CT Helper.....

An Example Calculation
for
CT Credit, Log Inactivation,
and
Total Log Removal/Inactivation

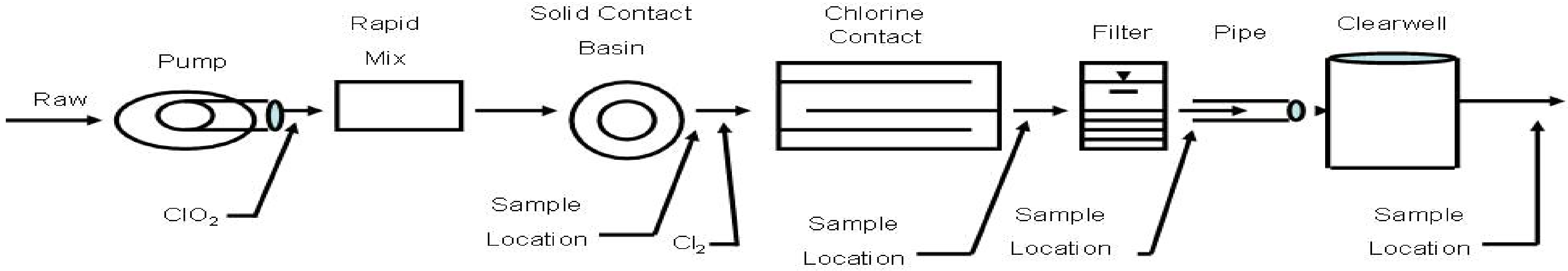
May 30, 2012

Rex Cox, MS, PE
785.296.5539
rcox@kdheks.gov

Dan Clair, MS, PE
785.296.5516
dclair@kdheks.gov

Kansas Department of Health and Environment
Division of Environment
1000 SW Jackson St., Suite 420
Topeka, KS 66612

CT Calculation Worksheet



Maximum Flow Rate: 300 gpm   Temperature: 18 °C

A	B	C	D	E	F	G	H	I	J	K	L	M
									Giardia(5) 0.5 Log Inactivation		Viruses(5) 2.0 Log Inactivation	
Disinfection Unit	Minimum Volume(1) (gallons)	Detention Time T (minutes)	Baffling Factor(2) (T_{10} / T)	T_{10} (minutes) (Col C X Col D)	pH	Residual(3) (mg/L)	Free Cl_2, Comb Cl_2, ClO_2 or O_3	CT_{Cal} (4) (Col. E X Col. G)	CT_{Req}(6) (EPA Tables)	CT_{Avail} Ratio(7) (Col I / Col J)	CT_{Req}(6) (EPA Tables)	CT_{Avail} Ratio(7) (Col I / Col L)
Pump Sta. Wet Well	1,489	4.96	0.1	0.496	--	--	--	--	--	--	--	--
Rapid Mix Basin	198	0.66	0.1	0.066	7.8	0.0	ClO_2	--	--	--	--	--
Solids Contact Basin	54,158	180.53	0.3	54.159	7.8	0.0	ClO_2	--	--	--	--	--
Chlorine Contact Basin	7,451	24.84	0.5	12.420	7.7	4	Free Cl_2	37.26	22	1.69	2	18.63
Rapid Sand Filter	2,244	7.48	0.7	5.236	7.9	2.5	Free Cl_2	13.09	22	0.60	2	6.55
Pipe	784	2.61	1.0	2.610	7.6	1.8	Comb Cl_2	4.70	250	0.02	428	0.01
Clearwell	54,172	180.57	0.1	18.057	7.6	1.8	Comb Cl_2	32.50	250	0.13	428	0.08

Notes:

1. If flow is in gpm, then volume must be in gallons.
2. T_{10} / T limited to 0.5 unless supported tracer study, filters and pipes excepted.
3. Minimum daily residual at effluent of disinfection unit.
4. Maximum residual value allowed in calculation is 3.0 mg/L
5. 0.5 and 2.0 log inactivation levels assume turbidity standards met.
6. CT_{Req} obtained from EPA CT tables for the disinfectant.
7. Calculate CT_{Avail} Ratio = CT_{Cal} / CT_{Req} for both Giardia and Viruses.
8. Total CT_{Avail} Ratio for Giardia and Viruses, sum columns K and M, respectively.
9. Multiply Total CT_{Avail} Ratio by 0.5 (Giardia) and 2.0 (Viruses), respectively.
10. Log removal credit levels shown assume turbidity standards are met.
11. Total Log Removal / Inactivation = Plant Log Removal Credit + Plant Log Inactivation

