Chlorine Contact Time Calculations

Steps to solving a math problem:

a. Read the problem and write down what is "given".
b. Determine what is being requested with the correct units.
c. Cross out anything "given" that has nothing to do with solving the problem.
d. Select the appropriate formulas & factors.
e. Write down the formula in vertical format.
f. Plug in the "given" numbers into the formula.
g. Make sure units on both sides of the equation match.
h. Convert all units to the same form using conversion factors in vertical format to cancel out like units in the numerator & denominator.
i. Solve the problem.

Equations:

\[
\text{Total detention time} = \frac{\text{Lowest operating volume}}{\text{Peak flow}}
\]

The operating volume should be taken during peak hour demand but the lowest operating volume may be substituted with Safe Drinking Water Branch’s approval.

\[
\text{Contact time} = \text{Total detention time} \times \text{Baffling factor}
\]

\[
CT\;calc = \text{Residual chlorine concentration} \times \text{Contact time}
\]

\[
\text{Inactivation Ratio} = \frac{CT\;calc}{CT\;req}
\]

4log virus inactivation check: \(\text{Inactivation ratio} \times 4 \geq 4 \rightarrow OK!\)

4log virus inactivation check: \(\text{Inactivation ratio} \times 4 < 4 \rightarrow \text{Rework Calculated Parameters}\)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>None, agitated basis, very low length to width ratio, high inlet and outlet flow velocities. Enclosed circular or rectangular tank with single inlet and outlet line. Enclosed circular or rectangular tank with inlet on top and outlet on the bottom, either directly below or on the same side as the inlet line.</td>
</tr>
<tr>
<td>0.3</td>
<td>Single or multiple unbaffled inlets and outlets, no intra-basin baffles. Enclosed circular or rectangular tank with inlet on top and outlet on the bottom on the opposite wall.</td>
</tr>
<tr>
<td>0.5</td>
<td>Baffled inlet or outlet with some intra-basin baffles.</td>
</tr>
<tr>
<td>0.7</td>
<td>Perforated inlet baffle, serpentine or perforated intra-basin baffles, outlet weir or perforated launders.</td>
</tr>
<tr>
<td>1</td>
<td>Very high length to width ratio (pipeline flow), perforated inlet, outlet, and intra-basin baffles.</td>
</tr>
</tbody>
</table>
Table B-2 – CTreq values for 4-log virus inactivation of viruses by free chlorine in mg/L•min

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6-9</td>
</tr>
<tr>
<td>0.5</td>
<td>12</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>15</td>
<td>4</td>
</tr>
<tr>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>25</td>
<td>2</td>
</tr>
</tbody>
</table>

1. Is the water system providing 4-log virus inactivation using 12.5% sodium hypochlorite?

**Given**

- Well capacity = 100 gpm
- Residual chlorine concentration = 0.1 mg/L free chlorine, measured at the outlet of the tank
- Tank’s total capacity = 50,000 gallons
- Tank’s lowest operating volume = 25,000 gallons
- Booster pump capacity = 250 gpm
- Tank has no baffles with a separate inlet and outlet. The inlet is located at the top of the tank and the outlet is located at the bottom of the tank on the opposite wall.
- pH = 7.5
- Temperature = 20°C

**Find**

If the water system is providing 4-log virus inactivation.

**Not Relevant**

- The well capacity has no bearing on the peak flow of the water system.
- Using the tank’s total capacity will increase the results and not cover the most conservative situation when the tank is at its lowest operating volume.

**Solution**

*From Table 3-2, Baffling factor = 0.3.*
*From Table B-2, CT req = $3 \frac{mg}{L \cdot min}$*
*Peak Flow = 250 gpm*
Total detention time = \frac{\text{Lowest Operating Volume}}{\text{Peak flow}}

Total detention time = \frac{25,000 \text{ gallons}}{250 \text{ gal/min}}

Total detention time = 100 \text{ min}

Contact time = Total detention time \times Baffling factor

Contact time = 100 \text{ min} \times 0.3

Contact time = 30 \text{ min}

CT_{calc} = \text{Residual chlorine concentration} \times \text{Contact time}

CT_{calc} = 0.1 \frac{\text{mg}}{\text{L}} \times 30 \text{ min}

CT_{calc} = 3 \frac{\text{mg}}{\text{L} \cdot \text{min}}

Inactivation ratio = \frac{CT_{calc}}{CT_{req}}

Inactivation ratio = \frac{3 \frac{\text{mg}}{\text{L} \cdot \text{min}}}{3 \frac{\text{mg}}{\text{L} \cdot \text{min}}}

Inactivation ratio = 1

4\log \text{ virus inactivation check} = \text{Inactivation ratio} \times 4

4\log \text{ virus inactivation check} = 1 \times 4

4\log \text{ virus inactivation check} = 4

4\log \text{ virus inactivation check} \geq 4, \text{ therefore, 4log virus inactivation is achieved! Answer: YES}
2. Is the water system providing 4log virus inactivation using 12.5% sodium hypochlorite?

