

ELECTRONIC SUPPLEMENTARY INFORMATION

A Pilot-Scale Study of Peracetic Acid and Ultraviolet Light for Wastewater Disinfection

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Tables

Table S1: Water quality parameters from daily sampling.

Day	Turbidity (NTU)	TOC (mg-C l ⁻¹)	DOC (mg-C l ⁻¹)	pH	NH ₃ (mg-N l ⁻¹)	UV ₂₅₄ (cm ⁻¹)
1	8.8	-	-	6.7	12	0.237
2	29	18	12	7	12	0.152
3	13	13	12	7.2	9.8	0.234
4	11	14	12	7.2	10	0.249
5	9.4	21	13	7.1	11	0.252
8	8.8	12	9.5	7.1	8.5	0.201
9	53	14	7.9	7.6	7.7	0.160
10	23	10	9.5	7.5	7.1	0.160
11	11	8.9	8.5	7.4	8.0	0.200
12	4.4	9.7	9.4	7.1	8.4	0.221
15	5.7	-	-	7	12	0.134
16	7.2	13	10	6.9	14	0.141
17	9.7	13	10	6.3	13	0.174
18	11	15	10	7.1	13	0.182
19	10	11	9.3	7.1	9.3	0.203
22	7.4	12	10	7.2	11	0.175
23	2.5	11	10	7.1	12	0.216
24	1.8	10	10	7	14	0.167
25	4.2	12	12	7.4	16	0.200
26	3.4	11	9.9	7.3	16	0.184

Table S2: Geometric mean (and range) of the number of colony forming units or plaque forming units per 100 ml for fecal coliforms, *E. coli*, *Enterococcus* spp., and somatic coliphage in secondary and tertiary effluent.

Indicator	Geometric mean (and range) of CFU or PFU per 100 ml	
	Secondary effluent	Tertiary effluent
Fecal coliforms	116,521 (63,749 - 212,977)	27,851 (16,882 - 45,945)
<i>E. coli</i>	86,410 (40,733 - 183,303)	19,616 (11,709 - 32,863)
<i>Enterococcus</i> spp.	30,189 (12,885 - 70,732)	5,763 (2,832 - 11,723)
Somatic coliphage	18,962 (12,037 - 29,870)	22,195 (4,547 - 108,336)

Table S3: Log reduction of fecal coliforms, *E. coli*, *Enterococcus* spp., and somatic coliphage in secondary effluent (average of daily samples collected at 10:00, n = 5 or 6). The calculation of propagated error followed the procedure described by³⁴.

Treatment		Fecal coliforms	<i>E. coli</i>	<i>Enterococcus</i> spp.	Somatic coliphage
PAA (mg min l⁻¹)	4.4	0.26 ± 0.48	0.33 ± 0.71	0.32 ± 0.55	0.20 ± 0.24
	8.8	0.55 ± 0.59	1.7 ± 0.66	0.27 ± 0.82	0.34 ± 0.23
	13.2	1.7 ± 0.48	2.1 ± 0.52	0.72 ± 0.44	0.51 ± 0.34
	13.4	0.46 ± 0.35	0.74 ± 0.61	0.32 ± 0.57	0.25 ± 0.26
	26.8	1.4 ± 0.87	2.2 ± 0.59	0.81 ± 0.83	0.58 ± 0.17
	40.2	2.3 ± 0.35	2.5 ± 0.49	2.1 ± 0.47	0.78 ± 0.33
	45	1.1 ± 0.84	1.1 ± 1.1	0.98 ± 0.76	0.60 ± 0.42
	90	2.4 ± 0.65	2.3 ± 0.52	2.6 ± 0.88	0.86 ± 0.13
	135	2.8 ± 0.33	3.1 ± 0.53	3.2 ± 0.38	1.4 ± 0.34
PAA + UV (mg min l⁻¹ + mJ cm⁻²)	49.8 + 30	1.5 ± 1.0	1.3 ± 1.0	1.3 ± 0.80	1.4 ± 0.41

Table S4: Log reduction of fecal coliforms, *E. coli*, *Enterococcus* spp., and somatic coliphage in tertiary effluent from two measurements.