		Giardia		Viruses
Total CT_{Avail} Ratio(8) (Values for Monthly Report)		2.44		25.27
Plant Log Inactivation(9) (Values for Profiling)	x 0.5 =	1.22	x 2.0 =	50.54
Plant Log Removal Credit(10) (SWTR Credits)		**2.5**		**2.0**
Total Log Removal / Inactivation(11) (SWTR Requires ≥ 3 Log Removal / Inactivation for Giardia & ≥ 4 Log Removal / Inactivation for Viruses)		3.72		52.54

Signature: ______________________________

Revised 05/30/2012

CT Helper
Example Calculation for Compliance
with
Total Log Removal/Inactivation Regulations

Step 1: **Draw Treatment Sequence**

Construct simple drawing of treatment stages
Locate all points of disinfectant application
Locate all sample points

Step 2: **Treatment Stages**

List in Column A of spreadsheet the treatment stages shown in the drawing

Step 3: **Raw Water Pump Station Wet Well**

Not included in this example CT calculations since a disinfectant not applied until rapid mix.

Step 4: **Rapid Mix Basin**

Not included in this example CT calculations since a disinfectant residual was not detected in the solids contact basin effluent which is the next sampling location downstream.

Step 5: **Solids Contact Basin**

Not included in this example CT calculations since a disinfectant residual was not detected in the solids contact basin effluent which is the next sampling location downstream.

Step 6: **Chlorine Contact Basin**

Minimum Volume:

V_{gross} (gal) = L (ft) x W (ft) x D_{min} (ft) x 7.481 gal/ft^3
= 20 x 11 x 6 x 7.481 = 9,875 gal

$V_{all\ baffle\ walls\ at\ min\ depth}$ (gal) = L (ft) x W (ft) x D_{min} (ft) x 7.481 gal/ft^3 x # of walls
= 18 x 1 x 6 x 7.481 x 3 = 2,424 gal

V_{total} (gal) = V_{gross} - $V_{all\ baffle\ walls\ at\ min\ depth}$
= 9,875 - 2,424 = 7,451 gal

Detention Time:

T = V_{total} (gal) ÷ $Q_{Peak\ Hourly\ Flow}$ (gpm)
= 7,451 ÷ 300 = 24.84 min

T_{10}/T = 0.5
See Table C-5 in appendix

T_{10} (min) = T x T_{10}/T
= 24.84 x 0.5 = 12.42 min

CT Calculations:

CT_{cal} (mg-min/L) = $[Residual]_{effluent}$ (mg/L) x T_{10} (min)
= 3 x 12.42 = 37.26 mg-min/L
residual is limited to 3.0 even if higher residual measured at facility

$CT_{req,\ Giardia}$ (mg-min/L) = 22 (mg-min/L)
See Table E-4 in appendix

$CT_{Avail\ Ratio,\ Giardia}$ (mg-min/L) = CT_{cal} (mg-min/L) ÷ $CT_{req,\ Giardia}$ (mg-min/L)
= 37.26 ÷ 22 = 1.69

$CT_{req,\ Viruses}$ (mg-min/L) = 2.0 (mg-min/L)
See Table E-7 in appendix

$CT_{Avail\ Ratio,\ Viruses}$ (mg-min/L) = CT_{cal} (mg-min/L) ÷ $CT_{req,\ Viruses}$ (mg-min/L)
= 37.26 ÷ 2.0 = 18.63

Step 7: **Rapid Sand Filters**

Minimum Volume:

V_{gross} (gal) = L (ft) x W (ft) x D_{min} (ft) x 7.481 gal/ft^3
= 8 x 12.5 x 5.5 x 7.481 = <u>4,115 gal</u>

$V_{media\ volume}$ (gal) = L (ft) x W (ft) x D (ft) x (1- f $_{void\ fraction}$) 7.481 gal/ft^3
= 8 x 12.5 x 2.5 x 7.481 = <u>1,870 gal</u>

