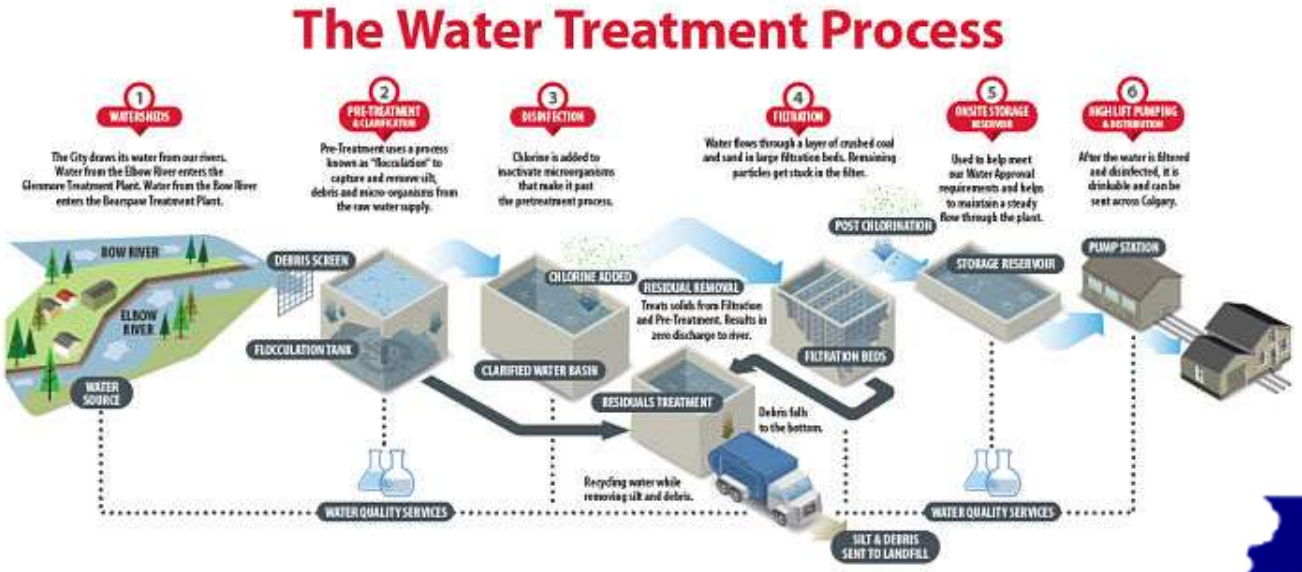
Disinfection Profiling and Benchmarking



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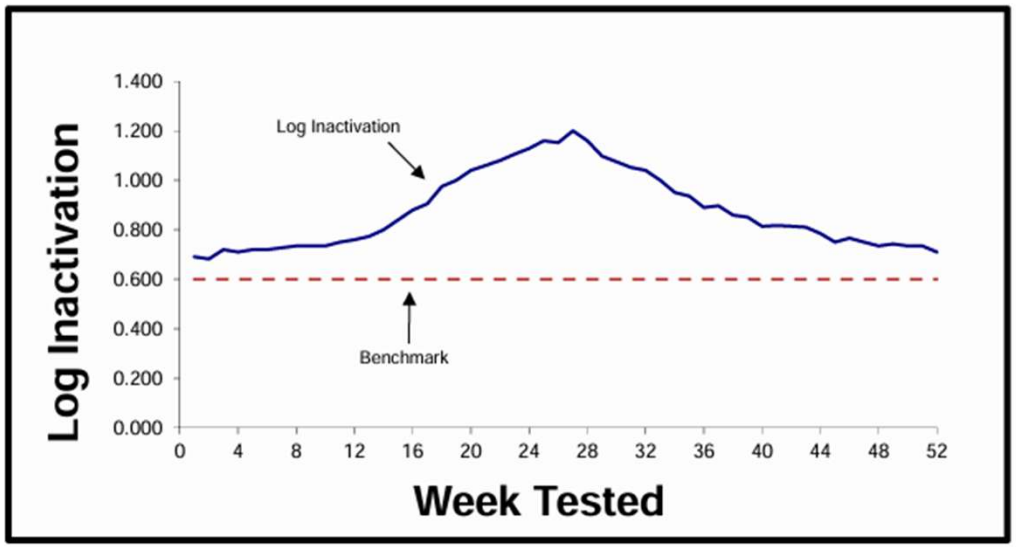
Disinfection Profiling and Benchmarking

Technical Guidance Manual



When is Disinfection Profiling Required

- Any system that uses surface water or ground water under the direct influence of surface water (GWUDI)
- Anytime a change is made in the disinfectant used or location of injection points
- Anytime an “open basin” is used in the treatment (more to come?)

Terminology

- Disinfection Profiling: A disinfection profile is this graphical representation of a system's level of pathogen (e.g., Giardia, Cryptosporidium, or virus) inactivation during the course of a year.