Treatment		Fecal coliforms	<i>E. coli</i>	<i>Enterococcus</i> spp.	Somatic coliphage
PAA (mg min l⁻¹)	4.4	0.36, 0.35	0.14, 0.56	0.16, 0.24	0.14, 0.21
	6.6	0.82, 1.9	1.4, 2.2	0.060, 0.39	0.30, 0.49
	8.8	1.8, 1.5	2.4, 2.3	1.1, 0.42	0.35, 0.28
	13.2	2.4, 2.2	2.5, 2.5	0.81, 0.31	0.55, 0.16
	13.4	1.2, 1.6	0.74, 2.3	0.28, 0.75	0.19, 0.27
	20.1	1.8, 2.4	2.2, 2.1	0.27, 0.34	0.60, 0.55

	26.8	1.2, 2.4	1.6, 2.3	0.66, 0.68	0.40, 0.50
	40.2	2.7, 2.6	2.5, 2.5	1.6, 0.42	0.69, 0.44
	45	2.5, 2.7	1.9, 2.6	1.1, 3.1	0.56, 0.86
	67.5	2.6, 2.6	2.3, 2.4	2.3, 2.5	1.6, 1.4
	90	2.9, 2.7	2.6, 2.7	3.0, 3.4	1.3, 1.2
	135	3.1, 3.4	2.8, 3.2	3.0, 3.7	1.3, 1.1
PAA + UV (mg min l⁻¹ + mJ cm⁻²)	49.7 + 30	2.7, 3.1	2.5, 3.2	1.2, 3.6	1.7, 2.2
	74.6 + 30	2.9, 2.9	2.6, 2.7	2.1, 2.1	2.3, 2.1
	99.4 + 30	3.4, 3.7	3.1, 3.3	2.2, 3.8	1.9, 2.2
	149.1 + 30	3.5, 4.3	2.9, 4.5	3.3, 3.7	2.3, 2.2

Table S5: Significance values for the ANOVA testing the null hypothesis that the log reductions are the same between secondary and tertiary effluent for each indicator, accounting for C·t.

	<i>p</i>
Fecal coliforms	0.010
<i>E. coli</i>	0.57
<i>Enterococcus</i> spp.	0.90
Somatic coliphage	0.90

Table S6: Minimum error sum of squares (ESS) and R² values for the model fitting for *Enterococcus* spp.

		Pilot reactor influent	Minimum Error Sum of Squares	R²
<i>Enterococcus</i> spp.	Chick-Watson	Secondary	14	0.75
		Tertiary	6.5	0.81
	Collins-Selleck	Secondary	11	0.79
		Tertiary	7.1	0.79

Table S7: Significance values for ANOVA testing the null hypothesis that the log reductions are the same among microorganisms in secondary effluent, accounting for C·t.

<i>p</i>	Fecal coliforms	<i>E. coli</i>	<i>Enterococcus</i> spp.
<i>E. coli</i>	0.09	-	-
<i>Enterococcus</i> spp.	0.03	4 × 10 ⁻⁶	-
Somatic coliphage	1 × 10 ⁻²⁶	1 × 10 ⁻²⁶	6 × 10 ⁻⁷

Table S8: Significance values for ANOVA testing the null hypothesis that the log reductions are the same among microorganisms in tertiary effluent, accounting for C·t.

p	Fecal coliforms	<i>E. coli</i>	<i>Enterococcus</i> spp.
<i>E. coli</i>	0.9	-	-
<i>Enterococcus</i> spp.	4×10^{-5}	1×10^{-5}	-
Somatic coliphage	1×10^{-26}	1×10^{-26}	1×10^{-4}

Table S9: Significance values for ANOVA testing the null hypothesis that the log reductions are the same between three PAA doses (2, 4 and 6 mg l⁻¹) in secondary effluent when holding a constant contact time (2.2, 6.7, or 22.6 min).