V_{total} (gal) = V_{gross} - $V_{media\ volume}$
= 4,115 - 1870 = <u>2,245 gal.</u>

Detention Time:

T = V_{total} (gal) ÷ Q $_{Peak\ Hourly\ Flow}$ (gpm)
= 2,245 ÷ 300 = <u>7.48 min</u>

T_{10}/T = <u>0.7</u>
See Table C-5 in appendix

T_{10} (min) = T x T_{10}/T
= 7.48 x .7 = <u>5.236 min</u>

CT Calculations:

CT_{cal} (mg-min/L) = Residual (mg/L) x T_{10} (min)
= 2.5 x 5.236 = <u>13.09 mg-min/L</u>

$CT_{req,\ Giardia}$ (mg-min/L) = <u>22 (mg-min/L)</u>
See Table E-4 in appendix

$CT_{Avail\ Ratio,\ Giardia}$ (mg-min/L) = CT_{cal} (mg-min/L) ÷ $CT_{req,\ Giardia}$ (mg-min/L)
= 13.09 ÷ 22 = <u>0.60</u>

$CT_{req,\ Viruses}$ (mg-min/L) =<u>2.0 (mg-min/L)</u>
See Table E-7 in the appendix

$CT_{Avail\ Ratio,\ Viruses}$ (mg-min/L) = CT_{cal} (mg-min/L) ÷ $CT_{req,\ Viruses}$ (mg-min/L)
= 13.09 ÷ 2.0 = <u>6.55</u>

Step 8: **Pipe Segment:**

Minimum Volume:

V_{gross} (gal) = π x R^2 (ft) x L_{min} (ft) x 7.481 gal/ft^3
=3.142 x $(4 \div 12)^2$ x 300 x 7.481 = 784 gal

Detention Time:

T = V_{total} (gal) ÷ $Q_{\text{Peak Hourly Flow}}$ (gpm)
= 784 ÷ 300 = 2.61 min

T_{10}/T = 1.0
See Table C-5 in appendix

T_{10} (min) = T x T_{10}/T
= 2.61 x 1.0 = 2.61 min

CT Calculations:

CT_{cal} (mg-min/L) = [Residual] $_{effluent}$ (mg/L) x T_{10} (min)
= 1.8 x 2.61 = 4.70 mg-min/L

$CT_{req, Giardia}$ (mg-min/L) = 250 (mg-min/L)
See Table E-12 in appendix

$CT_{Avail\ Ratio,\ Giardia}$ (mg-min/L) = CT_{cal} (mg-min/L) ÷ $CT_{req, Giardia}$ (mg-min/L)
= 4.70 ÷ 250 = 0.02

$CT_{req, Viruses}$ (mg-min/L) = 428 (mg-min/L)
See Table E-13 in appendix

$CT_{Avail\ Ratio,\ Viruses}$ (mg-min/L) = CT_{cal} (mg-min/L) ÷ $CT_{req, Viruses}$ (mg-min/L)
= 4.70 ÷ 428 = 0.01

Step 9: **Clearwell**

Minimum Volume:

V_{gross} (gal) = π x R^2 (ft) x D_{min} (ft) x 7.481 gal/ft^3
=3.142 x $(12.5)^2$ x 14.75 x 7.481 = <u>54,172 gal</u>

Detention Time:

T = V_{total} (gal) ÷ $Q_{\text{Peak Hourly Flow}}$ (gpm)
= 54,172 ÷ 300 = <u>180.57 min</u>

T_{10}/T = <u>0.1</u>
See Table C-5 in appendix

T_{10} (min) = T x T_{10}/T
= 180.57 x 0.1 = <u>18.057 min</u>

CT Calculations:

CT_{cal} (mg-min/L) = [Residual] $_{effluent}$ (mg/L) x T_{10} (min)
= 1.8 x 18.057 = <u>32.50 mg-min/L</u>

$CT_{req, Giardia}$ (mg-min/L) = <u>250 (mg-min/L)</u>
See Table E-12 in the appendix

$CT_{Avail\ Ratio,\ Giardia}$ (mg-min/L) = CT_{cal} (mg-min/L) ÷ $CT_{req, Giardia}$ (mg-min/L)
=32.50 ÷ 250 = <u>0.13</u>