- Disinfection Benchmarking: A disinfection benchmark is the lowest monthly average microbial inactivation achieved during the disinfection profiling time period.

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Steps For Disinfection Profiling

- Identifying Disinfection Segments within the Treatment Scheme
- Data Collection
- Calculating Contact Time (CT)
- Calculating Inactivation
- Developing Disinfection Profile and Benchmark
- Evaluating Disinfection Practices for Optimization
- Treatment Considerations

What does this mean?

- Log Inactivation: Log inactivation is the order of magnitude in which inactivation of unwanted organisms occurs and relates to the percentage of organisms inactivated. For example, a 2-log inactivation corresponds to a 99 percent inactivation and a 3-log inactivation corresponds to a 99.9 percent inactivation.

- Contact Time (CT): Is the product of the residual disinfectant concentration and the time (in minutes) that the disinfectant has been in contact with the water.

Identifying Disinfection Segments

- A disinfection segment is a section of a treatment system beginning at a disinfection injection point (or monitoring point) and ending at the next injection or monitoring point.

- A flow schematic of the treatment scheme is beneficial in identifying disinfection segments and determining home many segments are needed to meet inactivation requirements.

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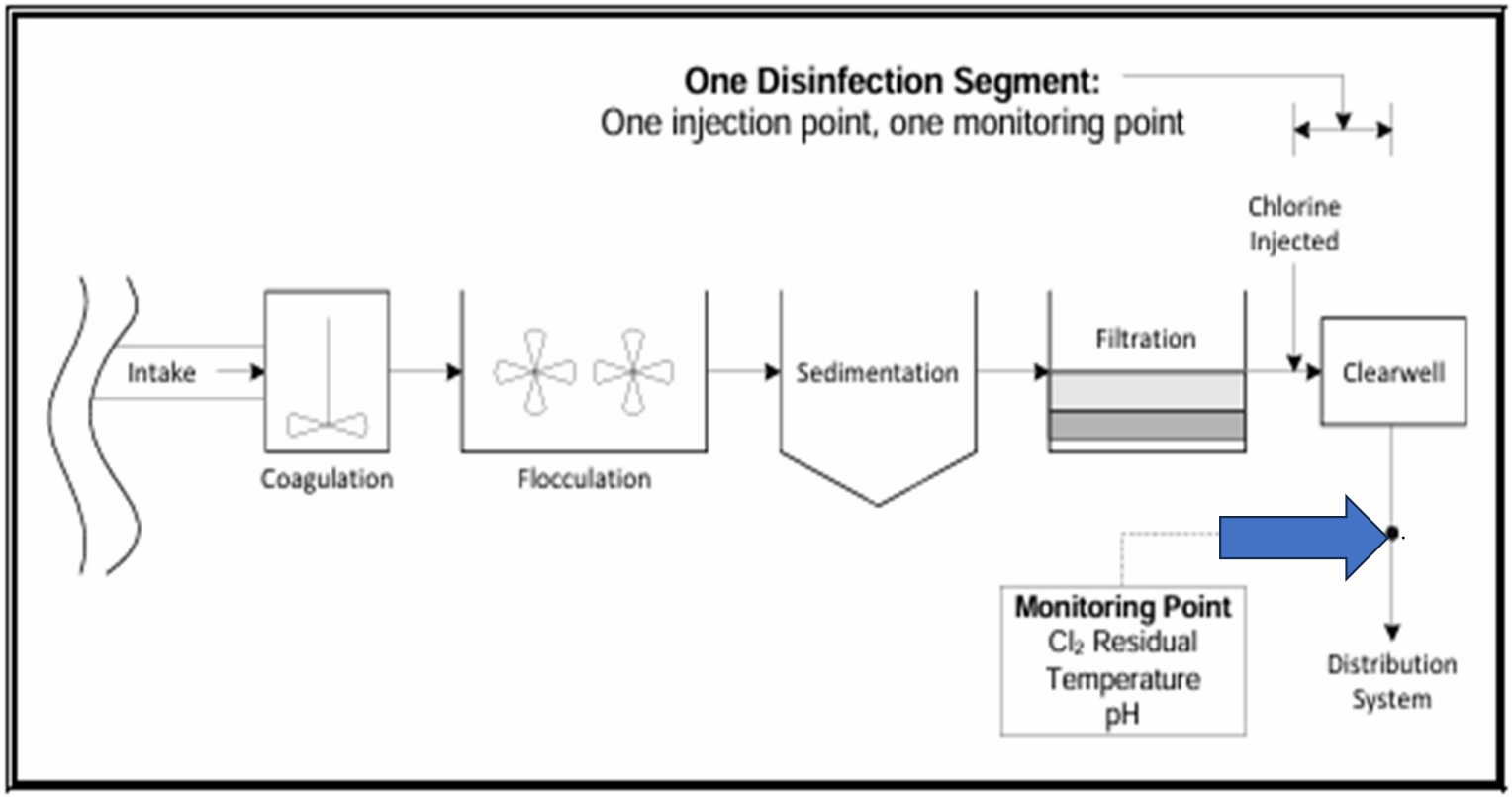
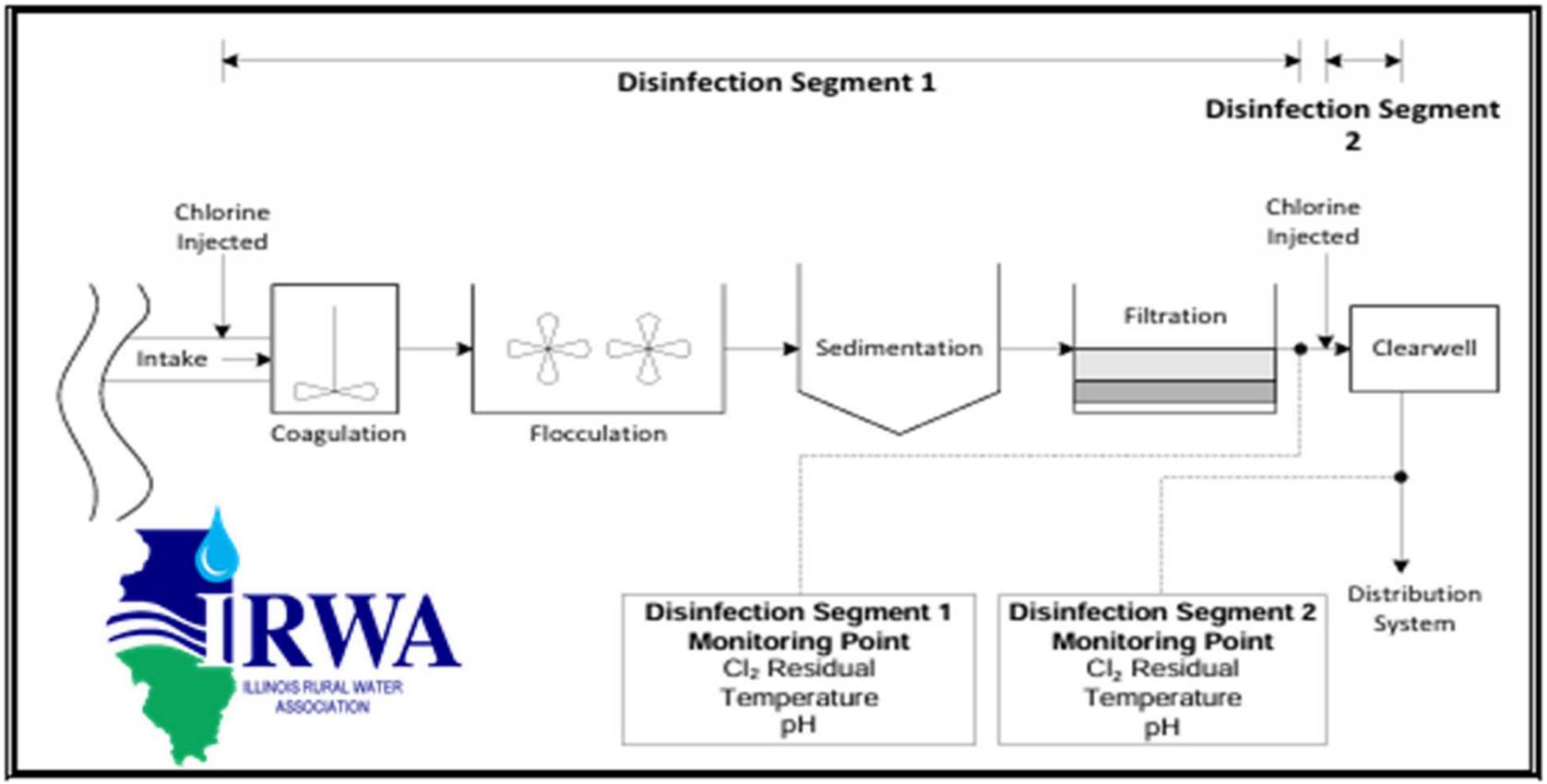
Disinfection Segment Example



Disinfection Segment Example



Data Collection for each Segment

- How often is data collection required for disinfection profiling?
  - ✓Once per week
  - ✓Data will be collected on the same day each week
  - ✓Typically identified in a Special Exception Permit issued by IEPA

- What data must be collected
  - ✓Peak Hourly Flow
  - ✓Residual Disinfectant Concentration
  - ✓Temperature
  - ✓pH (if chlorine is used)

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How to determine peak flow rates