(min)	(mg l⁻¹)	Fecal coliforms		<i>E. coli</i>		<i>Enterococcus</i> spp.		Somatic coliphage	
		2	4	2	4	2	4	2	4
2.2	4	0.98	-	0.021	-	0.99	-	0.99	-
	6	7×10^{-5}	0.45	1×10^{-4}	0.99	0.95	0.99	0.99	0.99
6.7	4	7×10^{-4}	-	0.016	-	0.97	-	0.99	-
	6	1×10^{-7}	0.99	3×10^{-4}	0.99	1×10^{-26}	7×10^{-3}	0.99	0.99
22.5	4	0.58	-	0.99	-	1×10^{-4}	-	0.99	-
	6	0.030	0.99	0.14	0.95	1×10^{-26}	0.99	0.99	0.99

Table S10: Significance values for ANOVA testing the null hypothesis that the log reductions are the same between three contact times (2.2, 6.7 and 22.5 minutes) at three PAA doses (2, 4 and 6 mg l⁻¹) in secondary effluent.

(mg l⁻¹)	(min)	Fecal coliforms		<i>E. coli</i>		<i>Enterococcus</i> spp.		Somatic coliphage	
		2.2	6.7	2.2	6.7	2.2	6.7	2.2	6.7
2	6.7	0.99	-	0.99	-	0.99	-	0.99	-
	22.5	2×10^{-4}	4×10^{-3}	5×10^{-5}	0.020	0.020	0.020	0.99	0.99
4	6.7	0.27	-	0.99	-	0.99	-	0.99	-
	22.5	6×10^{-4}	0.99	0.99	0.99	1×10^{-26}	1×10^{-6}	0.99	0.99
6	6.7	0.99	-	0.99	-	2×10^{-3}	-	0.99	-
	22.5	0.20	0.99	0.24	0.94	1×10^{-26}	0.072	0.27	0.91

Table S11: Significance values for ANOVA testing the null hypothesis that the log reductions are the same between four PAA doses (2, 3, 4 and 6 mg l⁻¹) at three contact times (2.2, 6.7 and 22.6) in tertiary effluent.

		Fecal coliforms			<i>E. coli</i>			<i>Enterococcus spp.</i>			Somatic coliphage		
(min)	(mg l⁻¹)	2	3	4	2	3	4	2	3	4	2	3	4
2.2	3	0.89	-	-	0.23	-	-	0.99	-	-	0.99	-	-
	4	0.44	0.99	-	7×10^{-3}	0.99	-	0.99	0.99	-	0.99	0.99	-
	6	7×10^{-3}	0.94	0.99	2×10^{-3}	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
6.7	3	0.99	-	-	0.99	-	-	0.99	-	-	0.99	-	-
	4	0.99	0.99	-	0.99	0.99	-	0.99	0.99	-	0.99	0.99	-
	6	0.4	0.99	0.98	0.89	0.99	0.99	0.99	0.95	0.99	0.99	0.99	0.99
22.5	3	0.99	-	-	0.99	-	-	0.99	-	-	0.99	-	-
	4	0.99	0.99	-	0.99	0.99	-	0.72	0.99	-	0.99	0.99	-
	6	0.99	0.99	0.99	0.99	0.99	0.99	0.11	0.46	0.99	0.99	0.99	0.99

Table S12: Significance values for ANOVA testing the null hypothesis that the log reductions are the same between three contact times (2.2, 6.7 and 22.5 minutes) at three PAA doses (2, 3, 4 and 6 mg l⁻¹) in tertiary effluent.