$CT_{req, Viruses}$ (mg-min/L) = <u>428 (mg-min/L)</u>
See Table E-13 in the Appendix

$CT_{Avail\ Ratio,\ Viruses}$ (mg-min/L) = CT_{cal} (mg-min/L) ÷ $CT_{req, Viruses}$ (mg-min/L)
= 32.50 ÷ 428 = <u>0.08</u>

Step 10: **CT Summary Evaluation**

<u>Giardia</u>

Total CT_{Avail} Ratio = Sum of CT_{Avail} Ratio for each stage.

= 1.69 + 0.60 + 0.02 + 0.13 = <u>2.44</u>

If ≥ 1.0 then the log inactivation requirement met.

Plant Log Inactivation = Total CT_{Avail} Ratios For All Stages x 0.5

= 2.44 x 0.5 = <u>1.22</u>

Plant Log Removal Credits = <u>2.5</u>
(Assume turbidity standards met.)

Total Log Inactivation / Removal = Plant Log Inactivation + Plant Log Removal Credits

= 1.22 + 2.5 = <u>3.72</u>

If ≥ 3.0, then the regulatory log inactivation/removal requirement met.

<u>Viruses</u>

Total CT_{Avail} = Sum of CT_{Avail} Ratio for each stages.

= 18.63 + 6.55 + 0.01 + 0.08 = 25.27

If ≥ 1.0, then 2.0 log activation requirement met.

Plant Log Inactivation = Total CT_{Avail} Ratios For All Stages x 2.0

= 25.27 x 2.0 = <u>50.54</u>

Plant Log Removal Credits = <u>2.0</u>
(Assume turbidity standards met.)

Total Log Inactivation / Removal = Plant Log Inactivation + Plant Log Removal Credits

= 50.54 + 2.0 = <u>52.54</u>

If ≥ 4.0 then the regulatory log inactivation/removal requirement met.

Symbols

V_{gross} = Total Interior Volume (ft^3 or gal)

L = Length (ft)

W = Width (ft)

D_{min} = Minimum Water Depth (ft)

T = Theoretical Hydraulic Detention Time (minutes)

T_{10}/T = Baffling Condition Multiplier

T_{10} = Theoretical Detention Time Adjusted For Non-ideal Flow Conditions

7.481 = conversion of cubic feet to gallons - 7.481 gal/ft^3

$\geq$ = greater than or equal to

π = 3.142

This Page Intentionally Left Blank

Appendix

This Page Intentionally Left Blank

CT Calculation Worksheet

Maximum Flow Rate: _______ gpm Temperature: ________ °C

A	B	C	D	E	F	G	H	I	J	K	L	M
									Giardia(5) 0.5 Log Inactivation		Viruses(5) 2.0 Log Inactivation	
Disinfection Unit	Minimum Volume(1) (gallons)	Detention Time T (minutes)	Baffling Factor(2) (T_{10} / T)	T_{10} (minutes) (Col C X Col D)	pH	Residual(3) (mg/L)	Free Cl_2, Comb Cl2, ClO_2 or O_3	CT_{Cal} (4) (Col. E X Col. G)	CT_{Req}(6) (EPA Tables)	CT_{Avail} Ratio(7) (Col I / Col J)	CT_{Req}(6) (EPA Tables)	CT_{Avail} Ratio(7) (Col I / Col L)

Notes:

1. If flow is in gpm, then volume must be in gallons.
2. T_{10} / T limited to 0.5 unless supported tracer study, filters and pipes excepted.
3. Minimum daily residual at effluent of disinfection unit.
4. Maximum residual value allowed in calculation is 3.0 mg/L
5. 0.5 and 2.0 log inactivation levels assume turbidity standards met.
6. CT_{Req} obtained from EPA CT tables for the disinfectant.
7. Calculate CT_{Avail} Ratio = CT_{Cal} / CT_{Req} for both Giardia and Viruses.
8. Total CT_{Avail} Ratio for Giardia and Viruses, sum columns K and M, respectively.
9. Multiply Total CT_{Avail} Ratio by 0.5 (Giardia) and 2.0 (Viruses), respectively.
10. Log removal credit levels shown assume turbidity standards are met.
11. Total Log Removal / Inactivation = Plant Log Removal Credit + Plant Log Inactivation