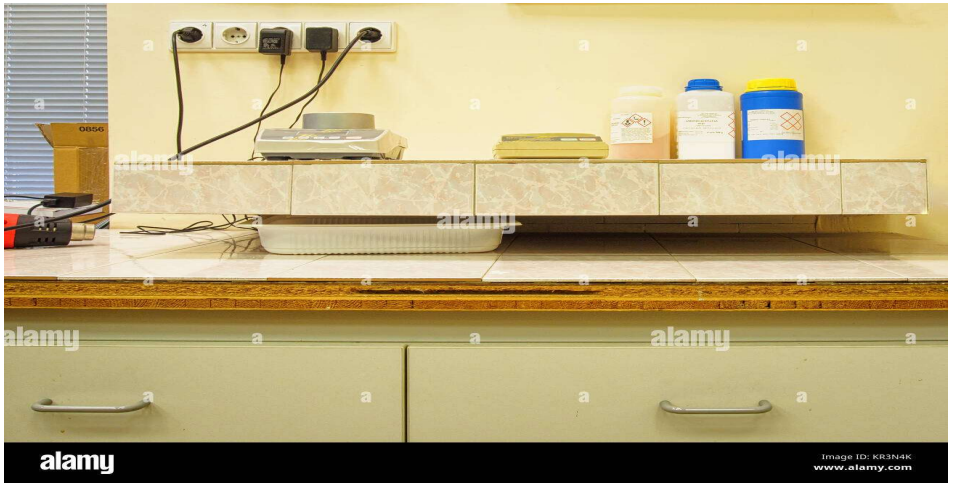
- Flow Meter Records
- Design Flow Rate
- Raw Water Pump Records
- Historical Maximum Flow Rate

USE WORST CASE SCENARIO

Each system will be different and may vary with the use of SCADA or may be determined by the content of the Special Exception Permit

Residual Disinfectant Concentration, Temperature and pH

- Results determined using benchtop analyses
- Samples must be taken at the end of the identified segment



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Data Usage – Determining CT

- Entering data into spreadsheet for CT calculation
- CT = Disinfectant Concentration x contact time
  - Determine the volume of the segment
  - Determine the baffling factor of the segment

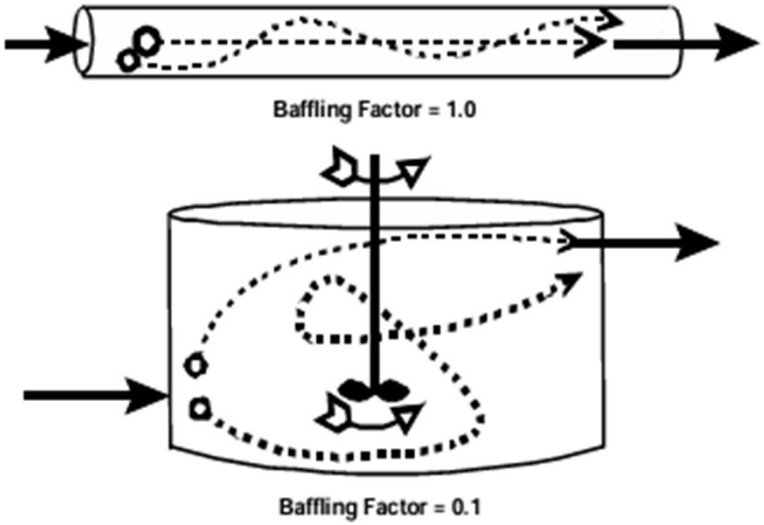
Table 4-2. Baffling Factors

Baffling Condition	Baffling Factor	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.

Source: USEPA, March 1991

More on Baffling Factors

- Baffling Factors are an indication of the physical characteristics of a basin that minimizes “short-circuiting” and maximizes contact time.



Example: One Segment Profile

	Segment 1 (Clearwell 1) BF=0.7	
Flow (gpm)	1200	
Chlorine Residual (mg/L)	2.1 (free)	
Temperature (C)	15	
pH	8.0	

Example: One Segment Profile

- Calculate Theoretical Detention Time (TDT)
  - TDT = V/Q = 200,000 gal / 1200 gpm = 166.7 minutes (segment 1)
- Calculate Contact Time (T)
  - T = TDT x BF = 166.7 x 0.7 = 116.7 minutes (segment 1)
- Calculate CT
  - CT calc = C x T = 2.1 mg/L x 116.7 = 245 min-mg/L (segment 1)

Example: One Segment Profile

- Calculate $CT_{99.9}$ (from tables provided in Guidance)

- $CT_{99.9}$ = 123 min-mg/L (segment 1 for 3-log inactivation of Giardia by Free Chlorine)
- $CT_{99.99}$ = 994 min-mg/L (segment 1 for 4-log inactivation of Viruses by Chloramine)