		Fecal coliforms		<i>E. coli</i>		<i>Enterococcus spp.</i>		Somatic coliphage	
(mg l⁻¹)	(min)	2.2	6.7	2.2	6.7	2.2	6.7	2.2	6.7
2	6.7	0.87	-	0.65	-	0.99	-	0.99	-
	22.5	7×10^{-4}	0.56	9×10^{-3}	0.99	0.012	0.11	0.99	0.99
3	6.7	0.99	-	0.99	-	0.99	-	0.99	-
	22.5	0.56	0.99	0.99	0.99	2×10^{-3}	3×10^{-3}	0.71	0.95
4	6.7	0.99	-	0.99	-	0.99	-	0.99	-
	22.5	0.72	0.94	0.99	0.99	2×10^{-4}	6×10^{-5}	0.95	0.99
6	6.7	0.99	-	0.99	-	0.99	-	0.99	-
	22.5	0.96	0.99	0.99	0.99	4×10^{-6}	2×10^{-4}	0.98	0.99

Table S13: Significance values for t-tests with the null hypothesis that the log reductions in PAA and PAA+UV treated samples are the same for secondary effluent (unpaired) and for tertiary effluent (paired).

	Secondary	Tertiary
Fecal coliforms	0.77	2×10^{-3}
<i>E. coli</i>	0.91	7×10^{-3}
<i>Enterococcus spp.</i>	0.99	0.98
Somatic coliphage	0.039	2×10^{-6}

Table S14: Pearson's correlation coefficient r and significance values for the correlations between matrix parameters and fecal coliforms log reductions.

	2 mg l ⁻¹		4 mg l ⁻¹		6 mg l ⁻¹	
	r	p	r	p	r	p
Turbidity (NTU)	-0.11	0.82	-0.54	0.34	-0.52	0.29
TOC (mg-C l ⁻¹)	-0.45	0.37	-0.77	0.13	-0.25	0.68
DOC (mg-C l ⁻¹)	-0.15	0.77	-0.26	0.67	-0.45	0.45
pH	-0.64	0.12	-0.71	0.18	0.37	0.47
NH ₃ (mg-N l ⁻¹)	0.12	0.80	-0.54	0.35	0.09	0.86
UV ₂₅₄ (cm ⁻¹)	0.35	0.44	0.69	0.20	0.14	0.79

Table S15: Pearson's correlation coefficient r and significance values for the correlations between matrix parameters and *E. coli* log reductions.

	2 mg l ⁻¹		4 mg l ⁻¹		6 mg l ⁻¹	
	r	p	r	p	r	p
Turbidity (NTU)	0.44	0.32	0.27	0.66	-0.32	0.54
TOC (mg-C l ⁻¹)	-0.08	0.88	-0.38	0.52	0.56	0.33
DOC (mg-C l ⁻¹)	-0.27	0.61	-0.90	0.04	0.33	0.58
pH	-0.71	0.07	0.04	0.94	0.38	0.46
NH ₃ (mg-N l ⁻¹)	-0.14	0.77	-0.94	0.02	-0.01	0.99
UV ₂₅₄ (cm ⁻¹)	0.47	0.29	-0.08	0.90	0.36	0.48

Table S16: Pearson's correlation coefficient r and significance values for the correlations between matrix parameters and *Enterococcus* spp. log reductions.

	2 mg l ⁻¹		4 mg l ⁻¹		6 mg l ⁻¹	
	r	p	r	p	r	p
Turbidity (NTU)	0.43	0.33	0.00	0.99	0.02	0.98
TOC (mg-C l ⁻¹)	-0.13	0.81	-0.68	0.21	0.24	0.69
DOC (mg-C l ⁻¹)	-0.16	0.76	-0.70	0.19	0.60	0.29
pH	-0.46	0.30	-0.02	0.98	0.55	0.26
NH ₃ (mg-N l ⁻¹)	-0.09	0.85	-0.73	0.16	-0.94	0.00
UV ₂₅₄ (cm ⁻¹)	0.79	0.04	0.13	0.84	0.60	0.21

Table S17: Pearson's correlation coefficient r and significance values for the correlations between matrix parameters and somatic coliphage log reductions.

