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**U.S. EPA CT VALUES (mg/L x min) for the Inactivation of Giardia Cysts with Ozone at Different Temperatures and pH from 6 to 9.<sup>12</sup>**

|              | Temperature °C (°F) |       |        |        |        |        |
|--------------|---------------------|-------|--------|--------|--------|--------|
| Inactivation | 0.5(32.1)           | 5(41) | 10(50) | 15(59) | 20(68) | 25(77) |
| 0.5 log      | 0.48                | 0.32  | 0.23   | 0.16   | 0.12   | 0.08   |
| 1.0 log      | 0.97                | 0.63  | 0.48   | 0.32   | 0.24   | 0.16   |
| 1.5 log      | 1.50                | 0.95  | 0.72   | 0.48   | 0.36   | 0.24   |
| 2.0 log      | 1.90                | 1.30  | 0.95   | 0.63   | 0.48   | 0.32   |
| 2.5 log      | 2.40                | 1.60  | 1.20   | 0.79   | 0.60   | 0.40   |
| 3.0 log      | 2.90                | 1.90  | 1.40   | 0.95   | 0.72   | 0.48   |

**CT Values for Inactivation of Viruses by Ozone<sup>12</sup>**

|              | Temperature, °C |      |      |      |      |      |
|--------------|-----------------|------|------|------|------|------|
| Inactivation | ≤1              | 5    | 10   | 15   | 20   | 25   |
| 2- log       | 0.48            | 0.32 | 0.23 | 0.16 | 0.12 | 0.08 |
| 3- log       | 0.97            | 0.63 | 0.48 | 0.32 | 0.24 | 0.16 |
| 4- log       | 1.50            | 0.95 | 0.72 | 0.48 | 0.36 | 0.24 |

**CT Values for 3-log (99.9%) Inactivation of Giardia Cysts by Free Chlorine at Water Temperature 10.0 °C (50°F)<sup>12</sup>**

| Free Residual,<br>Mg/L | pH    |     |     |     |     |     |       |
|------------------------|-------|-----|-----|-----|-----|-----|-------|
|                        | ≤ 6.0 | 6.5 | 7.0 | 7.5 | 8.0 | 8.5 | ≤ 9.0 |
| ≤ 0.4                  | 73    | 88  | 104 | 125 | 149 | 177 | 209   |
| 0.6                    | 75    | 90  | 107 | 128 | 153 | 183 | 218   |
| 0.8                    | 78    | 92  | 110 | 131 | 158 | 189 | 226   |
| 1.0                    | 79    | 94  | 112 | 134 | 162 | 195 | 234   |
| 1.2                    | 80    | 95  | 114 | 137 | 168 | 200 | 240   |
| 1.4                    | 82    | 98  | 116 | 140 | 170 | 206 | 247   |
| 1.6                    | 83    | 99  | 119 | 144 | 174 | 211 | 253   |
| 1.8                    | 88    | 101 | 122 | 147 | 179 | 215 | 259   |
| 2.0                    | 87    | 104 | 124 | 150 | 182 | 221 | 265   |
| 2.2                    | 89    | 105 | 127 | 153 | 186 | 225 | 271   |
| 2.4                    | 90    | 107 | 129 | 157 | 190 | 230 | 276   |
| 2.6                    | 92    | 110 | 131 | 160 | 194 | 234 | 281   |
| 2.8                    | 93    | 111 | 134 | 163 | 197 | 239 | 287   |
| 3.0                    | 95    | 113 | 137 | 166 | 201 | 243 | 292   |

### CT Values for Inactivation of Viruses by Free Chlorine<sup>12</sup>

| Log Inactivation |         |       |         |       |         |       |
|------------------|---------|-------|---------|-------|---------|-------|
| Temperature, °C  | 2.0-log |       | 3.0-log |       | 4.0-log |       |
|                  | pH6-9   | pH 10 | pH6-9   | pH 10 | pH6-9   | pH 10 |
| 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    |

Note: CT values can be adjusted to other temperatures by doubling the CT for each 10°C drop in temperature.

### CT Values for Inactivation of Giardia Cysts by Chloramine Within the pH Range 6 to 9<sup>12</sup>

| Inactivation | Temperature, °C |      |      |      |      |     |
|--------------|-----------------|------|------|------|------|-----|
|              | ≤1              | 5    | 10   | 15   | 20   | 25  |
| 0.5-log      | 635             | 365  | 310  | 250  | 185  | 125 |
| 1-log        | 1270            | 735  | 615  | 500  | 370  | 250 |
| 1.5-log      | 1900            | 1100 | 930  | 750  | 550  | 375 |
| 2-log        | 2535            | 1470 | 1230 | 1000 | 735  | 500 |
| 2.5-log      | 3170            | 1830 | 1540 | 1250 | 915  | 625 |
| 3-log        | 3800            | 2200 | 1850 | 1500 | 1100 | 750 |

### CT Values for Inactivation of Viruses by Chloramine\*<sup>12</sup>

| Inactivation | Temperature, °C |      |      |     |     |     |
|--------------|-----------------|------|------|-----|-----|-----|
|              | ≤1              | 5    | 10   | 15  | 20  | 25  |
| 2-log        | 1243            | 857  | 643  | 428 | 321 | 214 |
| 3-log        | 2063            | 1423 | 1067 | 712 | 534 | 356 |
| 4-log        | 2883            | 1988 | 1491 | 994 | 746 | 497 |

\*This table applies for systems using combined chlorine where chlorine is added prior to ammonia in the treatment sequence.