**GIVEN**

![Diagram of water system]

- Well capacity = 600 gpm
- Residual chlorine concentration = 0.1 mg/L free chlorine, measured at the outlet of the tank
- Tank’s total capacity = 600,000 gallons
- Tank’s lowest operating volume = 200,000 gallons
- Peak hour flow = 1,200 gpm
- Tank has no baffles with a separate inlet and outlet with high inlet and outlet flow velocities.
- pH = 6.8
- Temperature = 25°C

**FIND** If the water system is providing 4-log virus inactivation.

**NOT RELEVANT**
- The well capacity has no bearing on the peak flow of the water system.
- Using the tank’s total capacity will increase the results and not cover the most conservative situation when the tank is at its lowest operating volume.

**SOLUTION**

*From Table 3-2, Baffling factor = 0.1*

*From Table B-2, CT req = 2 \( \frac{mg}{L} \cdot min \)*

**Peak flow = 1,200 gpm**

Total detention time = \( \frac{\text{Lowest Operating Volume}}{\text{Peak flow}} \)

\[
Total \text{ detention time} = \frac{200,000 \text{ gallons}}{1,200 \text{ gal/min}}
\]

\[
Total \text{ detention time} = 166.67 \text{ min}
\]

Contact time = Total detention time \( \times \) Baffling factor

Contact time = 166.67 min \( \times \) 0.1

Contact time = 16.67 min
\[ CT_{\text{calc}} = \text{Residual chlorine concentration} \times \text{Contact time} \]

\[
CT \; \text{calc} = 0.1 \frac{mg}{L} \times 16.67 \; \text{min}
\]

\[
CT \; \text{calc} = 1.67 \frac{mg}{L} \cdot \text{min}
\]

\[
\text{Inactivation ratio} = \frac{CT \; \text{calc}}{CT \; \text{req}}
\]

\[
\text{Inactivation ratio} = \frac{1.67 \frac{mg}{L} \cdot \text{min}}{2 \frac{mg}{L} \cdot \text{min}}
\]

\[
\text{Inactivation ratio} = 0.84
\]

Round to 1 decimal place.

\[
\text{Inactivation ratio} = 0.8
\]

\[
4 \log \text{ virus inactivation check} = \text{Inactivation ratio} \times 4
\]

\[
4 \log \text{ virus inactivation check} = 0.8 \times 4
\]

\[
4 \log \text{ virus inactivation check} = 3.6
\]

\[
4 \log \text{ virus inactivation check} < 4, \text{ therefore } 4 \log \text{ virus inactivation is not achieved!}
\]

Answer: NO
3. Is the water system providing 4-log virus inactivation using 12.5% sodium hypochlorite?

GIVEN

- Well capacity = 200 gpm
- Residual chlorine concentration = 0.1 mg/L free chlorine, measured before the first customer
- Pipeline has a diameter of 12 inches and a length of 1,000 feet between the chlorine injection point and the first customer.
- Peak hour flow = 200 gpm
- pH = 6.6
- Temperature = 20°C

FIND If the water system is providing 4-log virus inactivation.

NOT RELEVANT - The well capacity has no bearing on the peak flow of the water system.

SOLUTION

From Table 3-2, Baffling factor = 1
From Table B-2, CT req = 3 \( \frac{mg}{L \cdot min} \)
Peak flow = 200 gpm
12 inches = 1 foot
1 ft³ = 7.48 gallons

Cross sectional area of the pipe = \( \frac{\pi}{4} \times (\text{Diameter}^2) \)

Cross sectional area of the pipe = \( \frac{\pi}{4} \times (1 \text{ foot}^2) \)

Cross sectional area of the pipe = 0.785 ft²

Lowest Operating Volume = Cross sectional area of the pipe \( \times \) Length

\[ \text{Lowest Operating Volume} = 0.785 \text{ ft}^2 \times 1,000 \text{ feet} \times 7.48 \frac{\text{gallons}}{ft^3} \]

\[ \text{Lowest Operating Volume} = 5,871.8 \text{ gallons} \]
Total detention time = \( \frac{\text{Lowest Operating Volume}}{\text{Peak flow}} \)

\[ \text{Total detention time} = \frac{5,871.8 \text{ gallons}}{200 \text{ gal/min}} \]

Total detention time = 29.36 min

Contact time = Total detention time \( \times \) Baffling factor

Contact time = 29.36 min \( \times \) 1

Contact time = 29.36 min

\( CT_{calc} = \text{Residual chlorine concentration} \times \text{Contact time} \)

\[ CT \text{ calc} = 0.1 \frac{mg}{L} \times 29.36 \text{ min} \]

\[ CT \text{ calc} = 2.94 \frac{mg}{L} \cdot \text{min} \]

Inactivation ratio = \( \frac{CT \text{ calc}}{CT \text{ req}} \)

\[ \text{Inactivation ratio} = \frac{2.94 \frac{mg}{L} \cdot \text{min}}{3 \frac{mg}{L} \cdot \text{min}} \]

Inactivation ratio = 0.98

Round to one decimal place

Inactivation ratio = 1.0

\( 4 \log \text{ virus inactivation check} = \text{Inactivation ratio} \times 4 \)

\[ 4 \log \text{ virus inactivation check} = 1.0 \times 4 \]

\[ 4 \log \text{ virus inactivation check} = 4.0 \]

\( 4 \log \text{ virus inactivation check} = 4, \text{therefore} 4 \log \text{ virus inactivation is achieved!} \)

Answer: YES