	2 mg l⁻¹		4 mg l⁻¹		6 mg l⁻¹	
	r	p	r	p	r	p
Turbidity (NTU)	0.34	0.46	0.40	0.43	0.12	0.82
TOC (mg-C l ⁻¹)	0.31	0.56	-0.05	0.93	0.88	0.05
DOC (mg-C l ⁻¹)	0.22	0.68	-0.74	0.09	0.66	0.22
pH	-0.93	0.00	0.40	0.43	0.21	0.69
NH ₃ (mg-N l ⁻¹)	0.35	0.44	-0.41	0.42	0.05	0.92
UV ₂₅₄ (cm ⁻¹)	-0.15	0.74	-0.19	0.72	0.06	0.91

Figures

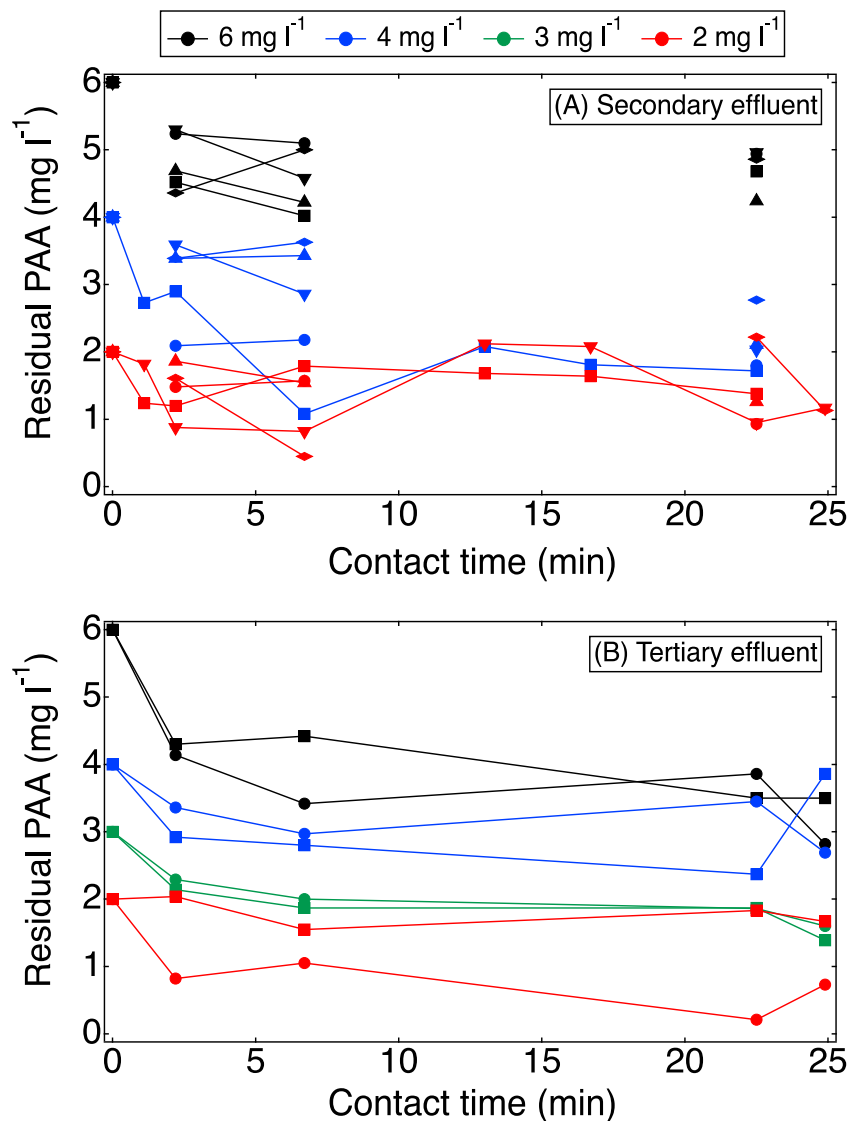


Figure S1: Residual PAA concentrations in secondary (A) and tertiary (B) effluents for each contact time based on the tap sampled. The residual was not measured for each tap every day. Data points collected on the same date and time are connected by lines to show changes in the residual over time. Applied