CT Tables

Table B-1. CT Values* for 3-Log Inactivation of *Giardia* Cysts by Free Chlorine

Chlorine Concentration (mg/L)	Temperature <= 0.5°C							Temperature = 5°C							Temperature = 10°C						
	pH							pH							pH						
	<=6.0	6.5	7.0	7.5	8.0	8.5	9.0	<=6.0	6.5	7.0	7.5	8.0	8.5	9.0	<=6.0	6.5	7.0	7.5	8.0	8.5	9.0
<=0.4	137	163	195	237	277	329	390	97	117	139	166	198	236	279	73	88	104	125	149	177	209
0.6	141	168	200	239	286	342	407	100	120	143	171	204	244	291	75	90	107	128	153	183	218
0.8	145	172	205	246	295	354	422	103	122	146	175	210	252	301	78	92	110	131	158	189	226
1.0	148	176	210	253	304	365	437	105	125	149	179	216	260	312	79	94	112	134	162	195	234
1.2	152	180	215	259	313	376	451	107	127	152	183	221	267	320	80	95	114	137	166	200	240
1.4	155	184	221	266	321	387	464	109	130	155	187	227	274	329	82	98	116	140	170	206	247
1.6	157	189	226	273	329	397	477	111	132	158	192	232	281	337	83	99	119	144	174	211	253
1.8	162	193	231	279	338	407	489	114	135	162	196	238	287	345	86	101	122	147	179	215	259
2.0	165	197	236	286	346	417	500	116	138	165	200	243	294	353	87	104	124	150	182	221	265
2.2	169	201	242	297	353	426	511	118	140	169	204	248	300	361	89	105	127	153	186	225	271
2.4	172	205	247	298	361	435	522	120	143	172	209	253	306	368	90	107	129	157	190	230	276
2.6	175	209	252	304	368	444	533	122	146	175	213	258	312	375	92	110	131	160	194	234	281
2.8	178	213	257	310	375	452	543	124	148	178	217	263	318	382	93	111	134	163	197	239	287
3.0	181	217	261	316	382	460	552	126	151	182	221	268	324	389	95	113	137	166	201	243	292

Chlorine Concentration (mg/L)	Temperature = 15°C							Temperature = 20°C							Temperature = 25°C						
	pH							pH							pH						
	<=6.0	6.5	7.0	7.5	8.0	8.5	9.0	<=6.0	6.5	7.0	7.5	8.0	8.5	9.0	<=6.0	6.5	7.0	7.5	8.0	8.5	9.0
<=0.4	49	59	70	83	99	118	140	36	44	52	62	74	89	105	24	29	35	42	50	59	70
0.6	50	60	72	86	102	122	146	38	45	54	64	77	92	109	25	30	36	43	51	61	73
0.8	52	61	73	88	105	126	151	39	46	55	66	79	95	113	26	31	37	44	53	63	75
1.0	53	63	75	90	108	130	156	39	47	56	67	81	98	117	26	31	37	45	54	65	78
1.2	54	64	76	92	111	134	160	40	48	57	69	83	100	120	27	32	38	46	55	67	80
1.4	55	65	78	94	114	137	165	41	49	58	70	85	103	123	27	33	39	47	57	69	82
1.6	56	66	79	96	116	141	169	42	50	59	72	87	105	126	28	33	40	48	58	70	84
1.8	57	68	81	98	119	144	173	43	51	61	74	89	108	129	29	34	41	49	60	72	86
2.0	58	69	83	100	122	147	177	44	52	62	75	91	110	132	29	35	41	50	61	74	88
2.2	59	70	85	102	124	150	181	44	53	63	77	93	113	135	30	35	42	51	62	75	90
2.4	60	72	86	105	127	153	184	45	54	65	78	95	115	138	30	36	43	52	63	77	92
2.6	61	73	88	107	129	156	188	46	55	66	80	97	117	141	31	37	44	53	65	78	94
2.8	62	74	89	109	132	159	191	47	56	67	81	99	119	143	31	37	45	54	66	80	96
3.0	63	76	91	111	134	162	195	47	57	68	83	101	122	146	32	38	46	55	67	81	97

CT Table

Chlorine Concentration (mg/L)	Temperature = 15°C						
	pH						
	<=6.0	6.5	7.0	7.5	8.0	8.5	9.0
<=0.4	49	59	70	83	99	118	140
0.6	50	60	72	86	102	122	146
0.8	52	61	73	88	105	126	151
1.0	53	63	75	90	108	130	156
1.2	54	64	76	92	111	134	160
1.4	55	65	78	94	114	137	165
1.6	56	66	79	96	116	141	169
1.8	57	68	81	98	119	144	173
2.0	58	69	83	100	122	147	177
2.2	59	70	85	102	124	150	181
2.4	60	72	86	105	127	153	184
2.6	61	73	88	107	129	156	188
2.8	62	74	89	109	132	159	191
3.0	63	76	91	111	134	162	195

Calculating Inactivation Ratios

Table B-2. CT Values* for 4-Log Inactivation of Viruses by Free Chlorine

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

*Although units did not appear in the original tables, units are min-mg/L.

Calculating Inactivation Ratios

- Segment 1 (Giardia)
- Inactivation Ratio = CT / $CT_{99.9}$ = 245 min-mg/L / 123 min-mg/L
  - = 1.99
- Giardia log Inactivation = 3 x Inactivation Ratio = 5.97

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Calculating Inactivation Ratios

- Segment 1 (Viruses)
- Inactivation Ratio = CT / $CT_{99.99}$ = 245 min-mg/L / 4 min-mg/L
  - = 61.3
- Giardia log Inactivation = 4 x Inactivation Ratio = 245.2

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What does all of this mean?

