LSN 21 Filtration and Disinfection

CEEG 340–Introduction to Environmental Engineering

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Filtration

Adapted from Davis and Cornwell. As part of their new treatment plant, the town of San Jose is going to install rapid sand filters after their sedimentation tanks. The design hydraulic loading rate (HLR) to the filter is 200 $\frac{m^3}{d \times m^2}$. How much filter surface area should be provided for the design flow rate of 0.5 $\frac{m^3}{s}$? GIVEN: $HLR = 200 \frac{m^3}{DAY \cdot m^2}$ $Q = 0.5 m^3/s$ FIND: A_{FILTER}

$HLR = \frac{Q}{A} \Rightarrow A = \frac{Q}{HLR} = \frac{0.5 \frac{m^3}{s} \times 86{,}400 \frac{s}{DAY}}{200 \frac{m^3}{m^2 \cdot DAY}} = 216 m^2$

$\boxed{A = 216 m^2}$

How large should each filter be if four filters are used?

$A_{1/4} = \frac{216}{4}$ $\boxed{A_{1/4} = 54 m^2}$

A number of states require that the design loading rate be met with one filter out of service. Check the HLR for the filter (when one is out of service) to make sure that the HLR is still within the acceptable design range of 2-6 $\frac{gpm}{ft^2}$.

GIVEN: 1 FILTER O.O.S., $HLR_{DESIGN} = 2\text{-}6 \frac{gpm}{ft^2}$

$A_{NEW} = \frac{3}{4} A = \frac{3}{4} \times 216$

$A_{NEW} = 162 m^2$

$HLR_{NEW} = \frac{Q}{A_{NEW}} = \frac{0.5 \frac{m^3}{s} \times 1000 \frac{L}{m^3} \times \frac{1 GAL}{3.785 L} \times \frac{60 s}{MIN}}{162 m^2 \times \frac{(3.28 ft)^2}{(1 m)^2}} = 4.5 \frac{gpm}{ft^2}$

$2 < 4.5 < 6$ ✓

$\boxed{HLR_{O.O.S.} = 4.5 \frac{gpm}{ft^2}}$ $\boxed{\text{HLR IS WITHIN ACCEPTABLE RANGE}}$

C•t Approach

A water treatment plant wants to achieve a 3-log removal of *Giardia* cysts with disinfectant residual of 2 mg/L for chlorine or ozone as a disinfectant.

Determine the contact time and volume of reactor required for each disinfectant with Q = 1 MGD, T = 10^0C, and pH = 6.5.

CHLORINE

FROM TABLE: $Ct = 104 \frac{mg \cdot min}{L}$ (TABLE 2-1)

GIVEN $C = 2 mg/L$

$2 mg/L \times t = 104 \frac{mg \cdot min}{L}$

$t = \frac{104}{2} = 52 min \Rightarrow$ CONTACT TIME, $\theta = 52$ MIN

FOR OZONE $C \cdot t = 1.48 \frac{mg \cdot min}{L}$ (TABLE 2-1)

GIVEN: $C = 2 mg/L$

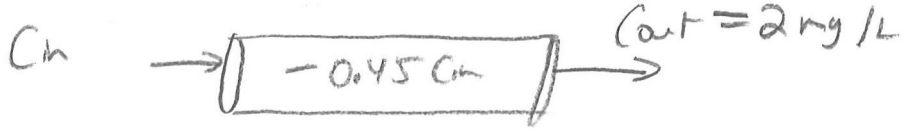
$t = \frac{1.48}{2} = 0.74 min$

CONTACT TIME, $\theta = 0.74$ MIN

How could you demonstrate that a contact tank has the appropriate retention time for disinfection?

CONDUCT A TRACER TEST W A CONSERVATIVE COMPOUND, SUCH AS METHYLENE BLUE.

Calculate the chlorine dose required for disinfection to maintain 2 mg/L residual with 45% on-site consumption due to oxidation (i.e., the reaction that destroys pathogens) and side reactions.



$C_{in} - 0.45 C_{in} = C_{out}$

$0.55 C_{in} = 2 mg/L$

$C_{in} = \frac{2 mg/L}{0.55} = 3.6 mg/L$

CHLORINE DOSE $C_{in} = 4 mg/L$

Table 2-3. CT Values for Inactivation of Viruses in Water at 10°C with pH 6.0–9.0

	CT values (in mg-min/L)		
Disinfectant	2-log Inactivation (99.0%)	3-log Inactivation (99.9%)	4-log Inactivation (99.99%)
Chlorine	3	4	6
Chloramine	643	1.067	1.491
Chlorine Dioxide	4.2	12.8	25.1
Ozone	0.5	0.8	1.0

CT values were obtained from Appendix E (AWWA, 1991).

Table 2-4. CT Values for Inactivation of Giardia Cysts in Water at 10°C with pH 6.0–9.0

	CT values (mg-min/L)					
Disinfectant	0.5-log Inactivation (68.0%)	1-log Inactivation (90.0%)	1.5-log Inactivation (96.8%)	2-log Inactivation (99.0%)	2.5-log Inactivation (99.7%)	3-log Inactivation (99.9%)
Chlorine[1]	17	35	52	69	87	104
Chloramine	310	615	930	1,230	1,540	1,850
Chlorine Dioxide	4	7.7	12	15	19	23
Ozone	0.23	0.48	0.72	0.95	1.2	1.43

CT values were obtained from Appendix E (AWWA, 1991).
[1] at pH 7.0 and chlorine residual ≤ 0.4 mg/L.

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	96	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	296	361	436	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	149	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	95	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	56	67	81	97

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