concentrations of 2, 3, 4, and 6 mg l⁻¹ are represented by red, green, blue, and black. Different shapes for a given applied concentration represent replicates.

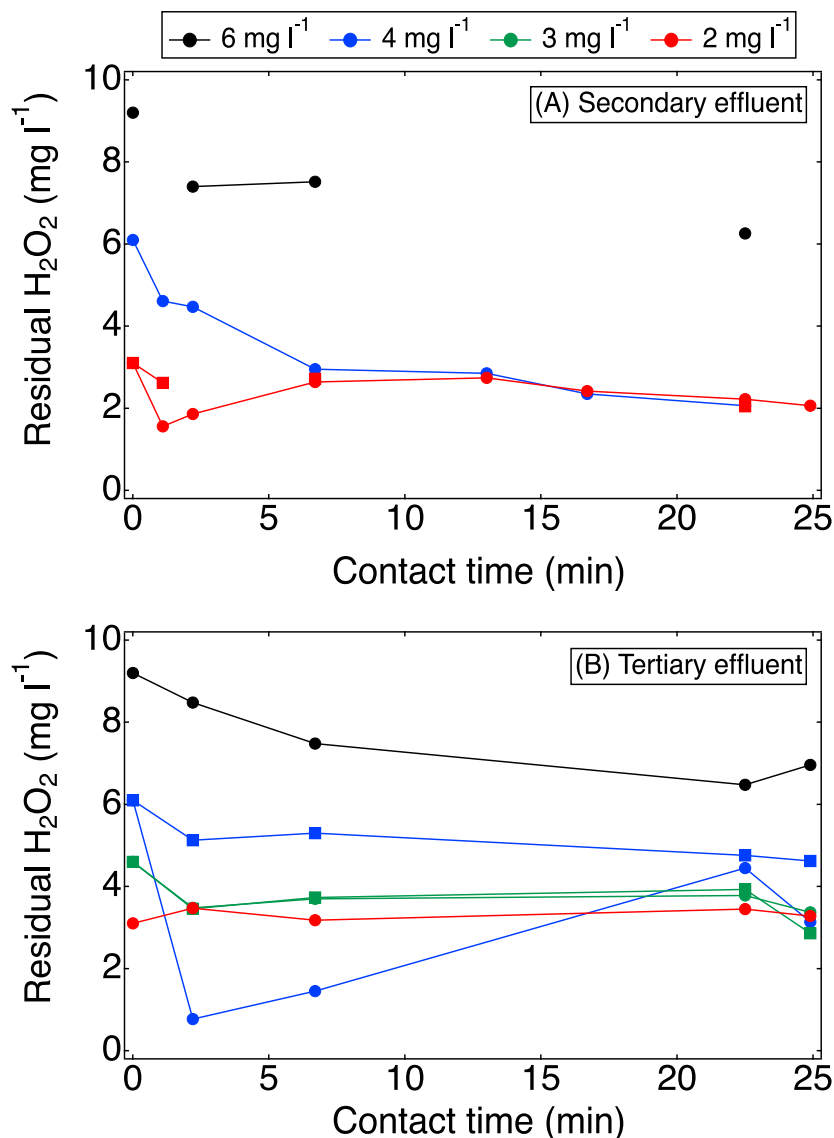


Figure S2: Residual H_2O_2 concentrations in secondary (A) and tertiary (B) effluents for each contact time based on the tap sampled. The residual was not measured for each tap every day. Data points collected on the same date and time are connected by lines to show changes in the residual over time. Applied concentrations of 3.1, 4.6, 6.1, and 9.2 mg l^{-1} are represented by red, green, blue, and black. Different shapes for a given applied concentration represent replicates.