### CT Values for Inactivation of Giardia Cysts by Chloramine Dioxide Within the pH Range 6 to 9<sup>12</sup>

| Inactivation | Temperature, °C |      |      |      |      |      |
|--------------|-----------------|------|------|------|------|------|
|              | ≤1              | 5    | 10   | 15   | 20   | 25   |
| 0.5-log      | 10              | 4.3  | 4.0  | 3.2  | 2.5  | 2.0  |
| 1-log        | 21              | 8.7  | 7.7  | 6.3  | 5.0  | 3.7  |
| 1.5-log      | 32              | 13.0 | 12.0 | 10.0 | 7.5  | 5.5  |
| 2-log        | 42              | 17.0 | 15.0 | 13.0 | 10.0 | 7.3  |
| 2.5-log      | 52              | 22.0 | 19.0 | 16.0 | 13.0 | 9.0  |
| 3-log        | 63              | 26.0 | 23.0 | 19.0 | 15.0 | 11.0 |

**CT Values for Inactivation of Viruses by Chloramine Dioxide  
Within the pH Range 6 to 9<sup>12</sup>**

| Temperature, °C |      |      |      |      |      |     |
|-----------------|------|------|------|------|------|-----|
| Inactivation    | ≤1   | 5    | 10   | 15   | 20   | 25  |
| 2-log           | 8.4  | 5.6  | 4.2  | 2.8  | 2.1  | 1.4 |
| 3-log           | 25.6 | 17.1 | 12.8 | 8.6  | 6.4  | 4.3 |
| 4-log           | 50.1 | 33.4 | 25.1 | 16.7 | 12.5 | 8.4 |

**Amounts of Various Agents Required to Oxidize 1 mg/L of  
Ferrous Iron<sup>21</sup>**

| Oxidizing Agent                                    | Practical Amount Required to Oxidize 1 mg/L Fe <sup>2+</sup> (mg/L) | Theoretical Stoichiometry(mg/L) |
|--|---|---------------------------------|
| Ozone(O <sub>3</sub> )                             | 0.4 to 0.7  | 0.43                            |
| Chlorine(Cl <sub>2</sub> )                         | 0.6 to 1.0  | 0.63                            |
| Potassium Permanganate (KmnO <sub>4</sub> )        | 0.9 to 2.0  | 0.94                            |
| Hydrogen Peroxide (H <sub>2</sub> O <sub>2</sub> ) | 0.3 to 0.5  | 0.30                            |
| Oxygen(O <sub>2</sub> )*                           | 0.86 to 1.1   | 0.14                            |
| Chlorine Dioxide ClO <sub>2</sub>                  | 1.0 to 1.6  | 1.2                             |

**Theoretical Amounts of Various Agents Required to Oxidize  
1 mg/L of Manganous Ion to MnO(O H<sub>2</sub>)**

| Oxidizing Agent               | Practical Amount Required to Oxidize 1 mg/L Mn <sup>2+</sup> (mg/L) | Theoretical Stoichiometry(mg/L) |
|-------------------------------|---|---------------------------------|
| Ozone                         | 0.5 to 1.0  | 0.87                            |
| Chlorine(Cl <sub>2</sub> )    | 1.7 to 2.0  | 1.28                            |
| KmnO <sub>4</sub>             | 2.0 to 2.7  | 1.91                            |
| ClO <sub>2</sub>              | 2.4 to 3.0  | 2.46                            |
| H <sub>2</sub> O <sub>2</sub> | 0.8 to 1.0  | 0.6                             |
| Oxygen                        | 2.5 to 3.3  | 0.29                            |

**Theoretical Amounts of Various Agents Required to Oxidize  
1 mg/L of Sulfide Ion**

| Oxidizing Agent               | Practical Amount Required to Oxidize 1 mg/L Mn <sup>2+</sup> (mg/L) | Theoretical Stoichiometry(mg/L) |
|-------------------------------|---|---------------------------------|
| Ozone                         | 2.2 to 3.6  | 1.5                             |
| Chlorine(Cl <sub>2</sub> )    | 2.0 to 3.0  | 2.2                             |
| KmnO <sub>4</sub>             | 4.0 to 6.0  | 3.3                             |
| ClO <sub>2</sub>              | 7.2 to 10.8   | 4.2                             |
| H <sub>2</sub> O <sub>2</sub> | 1.0 to 1.5  | 1.1                             |
| Oxygen                        | 2.8 to 3.6  | 0.5                             |

### Comparison of Percentages of Active Halogen Forms

| <u>Bromine</u>      |                    | pH  | <u>Chlorine</u>    |                     |
|---------------------|--------------------|-----|--------------------|---------------------|
| Percent as<br>(Obr) | Percent as<br>HOBr |     | Percent as<br>HOCl | Percent as<br>(OCI) |
| 4                   | 96                 | 7.2 | 66                 | 34                  |
| 6                   | 94                 | 7.5 | 48                 | 52                  |
| 13                  | 87                 | 7.8 | 33                 | 67                  |
| 17                  | 83                 | 8.0 | 22                 | 78                  |