		Giardia (K)		Viruses (M)
Total CT_{Avail} Ratio(8) (Values for Monthly Report)				
Plant Log Inactivation(9) (Values for Profiling)	x 0.5 =		x 2.0 =	
Plant Log Removal Credit(10) (SWTR Credits)		**2.5**		**2.0**
Total Log Removal / Inactivation(11) (SWTR Requires ≥ 3 Log Removal / Inactivation for Giardia & ≥ 4 Log Removal / Inactivation for Viruses)				

Signature: ____

Revised: 05/30/2012

This Page Intentionally Left Blank

Table C-5

Baffling Condition	T_{10}/T	Baffling Description
Unbaffled (mixed flow)	0.1	None, agitated basin, very low length to width ratio, high inlet and outlet flow velocities
Poor	0.3	Single or multiple unbaffled inlets and outlets, no intra-basin baffles
Average	0.5	Baffled inlet or outlet with some intra-basin baffles
Superior	0.7	Perforated inlet baffle, serpentine or perforated intra-basin baffles, outlet weir or perforated launders
Perfect (plug flow)	1.0	Very high length to width ratio (pipeline flow), perforated inlet, outlet, and intra-basin baffles

This table can be found in USEPA's "Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources", 1991 edition. The guidance manual can be found at http://www.epa.gov/safewater/mdbp/guidsws.pdf.

T_{10}/T limited to 0.5 unless supported tracer study, filters and pipes excepted.

TABLE E-4
CT VALUES FOR INACTIVATIONS
OF GIARDIA CYSTS BY FREE CHLORINE
AT 15 C

CHLORINE CONCENTRATION (mg/L)	pH<=6 Log Inactivations						pH=6.5 Log Inactivations						pH=7.0 Log Inactivations						pH=7.5 Log Inactivations					
	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0
<=0.4	8	16	25	33	41	49	10	20	30	39	49	59	12	23	35	47	58	70	14	28	42	55	69	83
0.6	8	17	25	33	42	50	10	20	30	40	50	60	12	24	36	48	60	72	14	29	43	57	72	86
0.8	9	17	26	35	43	52	10	20	31	41	51	61	12	24	37	49	61	73	15	29	44	59	73	88
1	9	18	27	35	44	53	11	21	32	42	53	63	13	25	38	50	63	75	15	30	45	60	75	90
1.2	9	18	27	36	45	54	11	21	32	43	53	64	13	25	38	51	63	76	15	31	46	61	77	92
1.4	9	18	28	37	46	55	11	22	33	43	54	65	13	26	39	52	65	78	16	31	47	63	78	94
1.6	9	19	28	37	47	56	11	22	33	44	55	66	13	26	40	53	66	79	16	32	48	64	80	96
1.8	10	19	29	38	48	57	11	23	34	45	57	68	14	27	41	54	68	81	16	33	49	65	82	98
2	10	19	29	39	48	58	12	23	35	46	58	69	14	28	42	55	69	83	17	33	50	67	83	100
2.2	10	20	30	39	49	59	12	23	35	47	58	70	14	28	43	57	71	85	17	34	51	68	85	102
2.4	10	20	30	40	50	60	12	24	36	48	60	72	14	29	43	57	72	86	18	35	53	70	88	105
2.6	10	20	31	41	51	61	12	24	37	49	61	73	15	29	44	59	73	88	18	36	54	71	89	107
2.8	10	21	31	41	52	62	12	25	37	49	62	74	15	30	45	59	74	89	18	36	55	73	91	109
3	11	21	32	42	53	63	13	25	38	51	63	76	15	30	46	61	76	91	19	37	56	74	93	111