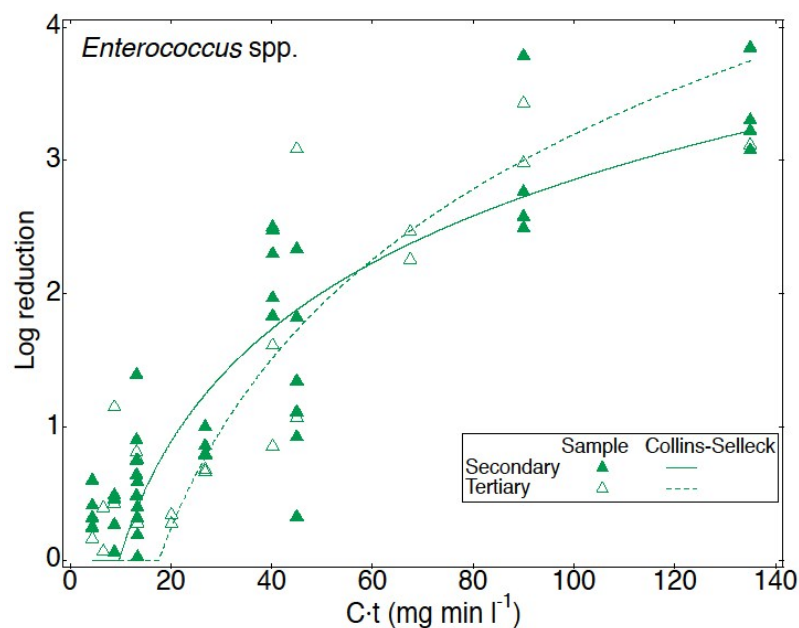


Figure S3: Relationship between log reductions and PAA exposure (C·t) for *Enterococcus* spp. in secondary (closed shape, solid line) and tertiary (open shape, dashed line) effluents fitted using the Collins-Selleck model.

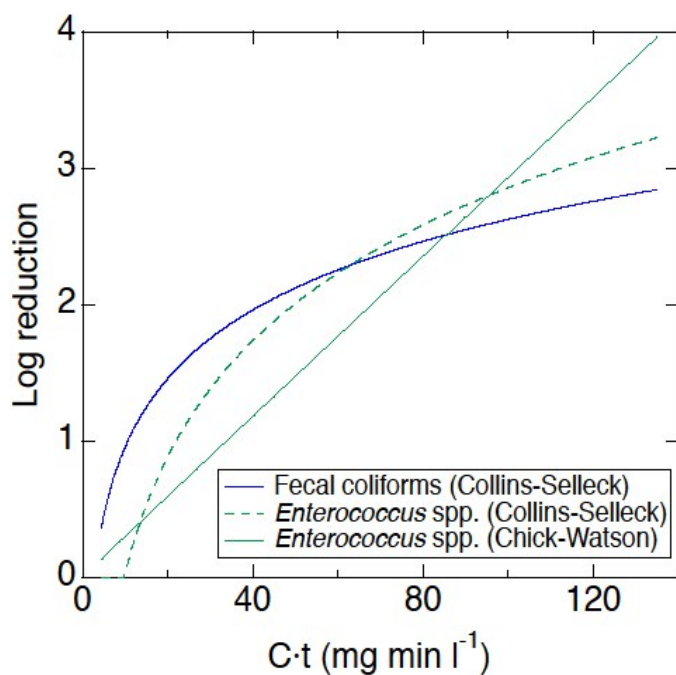


Figure S4: Comparison of the log reduction of fecal coliforms and *Enterococcus* spp. in secondary effluent predicted by Collins-Selleck and Chick-Watson models using fitted parameters.