- How can I tell if I'm in Compliance?
- Giardia
  - Giardia Log Inactivation for Segment 1 = 5.97
  - Required Giardia Log Inactivation = 3.0

- However: 2.5 Log Credit Removal is provided for Conventional Treatment
- Therefore: Only 0.5 Giardia Log Inactivation is needed
- 5.97 > 0.5 = Compliance Achieved

Table 7-2: Typical Removal Credits and Inactivation Requirements for Various Treatment Technologies

Process	Typical Log Removal Credits		Resulting Disinfection Log Inactivation Requirements	
	Giardia	Viruses	*Giardia*	Viruses
Conventional Treatment	2.5	2.0	0.5	2.0
Direct Filtration	2.0	1.0	1.0	3.0
Slow Sand Filtration	2.0	2.0	1.0	2.0
Diatomaceous Earth Filtration	2.0	1.0	1.0	3.0
Alternative (membranes, bag filters, cartridges)	*	*	*	*
Unfiltered	0	0	3.0	4.0

* Systems must demonstrate to the State by pilot study or other means that the alternative filtration technology provides the required log removal and inactivation shown in Table 7-1.

What does all of this mean?

- How can I tell if I'm in Compliance?
- Viruses
  - Virus Log Inactivation for Segment 1 = 245.2
  - Required Virus Log Inactivation = 4.0

- However: 2.0 Log Credit Removal is provided for Conventional Treatment
- Therefore: Only 2.0 Virus Log Inactivation is needed
- 245.2 > 2.0 = Compliance Achieved

There’s Got to be an easier way!!!

USEPA's Worksheet

Drinking Water Compliance and Enforcement Forms

Select the Start Date: January 1 2026

Enter Baffling Factor for Stage 1: 0.70
Enter Baffling Factor for Stage 2:
Enter Baffling Factor for Stage 3:
Enter Baffling Factor for Stage 4:
Enter Baffling Factor for Stage 5:
Enter Baffling Factor for Stage 6:

Sample Date	Week Number	Treatment Stage	Disinfectant	Residual Conc. (C) (mg/L)	pH	Temp. (Celsius)	Peak Flow (GPM)	Volume (gal)	TDT (min)	Contact Time (T) (min)	CT_{calc}	3-log CT_{req}	Log Inactivation (*Giardia*)	4-log CT_{req}	Log Inactivation (viruses)
January 1, 2026	1	Treatment Stage 1	Free Chlorine	2.10	8.00	15.0	1,200	200,000	166.7	116.7	245.0	122.89	5.98	4.00	245.00
		Treatment Stage 2	0										no disinfectant		no disinfectant
		Treatment Stage 3	0										no disinfectant		no disinfectant
		Treatment Stage 4	0										no disinfectant		no disinfectant
		Treatment Stage 5	0										no disinfectant		no disinfectant
		Treatment Stage 6	0										no disinfectant		no disinfectant
		System TOTAL											**5.98**		**245.00**
January 8, 2026	2	Treatment Stage 1	Free Chlorine						0.0	0.0	0.0		check pH		check pH
		Treatment Stage 2											no disinfectant		no disinfectant
		Treatment Stage 3											no disinfectant		no disinfectant

That Was Easier…Right?

Log Inactivation (*Giardia*)	4-log CT_{req}	Log Inactivation (viruses)	*Giardia* Monthly Average
5.98	4.00	245.00	
no disinfectant		no disinfectant	
no disinfectant		no disinfectant	
no disinfectant		no disinfectant	
no disinfectant		no disinfectant	
no disinfectant		no disinfectant	
		245.00	
check pH		check pH	

- Segment 1 (Giardia)
- Inactivation Ratio = CT / $CT_{99.9}$ = 245 min-mg/L / 123 min-mg/L
  - = 1.99
- Giardia log Inactivation = 3 x Inactivation Ratio = 5.97

- Segment 1 (Viruses)
- Inactivation Ratio = CT / $CT_{99.99}$ = 245 min-mg/L / 4 min-mg/L
  - = 61.3
- Giardia log Inactivation = 4 x Inactivation Ratio = 245.2

Benchmarking and Profiling

Select the Start Date: January 1 2026

Enter Baffling Factor for Stage 1: 0.70
Enter Baffling Factor for Stage 2:
Enter Baffling Factor for Stage 3:
Enter Baffling Factor for Stage 4:
Enter Baffling Factor for Stage 5:
Enter Baffling Factor for Stage 6:

Sample Date	Week Number	Treatment Stage	Disinfectant	Residual Conc. (C)	pH	Temp. (Celsius)	Peak Flow (GPM)	Volume (gal)	TDT (min)	Contact Time	CT_{calc}	3-log CT_{req}	Log Inactivation	4-log CT_{req}	Log Inactivation	*Giardia* Monthly Average	Virus Monthly Average
January 1, 2026	1	Treatment Stage	Free Chlorine	2.10	8.00	15.0	1,200	200,000	166.7	116.7	245.0	122.89	5.98	4.00	245.00		
		Treatment Stage	0										no disinfectant		no disinfectant		
		Treatment Stage	0										no disinfectant		no disinfectant		
		Treatment Stage	0										no disinfectant		no disinfectant		
		Treatment Stage	0										no disinfectant		no disinfectant		
		Treatment Stage	0										no disinfectant		no disinfectant		
		System TOTAL											**5.98**		**245.00**		
January 8, 2026	2	Treatment Stage	Free Chlorine	2.30	8.10	14.0	1,325	200,000	150.9	105.7	243.0	141.92	5.14	4.40	220.93		
		Treatment Stage											no disinfectant		no disinfectant		
		Treatment Stage											no disinfectant		no disinfectant		
		Treatment Stage											no disinfectant		no disinfectant		
		Treatment Stage											no disinfectant		no disinfectant		
		Treatment Stage											no disinfectant		no disinfectant		
		System TOTAL											**5.14**		**220.93**		
January 15, 2026	3	Treatment Stage	Free Chlorine	1.85	8.20	12.0	1,300	175,000	134.6	94.2	174.3	166.46	3.14	5.20	134.10		
		Treatment Stage											no disinfectant		no disinfectant		
		Treatment Stage											no disinfectant		no disinfectant		
		Treatment Stage											no disinfectant		no disinfectant		
		Treatment Stage											no disinfectant		no disinfectant		
		Treatment Stage											no disinfectant		no disinfectant		
		System TOTAL											**3.14**		**134.10**		
January 22, 2026	4	Treatment Stage	Free Chlorine	2.25	8.00	12.0	1,250	200,000	160.0	112.0	252.0	160.96	4.70	5.20	193.85		
		Treatment Stage											no disinfectant		no disinfectant		
		Treatment Stage											no disinfectant		no disinfectant		
		Treatment Stage											no disinfectant		no disinfectant		
		Treatment Stage											no disinfectant		no disinfectant		
		Treatment Stage											no disinfectant		no disinfectant		
		System TOTAL											**4.70**		**193.85**		
January 29, 2026	5	Treatment Stage	Free Chlorine	2.00	8.20	12.0	1,200	180,000	150.0	105.0	210.0	169.23	3.72	5.20	161.54		
		Treatment Stage											no disinfectant		no disinfectant		
		Treatment Stage											no disinfectant		no disinfectant		
		Treatment Stage											no disinfectant		no disinfectant		
		Treatment Stage											no disinfectant		no disinfectant		
		Treatment Stage											no disinfectant		no disinfectant		
		System TOTAL											**3.72**		**161.54**	**4.54**	**191.08**

