At a minimum, a **daily** grab sample must be obtained and monitored for chlorine residual, temperature, pH, and peak flow rate of the disinfected water. Continuous monitoring equipment is recommended. The water system must monitor and maintain a chlorine residual concentration to ensure that 4-log virus inactivation is provided **at all times**.

Inactivation through chlorination is a function of the chlorine concentration (C) and the time (T) the water is in contact with the chlorine before it reaches the first customer or its compliance monitoring point. CT is chlorine concentration (C) multiplied by the time (T) that the water is in contact with the chlorine. The water system must describe and provide calculations demonstrating how it will provide 4-log virus inactivation under worst case conditions.

Water systems must provide a system schematic indicating the location of chlorine injection, location of compliance monitoring, length and diameter of piping used for CT, and/or dimensions of CT tank. Water systems must monitor the chlorination system on a daily basis and must provide a monthly report to the Department by the 10th day of the following month. Upon receipt of the schematic, the Department can provide the water system with a customized spreadsheet to calculate the virus inactivation for its system.

Two examples of CT calculations are provided below.

Example 1:



- A water system injects chlorine into a 6-inch diameter pipe.
- The chlorine residual compliance monitoring point is 500 feet from the point of chlorine injection

- Maximum flow = 100 gallons per minute (gpm)
- Chlorine residual at the compliance monitoring point is 1.5 mg/L.
- pH of the water ranges from 6.5 to 8.1
- Temperature of the water is 5℃

CT is chlorine concentration (C) multiplied by the time (T) that the water is in contact with the chlorine.

Based on 500 feet of 6-inch pipe, the pipe volume = 98.175 ft^3 or 734 gallons.

$$Pipe\ Volume = \pi \times \left(\frac{Diameter\ of\ Pipe}{2}\right)^2 \times (Length\ of\ Pipe)$$

$$Pipe\ Volume = 3.14 \times \left(\frac{0.5\ ft}{2}\right)^2 \times (500\ ft) = 98.175\ ft^3$$

$$NOTE: \quad 1\ ft^3 = 7.48\ gallons$$

$$98.175\ ft^3 \times 7.48 = 734\ gallons$$

The time that the water is in contact with the chlorine is pipe volume (gallons) divided by maximum flow (gpm), which equals 7.34 minutes. CT = 1.5 mg/L multiplied by 7.34 minutes equals **11** minutes-milligram/liter.

$$Time\ in\ Contact\ (T) = (Pipe\ Volume) \div (Maximum\ Flow)$$

$$Time\ in\ Contact\ (T) = (734\ gallons) \div (100\ gpm) = 7.34\ minutes$$

$$CT = (Chlorine\ Residual) \times (Time\ in\ Contact)$$

$$CT = \left(1.5\frac{mg}{L}\right) \times (7.34\ \text{min}) = 11\frac{min * mg}{L}$$

Look at Table 1 below. For a temperature of 5℃ and pH between 6 - 9, the CT value must be at least **8** minutes-milligram/liter.

$$CT = \left(11\frac{min * mg}{L}\right) which\ is\ greater\ than\ the\ minimum\ \left(8\frac{min * mg}{L}\right).$$

Therefore the system provided at least 4-log virus inactivation.

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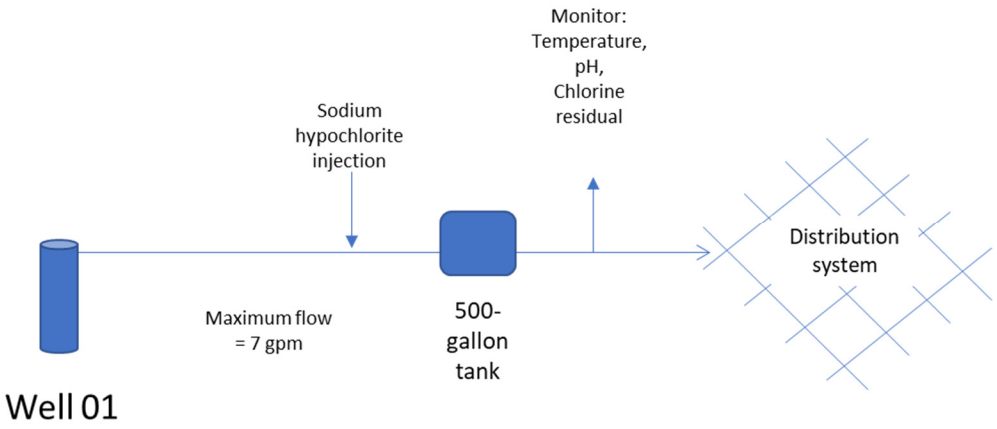
Example 2:



- 500-gallon tank
- Lowest tank volume = 100 gallons
- Unbaffled; baffling factor = 0.10
- Maximum flow = 7 gpm
- Chlorine residual 0.5 mg/L
- pH of the water is 8
- lowest temperature of the water is 10℃

If the chlorinated water goes into a 500-gallon tank prior to reaching the first customer, then the water system may monitor the chlorine residual after the tank. The contact volume would be the lowest volume of the tank multiplied by a baffling factor, (also sometimes called a short-circuiting factor), which is typically 0.10 for an unbaffled tank.

$$Contact\ Volume = (Lowest\ Volume\ of\ Tank) \times (Baffling\ Factor)$$

For example, an unbaffled 500-gallon tank with a lowest tank volume of 100 gallons would have a contact volume of 10 gallons (100 gallons multiplied by the baffling factor of 0.10).

$$Contact\ Volume = (100\ gallons) \times (0.10) = 10\ gallons$$

At a flow of 7 gpm, the contact time is 10 gallons divided by 7 gpm, which equals 1.4 minutes.

$$Time\ in\ Contact\ (T) = (10\ gallons) \div (7\ gpm) = 1.4\ minutes$$

If the chlorine residual is 0.5 mg/L, then CT is 0.5 mg/L multiplied by 1.4 minutes, which equals **0.7** minutes-milligrams per liter.

$$CT = \left(0.5\frac{mg}{L}\right) \times (1.4\ \text{min}) = 0.7\frac{min * mg}{L}$$

Looking at the table below, if the pH is 8 and the temperature is 10℃, then the CT must be at least **6** minutes-milligrams per liter.

$CT = \left(0.7\frac{min * mg}{L}\right) which\ is\ less\ than\ the\ minimum \left(6\frac{min * mg}{L}\right).$

Therefore the System in Example 2 would **NOT** meet 4-log virus inactivation.

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TABLE 1.
CT VALUES FOR
4- LOG INACTIVATION OF VIRUSES
BY FREE CHLORINE
(minutes-milligram/liter)

Temperature (℃)	pH	
	6-9	10
0.5	12	90
5	8	60
10	6	45
15	4	30
20	3	22
25	2	15

CT Compliance for Viruses by Free Chlorine

Water System: _____

System Number: _____ **Month and Year:** _____

Transmission Pipe or Tank Volume: _____ Gallons

Date	Flow Rate, gpm	Effective Contact Time, minutes	Temperature, °C	Chlorine Residual, mg/L	Calculated CT	4-log virus Inactivation? Y/N
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						
Min						
Median						
Max						

Print Name: _____

Signature: _____ **Date:** _____