CHLORINE CONCENTRATION (mg/L)	pH=8.0 Log Inactivations						pH=8.5 Log Inactivations						pH<=9.0 Log Inactivations					
	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0
<=0.4	17	33	50	66	83	99	20	39	59	79	98	118	23	47	70	93	117	140
0.6	17	34	51	68	85	102	20	41	61	81	102	122	24	49	73	97	122	146
0.8	18	35	53	70	88	105	21	42	63	84	105	126	25	50	76	101	126	151
1	18	36	54	72	90	108	22	43	65	87	108	130	26	52	78	104	130	156
1.2	19	37	56	74	93	111	22	45	67	89	112	134	27	53	80	107	133	160
1.4	19	38	57	76	95	114	23	46	69	91	114	137	28	55	83	110	138	165
1.6	19	39	58	77	97	116	24	47	71	94	118	141	28	56	85	113	141	169
1.8	20	40	60	79	99	119	24	48	72	96	120	144	29	58	87	115	144	173
2	20	41	61	81	102	122	25	49	74	98	123	147	30	59	89	118	148	177
2.2	21	41	62	83	103	124	25	50	75	100	125	150	30	60	91	121	151	181
2.4	21	42	64	85	106	127	26	51	77	102	128	153	31	61	92	123	153	184
2.6	22	43	65	86	108	129	26	52	78	104	130	156	31	63	94	125	157	188
2.8	22	44	66	88	110	132	27	53	80	106	133	159	32	64	96	127	159	191
3	22	45	67	89	112	134	27	54	81	108	135	162	33	65	98	130	163	195

This table can be found in Appendix E of USEPA's "Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources", 1991 edition. The guidance manual can be found at http://www.epa.gov/safewater/mdbp/guidsws.pdf.

A straight-line interpolation may be employed to determine a CT required value when the parameter measured at the treatment plant falls between two values in the CT table. Alternatively, the following rules may be applied in order to determine the CT required value.

1. Select a temperature that is equal to or less than the actual temperature.

2. Select a pH that is equal to or greater than the actual pH.

3. Select a disinfectant residual concentration that is equal to or greater than the actual disinfectant residual concentration.

TABLE E-7

CT VALUES FOR
INACTIVATION OF VIRUSES BY FREE CHLORINE

	Log Inactivations					
	2.0		3.0		4.0	
	pH		pH		pH	
Temperature (C)	6-9	10	6-9	10	6-9	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

This table can be found in Appendix E of USEPA's "Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources", 1991 edition. The guidance manual can be found at http://www.epa.gov/safewater/mdbp/guidsws.pdf.

A straight-line interpolation may be employed to determine a CT required value when the parameter measured at the treatment plant falls between two values in the CT table. Alternatively, the following rules may be applied in order to determine the CT required value.

1. Select a temperature that is equal to or less than the actual temperature.

2. Select a pH that is equal to or greater than the actual pH.

TABLE E-12

CT VALUES FOR
INACTIVATION OF *GIARDIA LAMBLIA* CYSTS
BY CHLORAMNE Ph 6-9

	Temperature (C)					
Inactivation	<=1	5	10	15	20	25
0.5-log	635	365	310	250	185	125
1.0-log	1,270	735	615	500	370	250
1.5-log	1,900	1,100	930	750	550	375
2.0-log	2,535	1,470	1,230	1,000	735	500
2.5-log	3,170	1,830	1,540	1,250	915	625
3.0-log	3,800	2,200	1,850	1,500	1,100	750

This table can be found in Appendix E of USEPA's "Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources", 1991 edition. The guidance manual can be found at http://www.epa.gov/safewater/mdbp/guidsws.pdf.

A straight-line interpolation may be employed to determine a CT required value when the parameter measured at the treatment plant falls between two values in the CT table. Alternatively, the following rule may be applied in order to determine the CT required value.

Select a temperature that is equal to or less than the actual temperature.

TABLE E-13

CT VALUES FOR
INACTIVATION OF VIRUSES BY CHLORAMINE

	Temperature (C)					
Inactivation	<=1	5	10	15	20	25
2-log	1,243	857	643	428	321	214
3-log	2,063	1,423	1,067	712	534	356
4-log	2,883	1,988	1,491	994	746	497

This table can be found in Appendix E of USEPA's "Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources", 1991 edition. The guidance manual can be found at http://www.epa.gov/safewater/mdbp/guidsws.pdf.

A straight-line interpolation may be employed to determine a CT required value when the parameter measured at the treatment plant falls between two values in the CT table. Alternatively, the following rule may be applied in order to determine the CT required value.

Select a temperature that is equal to or less than the actual temperature.