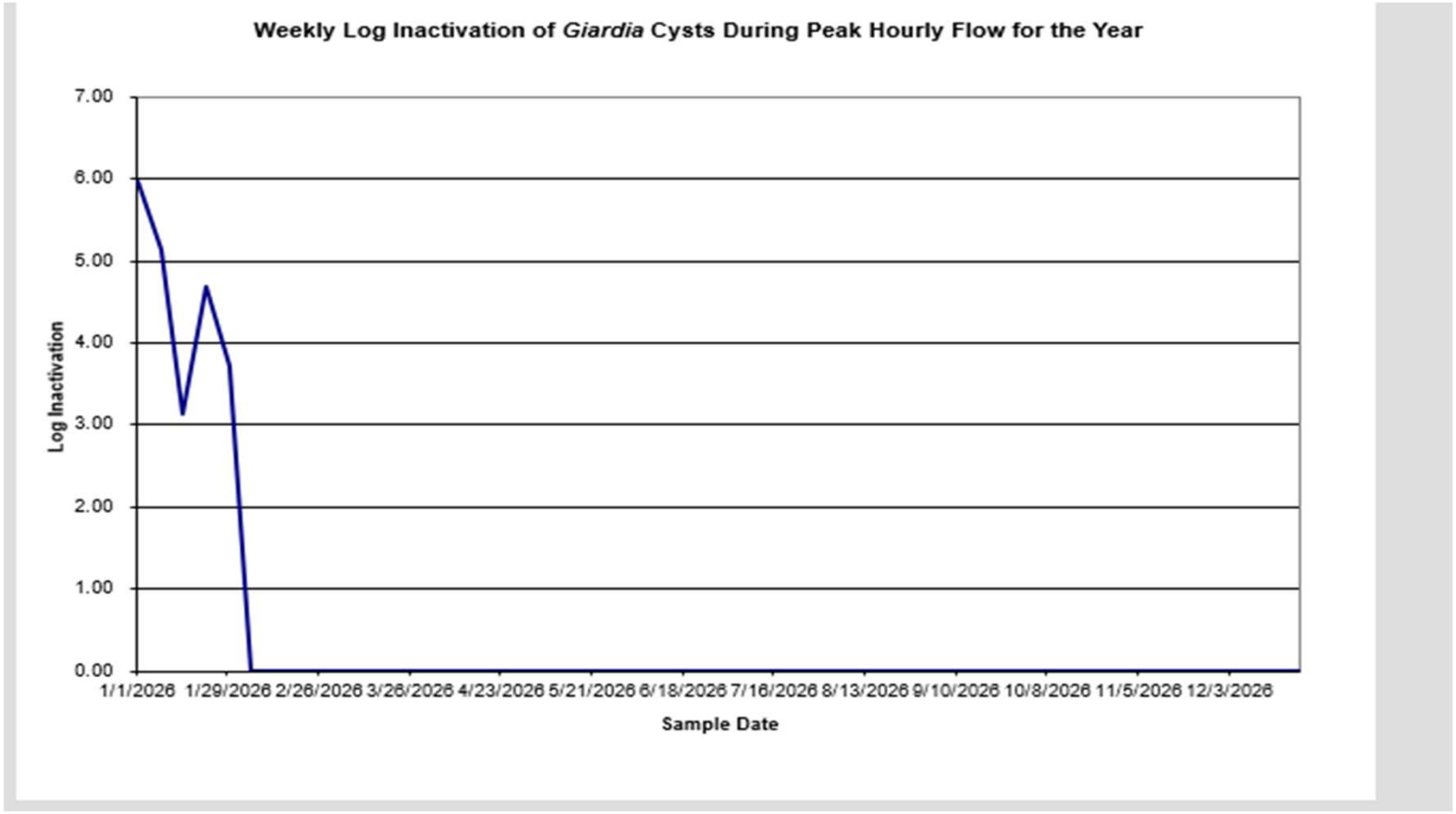
Benchmarking and Profiling

Avg. *Giardia* Log Inactivation for Year:	**0.44**
Giardia Benchmark for Year:	**0.00**
Min. *Giardia* Log Inactivation for Year:	**0.00**
Max. *Giardia* Log Inactivation for Year:	**5.98**

Sample Date	Week Number	Weekly *Giardia* Log	Monthly Average Log
January 1, 2026	1	5.98	
January 8, 2026	2	5.14	
January 15, 2026	3	3.14	
January 22, 2026	4	4.70	
January 29, 2026	5	3.72	4.54
February 5, 2026	6	0.00	
February 12, 2026	7	0.00	
February 19, 2026	8	0.00	
February 26, 2026	9	0.00	0.00
March 5, 2026	10	0.00	
March 12, 2026	11	0.00	
March 19, 2026	12	0.00	
March 26, 2026	13	0.00	0.00
April 2, 2026	14	0.00	
April 9, 2026	15	0.00	
April 16, 2026	16	0.00	
April 23, 2026	17	0.00	
April 30, 2026	18	0.00	0.00
May 7, 2026	19	0.00	
May 14, 2026	20	0.00	
May 21, 2026	21	0.00	
May 28, 2026	22	0.00	0.00
June 4, 2026	23	0.00	
June 11, 2026	24	0.00	
June 18, 2026	25	0.00	
June 25, 2026	26	0.00	0.00

Sample Date	Week Number	Weekly *Giardia* Log	Monthly Average Log
July 2, 2026	27	0.00	
July 9, 2026	28	0.00	
July 16, 2026	29	0.00	
July 23, 2026	30	0.00	
July 30, 2026	31	0.00	0.00
August 6, 2026	32	0.00	
August 13, 2026	33	0.00	
August 20, 2026	34	0.00	
August 27, 2026	35	0.00	0.00
September 3, 2026	36	0.00	
September 10, 2026	37	0.00	
September 17, 2026	38	0.00	
September 24, 2026	39	0.00	0.00
October 1, 2026	40	0.00	
October 8, 2026	41	0.00	
October 15, 2026	42	0.00	
October 22, 2026	43	0.00	
October 29, 2026	44	0.00	0.00
November 5, 2026	45	0.00	
November 12, 2026	46	0.00	
November 19, 2026	47	0.00	
November 26, 2026	48	0.00	0.00
December 3, 2026	49	0.00	
December 10, 2026	50	0.00	
December 17, 2026	51	0.00	
December 24, 2026	52	0.00	0.00

Benchmarking and Profiling



Impacts of Inputs

Input	Inactivation
pH ↑	↓
Temperature ↓	↓
Flow ↑	↓
Volume ↓	↓

What Do I Do With this Information?

- Evaluate Disinfection Practices for Optimization
  - Maximizing Inactivation
  - Minimizing DBPS and still meet Inactivation requirements
- Meeting Inactivation during maintenance and rehab system
  - Finished Water Storage Tanks
  - Changes in disinfectant being used
- Evaluating permanent Treatment Changes

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Questions?